GRAZING INFLUENCE ON SELECTED PARAMETERS OF THE AVIAN COMMUNITY ON A TEXAS HILL COUNTRY RANCH

by

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ABSTRACT

Many regionally declining populations of prairie and shrubland birds breed in the Edwards Plateau ecoregion of Central Texas. Additionally, Central Texas supports a wintering bird community rich in ground foraging sparrow species. Livestock grazing can have species specific and mixed results for local bird communities and other wildlife. I examined the degree to which grazing influences bird foraging frequency and bird abundance, richness, diversity, and evenness relative to herbaceous vegetative ground cover at Freeman Center, a 1,701 ha working cattle ranch in the Balcones Canyonlands subregion of the Edwards Plateau. For one year, I conducted avian surveys and herbaceous ground cover surveys on two grazed and two ungrazed pastures using twenty, 100 meter fixed radius point count sites and twenty, 100 meter transects extending from each site. I included a total of 383 Daubenmire frame surveys, 135 point count surveys, and 184 avian walking transect surveys in various analyses. I used General Linear Models (GLMs) to analyze herbaceous ground cover surveys in grazed and ungrazed sites. I incorporated significant herbaceous vegetation predictors into General Linear Mixed Models (GLMMs) to analyze breeding and wintering bird abundance, richness, diversity, and evenness. I also included site as an intercepts-only random factor. I built an additional GLMM to analyze avian winter ground foraging counts. I identified a total of 138 avian species from Freeman Center between January 2014 and May 2015. All breeding bird indices were significantly different among breeding seasons. Breeding bird richness positively correlated with forb cover ($\beta = 0.187$, $Z = 3.000$, $P = 0.003$). Breeding

bird diversity was positively correlated with tallest green grass (β = 0.631, $Z = 2.400$, $P = 0.016$) and forb cover (β = 0.171, $Z = 2.710$, $P = 0.007$). Except foraging counts, no wintering bird indices were significantly correlated with herbaceous ground cover predictors. Wintering bird foraging counts were positively correlated with forb cover (β = 0.809, $Z = 3.070$, $P = 0.002$). Breeding and wintering bird abundance, richness, diversity, and ground foraging counts were all higher in grazed sites than ungrazed sites. Results suggest that moderate grazing pressure promotes forb production and native forbs are important for breeding and wintering birds in the Texas hill country. Future studies should analyze herbaceous plant diversity and the dominant herbaceous plants in study sites throughout the Edwards Plateau. Judgment deferred rotational grazing should be appropriate when ranch managers have the knowledge, experience, resources, and prudence to make best-management decisions based on climate, rainfall, and sustainability. A multi-year study is necessary to assess long-term cattle use and the affects of climate and rainfall on the health and future of ranch operations and wildlife diversity at Freeman Center.

I. INTRODUCTION

Grazing of domestic livestock is an integral part of human lives and landscapes. Few ecosystems or habitat types are entirely free of livestock grazing (Wagner 1978). Historically, grazing by free ranging wild ungulates such as bison (*Bison bison*), elk (*Cervus canadensis*), and pronghorn antelope (*Antilocapra americana*) and natural wild fires maintained native rangelands throughout much of North America. With European colonization, grassland and shrubland communities throughout North America have experienced significant decline and degradation (Noss et al. 1995). An estimated >80 percent loss of native North American grasslands is attributed primarily to human driven land use changes, fire exclusion, and agriculture (Brennan and Kuvlesky 2005, Fuhlendorf and Engle 2001, Knopf 1994, Noss et al. 1995). Central Texas has a long history of agriculture and other anthropogenic activity. Before European settlers arrived, nomadic grazing by bison and wild fires were natural events that occurred in savannah, shrub-land, and grassland ecosystems (Perkins 1977, Smeins 1980). Bison were extirpated in many areas, replaced with domestic livestock, and wildfire suppression increased (Smith 1899, Webb 1931, Jackson 1965, Sauer 1975, Perkins 1977). These changes have allowed woody vegetation to encroach upon grasslands in many areas (Smeins 1980, Archer 1989). Ecological changes, post European settlement, have also led to increases in early succession grasses and forbs associated with rangelands (Barnes et al. 2000, Murray et al. 2013). In addition, exotic or nonindigenous herbaceous plant species associated with grazing have proliferated (Fleischner 1994, Flanders et al. 2006). King Ranch bluestem (*Bothriochloa ischaemum songarica*) is a classic case of an invasive, exotic, grazing tolerant grass introduced for cattle that can lower rangeland productivity (Flanders et al. 2006). Presently, challenges persist to envisioning the plant and animal communities of Central Texas, particularly the Hill Country, before European settlement. Current land management in central Texas seeks to utilize grazing as a management tool to maintain rangeland diversity and reestablish a more natural disturbance regime. Understanding the effects of grazing on wildlife in prairie and shrubland systems has been studied (Reid 1954, Holechek et al. 1982, Fleischner 1994, Johnson et al. 2011). Yet no studies have sought data on avifauna under managed grazing regimes in the Balcones Canyonlands of the Edwards Plateau.

Avifauna is well known to reflect the types, health, and heterogeneity of wildlife habitats (MacArthur 1961, Cody 1966, Karr and Roth 1971, Bock and Webb 1984). Additionally, the loss and degradation of North America's prairies has coincided with recent declines in associated bird communities. Northern Bobwhites (*Colinus virginianus*), Dickcissels (*Spiza americana*), Rufous-crowned Sparrows (*Aimophila ruficeps*), and Lark Sparrows (*Chondestes grammacus*) exemplify regionally declining species that commonly breed in Central Texas prairies and shrublands (Sauer et al. 2014). Central Texas also supports a wintering bird community rich in sparrow species, including Vesper Sparrows (*Pooecetes gramineus*), Savannah Sparrows (*Passerculus sandwichensis*), and members of other emberizid genera. Emberizine sparrows are well known as ground foraging seed-eaters, especially in their wintering ranges (Rodewald 2015). Many other bird species switch to or consume more herbaceous plants and seeds in the non-breeding season (Rodewald 2015). Thus the frequency of ground foraging increases in the non-breeding months and the associated rangeland habitats become important for a large portion of the avian community.

Low to moderate livestock grazing has been utilized with other management practices to create or maintain wildlife habitat, reflected in avifaunal abundance and diversity (Holechek et al. 1982, Johnson et al. 2011). Some grazing systems have benefitted grassland and shrubland bird communities through suppression of woody vegetation, promotion of native grasses, and the increase of bare ground access (Holechek et al. 1982). Generally, rest-rotation and deferred rotation systems are more associated with game bird habitat than continuous systems. The long term effects of heavy grazing and over stocking can have unintended ecological consequences for wildlife habitats and heavy use can offset the benefits of rotation (Holechek et al. 1982). Central Texas rangelands vary in grazing regimes, from specialized rotational grazing of large ranches to continuous grazing of small ranchettes. The impacts of continuous grazing on wildlife habitats are highly dependent upon stocking rates, whereas rotational grazing can have varying results for wildlife. Though specialized grazing systems have had mixed results for upland game birds, Attwater's Prairie Chicken (*Tympanuchus cupido attwateri*) habitat is currently managed with rotational grazing and prescribed burns (Holechek et al. 1982, Terry Rossignol p. c. 2015). In the Southeast, carefully managed grazing and prescribed burning can provide optimum Northern Bobwhite habitat (Reid 1954). Additionally, Hammerquist-Wilson and Crawford (1981) found that Northern Bobwhite numbers were greater in South Texas in a high intensity, low frequency (HILF) grazing system compared to a 4-pasture deferred-rotation system.

Much of the research on grassland songbirds associated with grazing has focused on nest success. In general, grassland songbird nest success is lower in areas grazed during the breeding season, likely due to increased Brown-headed Cowbird (*Molothrus* *ater*) nest parasitism and trampling from cattle (Rahmig et al. 2009, Perlut and Strong 2011). However, grazed prairies can still support high densities of grassland birds like Eastern Meadowlarks (*Sturnella magna*), Grasshopper Sparrows (*Ammodramus savannarum*), and Upland Sandpipers (*Bartramia longicauda*) (Powell 2008). Most grazing techniques for wildlife management have species specific mixed results (Holechek et al. 1982, Fleischner 1994). Thus livestock grazing as a wildlife management tool remains controversial. Even specialized low intensity grazing systems coupled with drought have shown to lower rangeland bird diversity (Bock and Bock 1999). Livestock grazing has received criticisms in the desert southwest. Many arid rangelands in western states evolved without large grazing herbivores and may be too sensitive to support cattle operations, especially in riparian systems (Taylor 1986, Fleischner 1994). Studies from the western United States have shown significant declines in biodiversity among plants, birds, and other wildlife affected by grazing (Fleischner 1994).

The local effect of grazing on avifauna in the Texas Hill Country remains largely unknown. Much of Central Texas lies in a transitional zone between prairies in the East and more arid shrublands and deserts to the West. Scientific research on cattle grazing effects on rangelands and associated wildlife throughout the eastern portion of the Edwards Plateau ecoregion, is basically non-existent. I speculate that characteristics of the landscape, including topographical relief, the abundance of woody plant communities, and low soil productivity, could limit available forage and suitable grazing areas, potentially increasing grazing pressures in sites selected by livestock. At least in the past 30 years, Hays County has experienced an increase in the number of individual land parcels, indicating a decrease in parcel size through subdivision (Hays Central

Appraisal District anonymous representative p. c. 2016). Even recent average farm size in Hays County has decreased from 207 acres in 2007 to 170 acres in 2012 (United States Department of Agriculture 2012). Such characteristics of the Texas Hill Country and historical changes in land parcel size may limit implementation of rotational grazing regimes and contribute to overstocking and depletion of Hill Country rangelands, potentially affecting avian communities and wildlife habitats.

The objectives of my research were: 1. Assess avian abundance, richness, evenness, diversity, and foraging counts relative to herbaceous vegetation height and cover in both grazed and ungrazed sites in the Texas Hill Country; 2. Collect the data needed to define avian community parameters with respect to species, guild, and season; 3. Assess the current grazing regime at Freeman Center based on the results from analyses of herbaceous vegetation and avian data in grazed and ungrazed sites. Determining avian community parameters and understanding how they relate to landscape activities are important data for ecologists and conservation biologists. Knowledge of wildlife populations, especially birds as indicator species, allows biologists and land managers to develop interdisciplinary management plans to accommodate humans and wildlife on the landscape. How wildlife and their habitats are affected by changing landscapes becomes critical when anthropogenic activities blend with the natural world. The research I conducted at Freeman Center is integral to the balance between ranch operations and wildlife conservation, to create a healthy, viable landscape for the future of agriculture and wildlife.

II. STUDY AREA

Freeman Center is a 1,701 ha ranch within the Balcones Canyonlands sub-region, on the eastern edge of the Edwards Plateau, approximately 8 km west of the Balcones Fault. The tract is located in southern Hays County (29.93808°, -93.00840°), northwest of San Marcos, Texas (Figure 1) and has been a working cattle ranch since the early 1940s. Before World War II, land in this area was used primarily for agricultural production, including cotton, cattle, goats, and sheep. Freeman Center is divided into 13 pastures, delineated by various fence types, and surrounded by a game fence approximately 2.5 m high. The majority of soils found on the ranch are Rumple Comfort/Comfort rock complexes (Barnes et al. 2000). The common vegetation types found on the ranch include: live oak savannah, mesquite/huisache savannah, juniper-live oak woodland, deciduous/mixed oak forest and mixed shrublands. The vegetation types are typical of those found on ranches throughout the Hill Country (Banks 2000, Barnes et al. 2000). Elevation on Freeman Center ranges from 204-287 m above sea level. Much of the topography consists of level to rolling terrain, yet steep slopes and escarpments occur along Sink Creek and other drainages (Barnes et al. 2000). The average annual rainfall for Hays County is 85.7 cm. The average maximum temperature in the summer is 35.5 degrees Celsius and the average minimum temperature in the winter is 4.4 degrees Celsius (Cecil and Greene 2010). During my study, Freeman Center maintained an average of 90 head of cattle, organized in a judgment deferred rotational grazing system. Judgment deferred involves observational assessment of herbaceous plant availability on rangelands for decisions regarding stocking rates, grazing pressure, and rest plans. Judgments should also consider historical and projected local climate and rainfall.

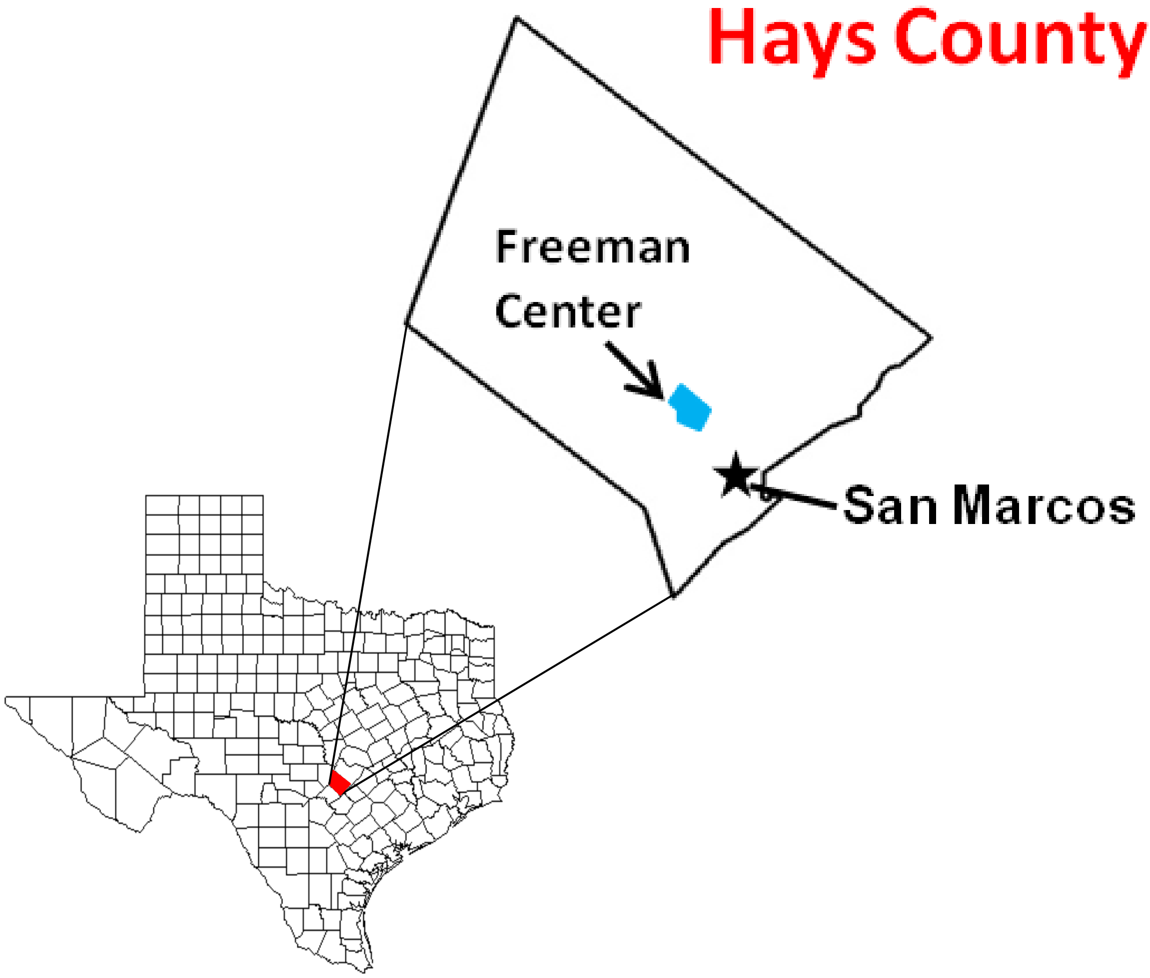

Figure 1. Approximate location of Freeman Center in Hays County, Texas, used in the study of herbaceous vegetation and avian community parameters in grazed and ungrazed pastures between April 2014 and April 2015.

III. METHODS

Most pastures at Freeman Center have been grazed by cattle and/or goats. The Front and Fernando pastures (Figure 2) have not been grazed in approximately 10 years. Yet before data collection, Fernando was used as a holding pasture and incurred light, brief grazing during the spring and fall months. These two pastures represented ungrazed controls in the short term, yet visually exhibited long term effects of woody encroachment and fire suppression. Originally, my study was designed to incorporate 4 pastures with different levels of grazing pressure (2 lightly grazed, and 2 moderately grazed). Because working cattle ranches are dynamic businesses, subjected to the vagaries of climate and rainfall, I suddenly modified the study design to accommodate cattle movements necessary for the health and well being of Freeman Center livestock. Two pastures (Crow's Nest and North Crawford) maintained cattle stocking rates of approximately 1 adult per 6 ha and were used as treatments to examine the effects of grazing on the bird community (Fig. 2). This stocking rate represents moderate grazing pressure, falling between Hays County's minimum stocking rates in native fair and native good pastures for open space valuation (Hays Central Appraisal District 2015). I randomly established 5 survey points, a minimum of 250 m apart, in each treatment and control pasture. Points falling in areas unlikely to be grazed by cattle (e.g. the edge of a cliff) were reassigned to adjacent, level areas, likely to be utilized by cattle. All relocated points maintained the 250 meter buffer from the nearest neighboring point. I also established 100 m walking transects at each point based on aerial maps and field observations. I directed the walking transects through rangeland habitat likely to be grazed. I established all transects to minimize spatial overlap and, wherever possible, to maintain a 250 m buffer.

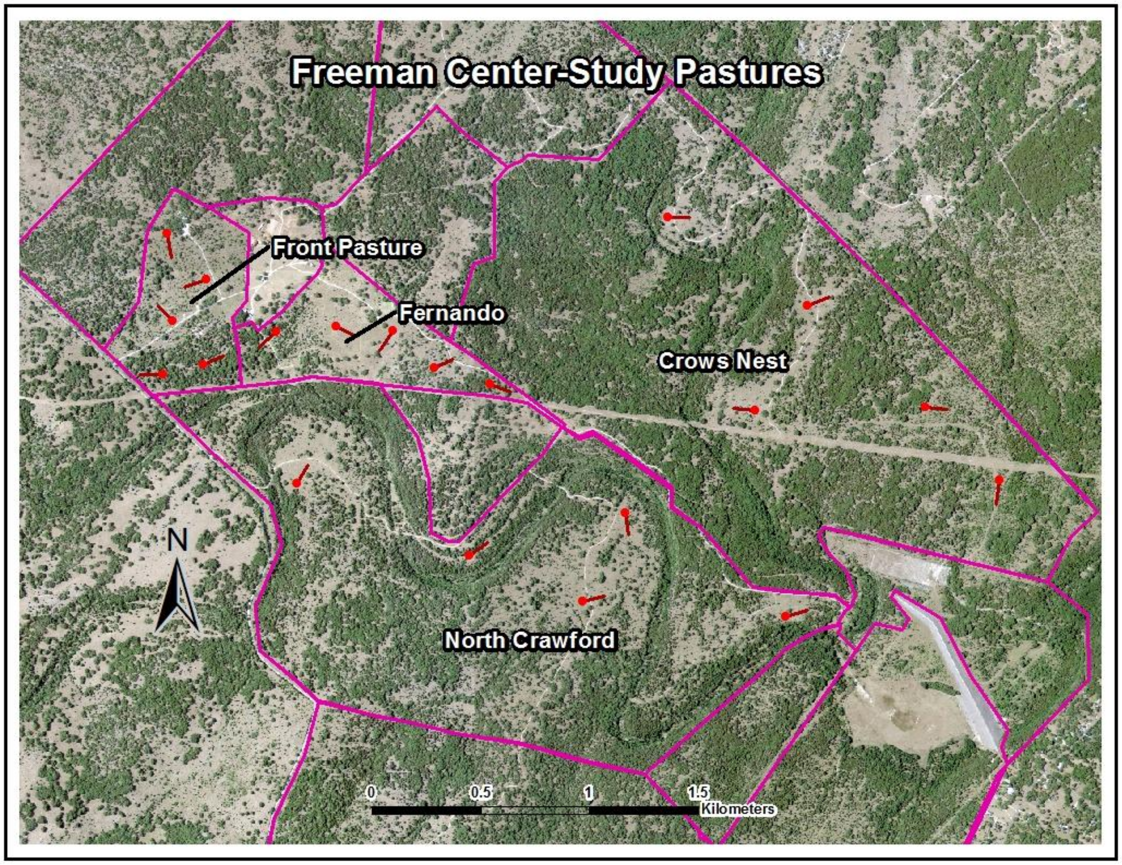

Figure 2. Satellite image of Freeman Center from 2008 with study pastures, points, and transects used to survey herbaceous vegetation and the avian community between 2014 and 2015 in the Balcones Canyonlands of Central Texas.

Herbaceous Vegetation Surveys

I surveyed herbaceous vegetation along each transect twice a month from April 2014 to April 2015. I used a modified version of the Daubenmire method (Daubenmire 1959) with 10 randomly selected 1 x 0.25m quadrats along each transect. I used six cover classes (Daubenmire 1959) to estimate cover of green grass, standing dead grass, forbs, woody vegetation, litter, and bare ground. Additionally, I recorded the greatest height (cm) of green grass, dead grass, and forbs in each quadrat.

Avian Surveys

I began breeding bird surveys no earlier than sunrise and ended no later than 4 hours after sunrise. I began wintering bird surveys after sunrise and ended no more than 6 hours after sunrise (Gutzwiller 1991, Ralph et al. 1995). Within the standard survey time period, I randomly selected starting survey times at all sites to avoid bias based on time of day. I did not survey in inclement weather, including moderate to heavy precipitation, winds greater than 25 km/hr, and foggy conditions that limited visibility to less than 100 meters (Ralph et al. 1995). I completed vegetation surveys and avian surveys at approximately the same time and location during each survey period to allow for spatiotemporal analysis of herbaceous cover and avian parameters of interest. Visual observations included flyovers, foraging birds, and habitat structure utilization. I recorded high flyovers as any bird flying above the tree canopy and low flyovers as any bird flying within or below the tree canopy. I excluded high flyovers from analyses because I could not determine habitat utilization. I included low flyovers in the analyses based on the assumption that birds flying low through a site likely utilized the area immediately around that site. Foraging birds included any individual observed carrying, consuming, or searching for food. Non ground-dwelling birds observed on the ground were assumed to be foraging. I recorded ground foraging separately from above ground foraging. Abundance was the total number of individuals observed during a survey. Richness was the total number of unique species observed during a survey. I calculated diversity based on the Shannon-Wiener function:

$$H' = -\sum_{i=1}^{S} \rho_i \ln \rho_i$$

The values of *H'* range from 0 → ∞, yet typically do not exceed 4 (Krebs 1999). Higher values of *H'* indicate greater diversity. I calculated evenness with Smith and Wilson's Index of Evenness (Evar) because it is independent of species richness and is sensitive to both rare and common species:

$$Evar = 1 - 2/\prod arctan\left\{\sum_{i=1}^{S}(\ln(x_s) - \sum_{i=0}^{n} \ln((x_t)/S)^2/S\right\}$$

The values of Evar range from 0 - 1 with 1 being maximum evenness, or all species having equal abundance (Krebs 1999).

I conducted avian fixed radius point count surveys twice a month at all survey sites during the breeding season from March 2014 through May 2015. Fixed radius point count surveys involved recording all visual and auditory bird detections up to 100 meters for the duration of 10 minutes at each station.

In addition to point counts, I conducted avian walking surveys along 100 m transects established from each point approximately twice a month from April 2014 to April 2015. On walking surveys along transects, I recorded all visible birds within 50 m of the walking line. Additionally, I recorded aural identifications within 100 m along each walking transect. Though point count surveys have shown to be consistent and effective for monitoring breeding birds, the application of point counts outside of the breeding season is often modified or replaced with other techniques (Gutzwiller 1991, Fletcher Jr. et al. 2000). Birds not actively engaged in breeding behavior tend to sing less often and are less conspicuous (Fletcher Jr. et al. 2000). In some cases, walking transects have shown to produce more reliable data from bird surveys outside of the breeding season (Fletcher et al. 2000, Wilson et al. 2000). Additionally, preliminary surveys indicated that walking transects were a good alternative to point counts to provide more ground foraging data.

Statistical Methods

General linear models (GLMs) and general linear mixed-effect models (GLMMs) allow for non-normal response variables and error structures that fit their distributions. They are appropriate alternatives to standard linear models when response variables are not continuous and violate the assumptions of normality, homoscedasticity, and balance (Bolker et al. 2009). I used the stats package "glmmADMB" in the statistical program "R" to fit models with the Laplace approximation because it allowed for flexibility with GLMs and GLMMs (Bolker et al. 2009, Skaug et al. 2011). I used Wald Z-tests for significance of fixed effects and their interactions.

Herbaceous Vegetation Models.--

I calculated the mean for each cover class and mean heights from each vegetation survey. I used a matrix of scatter-plots and Variance Inflation Factors (VIF) in the statistical program “R” (R Core Team 2014) to assess collinearity among vegetation predictors. I removed tallest forb and tallest dead grass because they appeared correlated with more than one other predictor in the scatter-plots. Additionally, I removed standing dead grass because it had a VIF value greater than four and appeared highly correlated with other predictors in the scatter-plots (Williams 2015). I incorporated the remaining variables: green grass cover, bare ground cover, woody cover, forb cover, litter cover, tallest forb, and tallest green grass as fixed predictors into a GLM to assess which vegetation variables were significantly influenced by grazing. I used grazed vs. ungrazed as a binary response variable with the binomial error structure to fit the full GLM that included all possible interactions among predictors. No significant interactions were present so I analyzed the model without interactions. Woody cover was the only non-significant predictor (Table 1) and to obtain a better fit, I analyzed the model again without woody cover as a predictor. I found the coefficient estimate for green grass cover varied among models and conflicted with the means for grazed and ungrazed sites. After further investigation, I determined that collinearity caused the conflict and I removed green grass cover from the model (Williams 2015). I used the remaining significant vegetation variables in various GLMMs to assess the influences of grazing on the avian parameters. I excluded the fixed binary predictor “Grazed” from the avian models because it was highly correlated with most if not all of the vegetation factors.

Breeding Bird Models.--

I designed four additive GLMMs for breeding birds using each avian index and included bare ground cover, litter cover, forb cover, and tallest green grass as continuous fixed predictors. To account for the random selection of survey sites in each pasture, I included intercepts-only nested random effects of "site within pasture" for all the initial models. I also used breeding season (2014 and 2015) as a fixed factor to address the differences in indices between breeding seasons. I did not use foraging counts in breeding bird analyses because the incidence of ground foraging was rare and above ground foraging was difficult to distinguish due to the abundance of woody vegetative foliage. I excluded any point count surveys that detected non-breeding wintering birds. Likewise, I removed all transient migrants from the breeding bird analyses.

Wintering Bird Models.--

I designed four additive GLMMs for wintering birds using each avian index and included bare ground cover, litter cover, forb cover, and tallest green grass as continuous fixed predictors. To account for the random selection of survey site in each pasture, I included intercepts-only nested random effects of "site within pasture" for all the initial models. I determined the beginning of survey data for wintering bird analyses was the end of October, when no migratory breeding birds were detected and many of the non-breeding wintering species had already arrived. Likewise, for wintering bird analyses, I analyzed survey data ending in March when migratory breeding birds began to arrive. I excluded any transect surveys that detected non-wintering breeding birds. Also, I removed all transient migratory species from wintering bird analyses. Initially, I analyzed all wintering bird models with month as a fixed categorical predictor to account for changes across months.

Wintering Bird Ground Foraging Model.--

For wintering birds only, I built a fifth GLMM using ground foraging counts as the response variable and included bare ground cover, litter cover, forb cover, and tallest green grass as continuous fixed predictors. To account for the random selection of survey sites in each pasture, I included intercepts-only nested random effects of "site within pasture." I also included month as a fixed categorical predictor.

Model Building.--

I began avian model building by fitting each response variable to the appropriate error distribution. The Poisson and negative binomial distributions as well as their various extensions (e.g. zero-inflation, hurdle models), have shown to best-fit count data and other non-normally distributed data (Bolker et al. 2009, Linden and Mantyniemi 2011, Skaug et al. 2011). During initial data exploration, I used the package "car" in the program "R" to fit avian abundance, richness, diversity, evenness, and foraging counts to error distributions including: Poisson, negative binomial, gamma, and Gaussian (Fox and Weisberg 2011). If Poisson and/or negative binomial distributions best described a response variable distribution, I used Akaike Information Criterion (AIC) to assess response variable fit to these error distributions and their extensions including: type 1 negative binomial (linear mean-variance relationship), type 2 negative binomial (quadratic mean-variance relationship), and with and without zero-inflation (accounts for excessive zeros in a data set) where appropriate. Similarly, if more than one error distribution best described a response variable, I used AIC to determine the appropriate distribution to use. Only models with $\Delta\text{AIC} \leq 2$ were considered competing for best-fit error distribution model selection. Type 1 and 2 negative binomial models with competing AIC values were assessed using the negative binomial dispersion parameter (NBDP). A much greater than expected dispersion parameter estimate based on the mean-variance relationship (e.g. $\mu = 14.32$, $\sigma = 33.52$; NBDP = 403), indicated that the distribution was not a good fit for that particular response variable (Lord 2006). I carried out model selection for each response variable by stepwise removal of non-significant fixed effects and using AIC to determine best-fit models. I only reported models with $\Delta AIC \leq 2$ to be considered for best-fit models of the data (Burnham and Anderson 2002). For all models, I removed the nested random effect of "site in pasture" because it accounted for little or none of the variance in any model. I kept "site" as a single intercepts-only random factor in all models, regardless of effect, to address potential spatial autocorrelation, the random selection of survey sites, and attain more conservative statistical results (Bolker et al. 2009). Additionally, I detected no significant difference in wintering bird indices across months, so I removed the fixed factor "month" from all the competing wintering bird models.

IV. RESULTS

Herbaceous Vegetation

I completed a total of 383 herbaceous ground cover surveys from April 2014 to April 2015, totaling 3,830 Daubenmire quadrats. All surveys were included in the initial GLMs to assess which predictors were significantly influenced by grazing. After I removed all non-significant factors, tallest green grass was negatively correlated with grazed sites ($\beta = -3.231$, $Z = -1.990$, $P = 0.046$). Mean tallest green grass (cm) was 39% lower in grazed sites ($\bar{X} = 21.80$ cm, SD = 10.3 cm) than ungrazed sites ($\bar{X} = 35.680$ cm, SD = 10.040 cm). Bare ground cover was positively correlated with grazed sites ($\beta = 3.492$, $Z = 7.850$, $P < 0.001$). Mean bare ground cover value was 98% higher in grazed sites ($\bar{X} = 1.930$, SD = 0.550) than ungrazed sites ($\bar{X} = 0.976$, SD = 0.400). Forb cover was positively correlated with grazed sites ($\beta = 1.592$, $Z = 5.270$, $P < 0.001$). Mean forb cover value was 25% higher in grazed sites ($\bar{X} = 2.350$, SD = 0.620) than ungrazed sites ($\bar{X} = 1.874$, SD = 0.639). Litter cover was also positively correlated with grazed sites ($\beta = 1.340$, $Z = 2.910$, $P = 0.003$). Mean litter cover value was 24% higher in grazed sites ($\bar{X} = 1.790$, SD = 0.45) than ungrazed sites ($\bar{X} = 1.439$, SD = 0.445).

Table 1. Competing binomial herbaceous vegetation models with grazed vs. ungrazed as a binary response variable. Ground cover data was collected along 100 m transects at Freeman Center between 2014 and 2015 in grazed and ungrazed sites. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Vegetation1	Binomial	Intercept	-9.439	1.492	-6.330	<0.001*	-
		Forbs	1.592	0.302	5.270	<0.001*	
		Bare	3.492	0.445	7.850	<0.001*	
		Litter	1.340	0.460	2.910	0.004*	
		TGG	-3.231	1.620	-1.990	0.046*	
Vegetation2	Binomial	Intercept	-9.442	1.524	-6.200	<0.001*	2
		Forbs	1.593	0.310	5.140	<0.001*	
		Bare	3.492	0.446	7.830	<0.001*	
		Litter	1.341	0.460	2.910	0.004*	
		TGG	-3.232	1.622	-1.990	0.046*	
		Woody	0.009	0.808	0.010	0.991	

Breeding Birds

From a total of 284 point count surveys, I included 145 in the breeding bird analyses. I conducted 65 point count surveys in the 2014 breeding season and 80 in the 2015 breeding season. I detected a total of 2,067 birds, of which 1,152 were detected in the 2014 breeding season and 915 in the 2015 breeding season. The overall mean abundance per survey was 14.3 individuals and the overall richness per survey was 8.89 unique species. The most commonly detected species across both breeding seasons were Northern Cardinal (*Cardinalis cardinalis*), Bewick's Wren (*Thryomanes bewickii*), and Northern Mockingbird (*Mimus polyglottos*) (grand totals = 282, 267, and 216 respectively). I also detected Northern Cardinals, Bewick's Wrens, and Northern Mockingbirds on 134, 132, and 104 (92%, 91%, and 72%, respectively) of analyzed point counts, the highest among all breeding birds. Total breeding bird species richness was 53 (44 in 2014 and 43 in 2015). Notable species observed during the analyzed point counts were: Golden-cheeked Warbler (*Setophaga chrysoparia*), Northern Parula (*Setophaga americana*), Yellow-breasted Chat (*Icteria virens*), Bullock's Oriole (*Icterus bullockii*), Vermillion Flycatcher (*Pyrocephalus rubinus*), and Northern Bobwhite (*Colinus virginianus*).

The only significant factor in all breeding bird abundance models was between breeding seasons (β = -0.493, Z = -5.24, P < 0.001). Mean abundance declined by 35% from the breeding season of 2014 ($\bar{X}$ = 17.785, SD = 5.407) to the breeding season of 2015 ($\bar{X}$ = 11.475, SD = 4.357). There was no significant correlation in breeding bird abundance among the vegetation factors (Table 2). However, mean abundance was 25% higher in grazed sites ($\bar{X}$ = 16.200, SD = 5.558) than ungrazed sites ($\bar{X}$ = 12.271, SD = 5.321).

Table 2. Competing breeding bird models with abundance as the response variable for 100 m fixed radius point count surveys conducted during the breeding seasons of 2014 and 2015 at Freeman Center. Breeding season and herbaceous vegetation parameters were used as predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Abundance1	Poisson	Intercept	2.855	0.060	47.670	<0.001*	-
		Season(2015)	-0.446	0.045	-9.980	<0.001*	
Abundance2	Poisson	Intercept	2.651	0.153	17.350	<0.001*	0
		Season(2015)	-0.533	0.076	-7.060	<0.001*	
		Forbs	0.097	0.068	1.430	0.150	
Abundance3	Poisson	Intercept	2.591	0.173	14.940	<0.001*	1.5
		Season(2015)	-0.533	0.075	-7.110	<0.001*	
		Forbs	0.100	0.067	1.500	0.130	
		Bare	0.038	0.055	0.690	0.490	

Table 3. Competing breeding bird models with species richness as the response variable for 100 m fixed radius point count surveys conducted during the breeding seasons of 2014 and 2015 at Freeman Center. Breeding season and herbaceous vegetation parameters were used as predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Richness1	Poisson	Intercept	1.806	0.179	10.110	<0.001*	-
		Season(2015)	-0.495	0.083	-5.940	<0.001*	
		Forbs	0.187	0.062	3.000	0.003*	
		TGG	0.442	0.290	1.520	0.127	
Richness2	Poisson	Intercept	1.975	0.140	14.150	<0.001*	0.4
		Season(2015)	-0.536	0.078	-6.870	<0.001*	
		Forbs	0.184	0.062	3.000	0.003*	
Richness3	Poisson	Intercept	1.791	0.238	7.530	<0.001*	2
		Season(2015)	-0.492	0.091	-5.410	<0.001*	
		Forbs	0.187	0.063	2.960	0.003*	
		Bare	0.007	0.067	0.100	0.923	
		TGG	0.462	0.358	1.290	0.197	

Breeding bird richness declined among sites between breeding seasons (β = -0.493, $Z = -5.360$, $P < 0.001$), with a mean breeding bird richness decrease of 30% from the 2014 breeding season ($\bar{X} = 10.692$, SD = 2.524) to the 2015 breeding season ($\bar{X} = 7.425$, SD = 2.584). The only other significant predictor was forb cover (Table 3) and breeding bird richness was positively correlated with forb cover (β = 0.1874, $Z = 3.000$, $P = 0.003$). Mean breeding bird richness was 11% higher in grazed sites ($\bar{X} = 9.387$, SD = 2.645) than ungrazed sites ($\bar{X} = 8.357$, SD = 3.323).

Table 4. Competing breeding bird models with Shannon-Weiner diversity as the response variable for 100 m fixed radius point count surveys conducted during the breeding seasons of 2014 and 2015 at Freeman Center. Breeding season and herbaceous vegetation parameters were used as predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Diversity1	Gaussian	Intercept	1.613	0.157	10.260	<0.001*	-
		Season(2015)	-0.457	0.080	-5.690	<0.001*	
		Forbs	0.171	0.063	2.710	0.007*	
		TGG	0.631	0.263	2.400	0.016*	
Diversity2	Gaussian	Intercept	1.533	0.204	7.510	<0.001*	1.6
		Season(2015)	-0.434	0.089	-4.910	<0.001*	
		Forbs	0.164	0.065	2.540	0.011*	
		Bare	0.040	0.064	0.610	0.539	
		TGG	0.739	0.315	2.340	0.019*	

Table 5. Competing breeding bird models with Smith and Wilson's evenness as the response variable for 100 m fixed radius point count surveys conducted during the breeding seasons of 2014 and 2015 at Freeman Center. Breeding season and herbaceous vegetation parameters were used as predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Evenness1	Gaussian	Intercept	0.859	0.033	26.070	<0.001*	-
		Season(2015)	0.039	0.012	3.300	<0.001*	
		Bare	-0.019	0.011	-1.830	0.068	
		TGG	0.101	0.057	1.780	0.075	
Evenness2	Gaussian	Intercept	0.912	0.014	63.310	<0.001*	1.1
		Season(2015)	0.027	0.001	2.760	0.006*	
		Bare	-0.030	0.009	-3.520	<0.001*	
Evenness3	Gaussian	Intercept	0.811	0.019	41.840	<0.001*	1.1
		Season(2015)	0.047	0.011	4.470	<0.001*	
		TGG	0.157	0.049	3.230	0.001*	
Evenness4	Gaussian	Intercept	0.869	0.038	22.830	<0.001*	1.7
		Season(2015)	0.042	0.014	3.030	0.003*	
		Forbs	-0.005	0.009	-0.500	0.614	
		Bare	-0.019	0.011	-1.830	0.067	
		TGG	0.101	0.057	1.790	0.074	

Based on the best-fit model (Table 4), breeding bird diversity decreased between breeding seasons (β = -0.457, *Z* = -5.690, *P* < 0.001), with a mean breeding bird diversity decrease of 16% from the breeding season of 2014 ($\bar{X}$ = 2.202, SD = 0.280) to the breeding season of 2015 ($\bar{X}$ = 1.841, SD = 0.399). Breeding bird diversity was positively correlated with tallest green grass (β = 0.631, *Z* = 2.400, *P* = 0.016). Breeding bird diversity was also positively correlated with forb cover (β = 0.171, *Z* = 2.710, *P* = 0.007). Mean breeding bird diversity was 6% higher in grazed sites ($\bar{X}$ = 2.063, SD = 0.299) than ungrazed sites ($\bar{X}$ = 1.939, SD = 0.468).

Breeding bird evenness slightly increased between breeding seasons (β = 0.039, *Z* = 3.300, *P* = 0.001), with a mean breeding bird evenness increase of 3.5% from the breeding season of 2014 ($\bar{X}$ = 0.869, SD = 0.063) to the breeding season of 2015 ($\bar{X}$ = 0.900, SD = 0.059). Based on the best-fit model, no other predictors significantly affected breeding bird evenness (Table 5). However, one competing model showed that breeding bird evenness had a slight negative correlation with bare ground (β = -0.030, *Z* = -3.52, *P* < 0.001). Another competing model showed that breeding bird evenness was positively correlated with tallest green grass (β = 0.157, *Z* = 3.230, *P* = 0.001). Mean breeding bird evenness was 5% lower in grazed sites ($\bar{X}$ = 0.864, SD = 0.059) than ungrazed sites ($\bar{X}$ = 0.910, SD = 0.058).

Due to multicollinearity, I excluded the binary categorical predictor of grazed vs. ungrazed in bird models with vegetation predictors. Post-hoc, I built GLMMs comparing the fixed binary predictor grazed vs. ungrazed among all response variables. I also included year as a fixed predictor and site as an intercepts-only random factor. Among breeding bird point counts, only abundance and evenness were significantly different between grazed and ungrazed sites; abundance was positively correlated with grazed sites ($\beta = 0.281$, $Z = 3.030$, $P = 0.002$), and evenness was negatively correlated with grazed sites ($\beta = -0.047$, $Z = -5.000$, $P < 0.001$).

Wintering Birds

From 435 avian transect surveys that I completed between April 2014 and April 2015, I used 184 in wintering bird analyses from the end of October 2014 through the middle of March 2015. I detected a total of 1,095 birds during surveys used in analyses. The overall mean abundance per survey was 12.17 individuals and the overall mean richness per survey was 5.73 unique species. The most abundant wintering birds detected were Northern Cardinal, Bewick's Wren, and Vesper Sparrow (260, 198, and 185 individuals respectively). However, Bewick's Wrens, Northern Cardinals, and Northern Mockingbirds were detected on 125 (68%), 112 (61%), and 97 (53%) analyzed surveys, respectively. Other notably abundant species were 98 Black-crested Titmice (*Baeolophus atricristatus*), 94 Mourning Doves (*Zenaida macrura*), 76 Verdins (*Auriparus flaviceps*), 61 Ruby-crowned Kinglets (*Regulus calendula*), and 60 Field Sparrows (*Spizella pusilla*). Emberizine sparrow richness was represented by: Rufous-crowned Sparrows, Field Sparrows, Chipping Sparrows (*Spizella passerina*), Grasshopper Sparrows (*Ammodramus savannarum*), Savannah Sparrows, Vesper Sparrows, Lark Sparrows, White-throated Sparrows (*Zonotrichia albicollis*), White-crowned Sparrows (*Zonotrichia leucophrys*), Song Sparrows (*Melospiza melodia*), and Lincoln's Sparrows (*Melospiza lincolnii*).

Table 6. Competing wintering bird models with abundance as the response variable for 100 m walking transect surveys conducted between October 2014 and March 2015 at Freeman Center. Herbaceous vegetation variables significantly different between grazed and ungrazed sites were used as continuous predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Abundance1	Negative	Intercept	1.951	0.213	9.170	<0.001*	-
	Binomial	Bare	0.181	0.126	1.430	0.150	
Abundance2	Negative	Intercept	2.189	0.310	7.070	<0.001*	0.8
	Binomial	Bare	0.229	0.135	1.700	0.089	
		Litter	-0.204	0.187	-1.090	0.276	

Table 7. Competing wintering bird models with species richness as the response variable for 100 m walking transect surveys conducted between October 2014 and March 2015 at Freeman Center. Herbaceous vegetation variables significantly different between grazed and ungrazed sites were used as continuous predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Richness1	Negative	Intercept	1.747	0.225	7.750	<0.001*	-
	Binomial1	Litter	-0.083	0.140	-0.600	0.550	
Richness2	Negative	Intercept	1.682	0.232	7.250	<0.001*	1.5
	Binomial1	Bare	0.076	0.100	0.760	0.450	
		Litter	-0.116	0.144	-0.800	0.420	

There were no significant correlations in wintering bird abundance, richness, diversity, or evenness among all vegetation factors for all competing models (Tables 6-9). However, mean wintering bird abundance was 55% higher in grazed sites ($\bar{X}$ = 12.167, SD = 9.743) than ungrazed sites ($\bar{X}$ = 7.840, SD = 6.761), mean wintering bird richness was 22% higher in grazed sites ($\bar{X}$ = 5.733, SD = 3.104) than ungrazed sites ($\bar{X}$ = 4.691, SD = 3.145), and mean wintering bird diversity was 8.6% higher in grazed sites ($\bar{X}$ = 1.394, SD = 0.638) than ungrazed sites ($\bar{X}$ = 1.274, SD = 0.689). Contrarily, mean wintering bird evenness was 4.5% lower in grazed sites ($\bar{X}$ = 0.823, SD = 0.217) than ungrazed sites ($\bar{X}$ = 0.861, SD = 0.220).

Table 8. Competing wintering bird models with Shannon-Weiner Diversity as the response variable for 100 m walking transect surveys conducted between October 2014 and March 2015 at Freeman Center. Herbaceous vegetation variables significantly different between grazed and ungrazed sites were used as continuous predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Diversity1	Gaussian	Intercept	1.423	0.227	6.280	<0.001*	-
		Litter	-0.063	0.139	-0.450	0.650	
Diversity2	Gaussian	Intercept	1.395	0.237	5.890	<0.001*	1.9
		Bare	0.036	0.105	0.340	0.730	
		Litter	-0.080	0.147	-0.540	0.590	

Table 9. Competing wintering bird models with Smith and Wilson's evenness as the response variable for 100 m walking transect surveys conducted between October 2014 and March 2015 at Freeman Center. Herbaceous vegetation variables significantly different between grazed and ungrazed sites were used as continuous predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Evenness1	Gaussian	Intercept	0.877	0.047	18.690	<0.001*	-
		Bare	-0.033	0.028	-1.180	0.240	
Evenness2	Gaussian	Intercept	0.820	0.072	11.420	<0.001*	0.9
		Bare	-0.047	0.030	-1.540	0.120	
		Forbs	0.036	0.034	1.040	0.300	

Wintering Bird Ground Foraging

Based on the best-fit model (Table 10), wintering bird ground foraging counts were positively correlated with forb cover (β = 0.809, *Z* = 3.070, *P* = 0.002). Mean ground foraging counts were 105% higher in grazed sites ($\bar{X}$ = 3.644, SD = 5.437) than ungrazed sites ($\bar{X}$ = 1.777, SD = 4.038).

Table 10. Competing wintering bird models with foraging count as the response variable for 100 m walking transect surveys conducted between October 2014 and March 2015 at Freeman Center. Herbaceous vegetation variables significantly different between grazed and ungrazed sites were used as continuous predictors along with an intercepts-only random effect of survey site. β = coefficient estimates, Family = error distribution, ZI = Zero Inflation, and * indicates significant *P*-values.

Model	Family	Fixed Effects	β	SE	*Z*	*P*	ΔAIC
Foragers1	Negative	Intercept	-0.842	0.642	-1.310	0.190	-
	BinomialZI	Forbs	0.809	0.264	3.070	0.002*	
Foragers2	Negative	Intercept	-0.969	0.648	-1.490	0.135	1.2
	BinomialZI	Bare	0.261	0.285	0.920	0.360	
		Forbs	0.697	0.286	2.440	0.015*	

Similar to breeding birds, I built post-hoc GLMMs for wintering birds with grazed vs. ungrazed as a fixed binary predictor. I also included site as an intercepts-only random factor. Only wintering bird abundance and ground foraging counts differed significantly between grazed and ungrazed sites. Wintering bird abundance was positively correlated with grazed sites (β = 0.482, *Z* = 2.590, *P* = 0.010) and ground foraging was positively correlated with grazed sites (β = 0.960, *Z* = 2.320, *P* = 0.020).

V. DISCUSSION

Vegetation

Based on my results, moderate grazing at Freeman Center between 2014 and 2015 affected the herbaceous community by altering ground cover heights and relative amounts. Results from the GLM comparing grazed and ungrazed vegetation confirms previous research that bare ground, forb, and litter cover typically increases with grazing pressure. Grazing tends to open up the ground, allowing increases in forb production as well as making litter accumulation more visible. Grass height typically decreases with grazing pressure due to cattle consumption (Holechek et al. 1982, Naeth et al. 1991, Hayes and Holl 2003). I expected correlations among vegetation predictors. Removing highly correlated predictor variables is a common practice in mixed modeling, because analyzing correlated predictors can increase the chance of committing Type I and/or Type II errors (Williams 2015).

Breeding Birds

Most of the results I obtained from the breeding bird GLMMs, using herbaceous vegetation predictors, were consistent with mean differences in the indices between grazed and ungrazed sites. Breeding bird abundance and distribution can vary significantly from year to year, especially considering the stochastic climate and rainfall patterns in Central Texas (Cecil and Green 2010, Sauer et al. 2014). My survey efforts varied across breeding seasons. I conducted more breeding bird surveys in 2015 across fewer months than 2014. Thus changes in index values could also be explained by changes in survey efforts from the breeding season of 2014 to the breeding season of 2015. Breeding bird richness increased with forb cover, which is not unexpected since many breeding birds are known to utilize forbs for foraging, nest material, and cover (Rodewald 2015).

Differences in mean breeding bird abundance in grazed and ungrazed sites could have been confounded by other habitat factors. Grazed areas had overall less vegetation, as reflected in herbaceous surveys and anecdotal assessment of woody encroachment in ungrazed areas. Increased visual bird detections at grazed sites could be due to the increased visibility in the survey areas. However, since breeding bird abundance is based more on aural than visual observations during point count surveys, this bias may not have greatly affected my data. The difference in evenness between grazed and ungrazed sites was likely an artifact of abundance. Low abundance counts typically have higher evenness values (Alatalo 1981). Thus, significantly lower evenness values may not suggest an actual ecological problem in short-term studies, especially of highly mobile animals. A multi-year study could incorporate my data and similar methods to analyze long term cattle use and account for climatic variation.

Breeding bird diversity models with vegetation predictors were inconsistent with post-hoc GLMMs because diversity was positively correlated with tallest green grass and forb cover. These results may indicate that breeding bird diversity increased with forb cover and taller grasses among sites, independent of livestock grazing. Additionally, the prevalence of King Ranch bluestem and Bermuda grass (*Cynodon dactylon*) at some sites could have confounded the results. Survey sites where these grasses were abundant averaged less forb cover. Bird abundance and diversity typically decreases in areas dominated by King Ranch bluestem, Bermuda grass, and other low productivity grasses (Flanders et al. 2006). Areas where taller grass species like little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), and gramas (*Bouteloua spp.*) were present, grass diversity, height, and forb cover seemed to increase. Studies have shown that greater forb and grass diversity tends to increase wildlife diversity (Conover et al. 2014, Flanders et al. 2006, Fuhlendorf and Engle 2001). Future research at Freeman Center should analyze herbaceous vegetation diversity as well as document the dominant herbaceous species in any survey area to address potential habitat differences in survey sites.

Wintering Birds

Though wintering bird abundance, richness, diversity and evenness were not significantly correlated with any vegetation predictors, higher abundance counts in grazed sites may indicate greater use of grazed areas by wintering birds. Abundance of wintering birds may also be influenced by ground foraging species like Mourning Doves, ground doves, meadowlarks (*Sturnella spp.*), and many sparrows which exhibit flocking behavior in the winter.

Wintering Bird Ground Foraging

In a similar manner to wintering bird abundance, wintering bird ground foraging counts likely reflected behaviors of flocking species. Doves, meadowlarks, and flocking sparrows (e.g. Chipping Sparrow), primarily utilize ground foraging in the winter months (Rodewald 2015). Observations of large flocks during a survey likely increased foraging counts in grazed sites because mixed flocks typically select areas with shorter grasses and significant amounts of bare ground (Rodewald 2015).

Perhaps the most interesting results were found in the vegetation model for wintering bird ground foraging. The positive correlation of ground foraging and forb cover suggests that in addition to grass seeds, cool season forbs provide resources important to ground foraging wintering birds on the Edwards Plateau. Northern Bobwhites and some songbirds consume legumes and other forbs in the crucial winter months (Stephens 2008, Rodewald 2015). In addition, forbs harbor insects and plant materials that wildlife consume throughout the year. Conservation of bees and other pollinators greatly depends on the availability of forbs as well (McPeake 2012, Smith 2010). Increasing concern about monarch butterflies (*Danaus plexippus*) and milkweeds (*Asclepias spp.*), further highlights the importance of forbs in an area central to the butterfly's migration pathway (Frost and Gore 2008). In South Texas, clammyweed (*Polanisia dodecandra*), redseed plantain (*Plantago rhodosperma*), and hookers plantain (*Plantago hookeriana*) have provided forage and resources for various wildlife, including: Northern Bobwhites, Mourning Doves, Wild Turkeys, and white-tailed deer. These forbs also support pollinators and provide livestock forage (Smith 2010). Central Texas native seed mixes that include cool season forbs like Texas bluebonnet (*Lupinus texensis*) and Engelmann's daisy (*Engelmannia peristenia*) are appropriate for the Edwards Plateau ecoregion and can improve winter forage availability for birds and other wildlife (Native Plant Information Network 2015).

Species of Conservation Concern

During my field work, I observed both Golden-cheeked Warbler and Black-capped Vireo (*Vireo atricapilla*) at Freeman Center. Multiple male Golden-cheeked Warblers were observed singing both versions of their song in potential breeding habitat, but I failed to observe any females or evidence of nesting. Future management should consider conserving juniper/oak woodland habitat for Golden-cheeked Warblers. I found one male Black-capped Vireo singing within the front pasture in early spring, in what appeared to be marginal habitat. I returned to the area on more than one occasion and failed to observe another Black-capped Vireo on the property. Though Black-capped Vireos could nest on Freeman Center, potential nesting habitat would likely need to be managed with prescribed burns and selective vegetation removal. Additionally, I observed multiple Grasshopper Sparrows during migration, late spring, and the winter months. However, I found no evidence for nesting of Grasshopper Sparrow on Freeman Center. A typically over-grazing intolerant species, I found Grasshopper Sparrows in equal numbers within grazed and ungrazed areas, suggesting responsible grazing management. Other rare, unusual, or species of conservation concern that I observed throughout my field work included: Le Conte's Sparrow (*Ammodramus leconteii*), Upland Sandpiper, Prairie Falcon (*Falco mexicanus*), Pyrrhuloxia (*Cardinalis sinuatus*), and Bell's Vireo (*Vireo bellii*). Grazing may have mixed affects on these species, and their habitat requirements should be considered in management plans. A complete list of all the species I observed from Freeman Center, including those used in analyses, is located in APPENDIX A.

Grazing and Wildlife Management

Given that forb cover was positively correlated with grazed sites, moderate grazing pressure likely increased forb production. Breeding bird richness, breeding bird diversity, and wintering bird foraging counts were all positively correlated with forb cover. These results suggest that forb production is very important to breeding and wintering birds in the Texas Hill Country. Overall increases in avian abundance and ground foraging at grazed sites, suggests low to moderate grazing can benefit much of the bird community at Freeman Center. Using grazing techniques to find a balance between forb and grass production should optimize herbaceous diversity and benefit the greatest diversity of grassland, savanna, and shrubland wildlife.

Special attention to climate patterns and rainfall is integral to successful livestock operations. I think a judgment deferred rotational grazing system is compatible with wildlife on the Edwards Plateau when ranch managers have enough land, tools, knowledge, experience, and financial support to make livestock movement decisions based on long term sustainability. Management practices like responsible grazing that promotes forb production and herbaceous vegetation diversity, creating and protecting habitat for species of conservation concern, and continued Brown-headed Cowbird trapping, should promote avifaunal, small mammal, and herpetofaunal diversity (Jones et al. 2000, Rahmig et al. 2009, Perlut and Strong 2011, DeGolier et al. 2015). Blending wildlife conservation and anthropogenic activities is imperative for the sustainability of our ecosystems and our lives. The future of conservation lies in the ability of humans to make conscious, informed decisions regarding our natural world that consider both the needs of humans and the needs of wildlife.

APPENDIX SECTION

APPENDIX A. All avian species encountered at Freeman Center during the study of herbaceous vegetation and avian parameters in grazed and ungrazed sites between January 2014 and April 2015. * indicates species not included in analyses/incidental observations.

Species	**Breeding Analyses**	**Wintering Bird Analyses**	**Ground Foraging Analysis**	**Other***
Double-crested Cormorant (*Phalacrocorax auritus*)				X
Great Blue Heron (*Ardea herodias*)				X
Cattle Egret (*Bubulcus ibis*)				X
Black-bellied Whistling-Duck (*Dendrocygna autumnalis*)				X
Gadwall (*Anas strepera*)				X
Green-winged Teal (*Anas crecca*)				X
Turkey Vulture (*Cathartes aura*)	X	X		
Black Vulture (*Coragyps atratus*)	X			
Northern Harrier (*Circus cyaneus*)				X
Mississippi Kite (*Ictinia mississippiensis*)				X
Sharp-shinned Hawk (*Accipiter striatus*)				X
Cooper's Hawk (*Accipiter cooperii*)	X	X	X	
Red-shouldered Hawk (*Buteo lineatus*)	X			
Broad-winged Hawk (*Buteo platypterus*)				X
Swainson's Hawk (*Buteo swainsoni*)				X
Red-tailed Hawk (*Buteo jamaicensis*)	X			
Osprey (*Pandion haliaetus*)				X
Crested Caracara (*Caracara cheriway*)	X			
American Kestrel (*Falco sparverius*)		X		X
Prairie Falcon (*Falco mexicanus*)				X
Northern Bobwhite (*Colinus virginianus*)	X	X	X	
Chukar (*Alectoris chukar*)				X
Wild Turkey (*Meleagris gallopavo*)	X	X		
Sandhill Crane (*Grus canadensis*)				X
Killdeer (*Charadrius vociferus*)				X
Greater Yellowlegs (*Tringa melanoleuca*)				X
Spotted Sandpiper (*Actitis macularius*)				X
Upland Sandpiper (*Bartramia longicauda*)				X
American Woodcock (*Scolopax minor*)				X
Franklin's Gull (*Leucophaeus pipixcan*)				X
Mourning Dove (*Zenaida macroura*)	X	X	X	
White-winged Dove (*Zenaida asiatica*)	X			

Inca Dove (*Columbina inca*)	X			
Common Ground-Dove (*Columbina passerina*)	X	X	X	
Yellow-billed Cuckoo (*Coccyzus americanus*)	X			
Greater Roadrunner (*Geococcyx californianus*)	X	X		
Barn Owl (*Tyto alba*)				X
Great Horned Owl (*Bubo viginianus*)				X
Eastern Screech-Owl (*Megascops asio*)				X
Chuck-will's-widow (*Antrostomus carolinensis*)				X
Common Nighthawk (*Chordeiles minor*)				X
Chimney Swift (*Chaetura pelagica*)	X			
Black-chinned Hummingbird (*Archilochus alexandri*)	X			
Golden-fronted Woodpecker (*Melanerpes aurifrons*)	X	X		
Ladder-backed Woodpecker (*Picoides scalaris*)	X	X		
Northern Flicker (*Colaptes auratus*)		X		
Olive-sided Flycatcher (*Contopus cooperi*)				X
Least Flycatcher (*Empidonax minimus*)				X
Eastern Phoebe (*Sayornis phoebe*)	X	X	X	
Say's Phoebe (*Sayornis saya*)				X
Vermilion Flycatcher (*Pyrocephalus rubinus*)	X			
Ash-throated Flycatcher (*Myriarchus cinerascens*)	X			
Great Crested Flycatcher (*Myriarchus crinitus*)				X
Eastern Kingbird (*Tyrannus tyrannus*)				X
Couch's Kingbird (*Tyrannus couchii*)				X
Western Kingbird (*Tyrannus verticalis*)	X			
Scissor-tailed Flycatcher (*Tyrannus forficatus*)	X			
Loggerhead Shrike (*Lanius ludovicianus*)				X
Red-eyed Vireo (*Vireo olivaceus*)				X
Warbling Vireo (*Vireo gilvus*)				X
Bell's Vireo (*Vireo bellii*)				X
Black-capped Vireo (*Vireo atricapilla*)				X
White-eyed Vireo (*Vireo griseus*)	X			
Blue-headed Vireo (*Vireo solitarius*)				X
Blue Jay (*Cyanocitta cristata*)		X		
Western Scrub-Jay (*Aphelocoma californica*)	X	X	X	
Common Raven (*Corvus corax*)		X		
American Crow (*Corvus brachyrhynchos*)				X
Purple Martin (*Progne subis*)	X			
Cliff Swallow (*Petrochelidon pyrrhonota*)				X
Cave Swallow (*Petrochelidon fulva*)				X
Barn Swallow (*Hirundo rustica*)	X			
Black-crested Titmouse (*Baeolophus atricristatus*)	X	X	X	
Carolina Chickadee (*Poecile carolinensis*)	X	X		
Verdin (*Auriparus flaviceps*)	X	X	X	

Carolina Wren (*Thryothorus ludovicianus*)	X	X	X	
Bewick's Wren (*Thyromanes bewickii*)	X	X	X	
House Wren (*Troglodytes aedon*)		X	X	
Canyon Wren (*Catherpes mexicanus*)	X			
Golden-crowned Kinglet (*Regulus satrapa*)				X
Ruby-crowned Kinglet (*Regulus calendula*)		X		
Blue-gray Gnatcatcher (*Polioptila caerulea*)	X			
Eastern Bluebird (*Sialia sialis*)	X	X	X	
American Robin (*Turdus migratorius*)		X		
Hermit Thrush (*Catharus guttatus*)				X
Northern Mockingbird (*Mimus polyglottos*)	X	X	X	
Brown Thrasher (*Toxostoma rufum*)				X
Long-billed Thrasher (*Toxostoma longirostre*)				X
European Starling (*Sturnus vulgaris*)	X	X		
Cedar Waxwing (*Bombycilla cedrorum*)		X		
Northern Parula (*Setophaga americana*)	X			
Orange-crowned Warbler (*Oreothlypis celata*)		X		
Tennessee Warbler (*Oreothlypis peregrina*)				X
Nashville Warbler (*Oreothlypis ruficapilla*)				X
Yellow Warbler (*Setophaga petechia*)				X
Yellow-rumped Warbler (*Setophaga coronata*)		X		
Black-throated Green Warbler (*Setophaga virens*)				X
Golden-cheeked Warbler (*Setophaga chrysoparia*)	X			
Black-and-white Warbler (*Mniotilta varia*)				X
Yellow-breasted Chat (*Icteria virens*)	X			
Summer Tanager (*Piranga rubra*)	X			
Pyrrhuloxia (*Cardinalis sinuatus*)				X
Northern Cardinal (*Cardinalis cardinalis*)	X	X	X	
Blue Grosbeak (*Passerina caerulea*)	X			
Indigo Bunting (*Passerina cyanea*)				X
Painted Bunting (*Passerina ciris*)	X			
Dickcissel (*Spiza americana*)	X			
Spotted Towhee (*Pipilo maculatus*)		X	X	
Eastern Towhee (*Pipilo erythrophthalmus*)				X
Canyon Towhee (*Melozone fusca*)				X
Rufous-crowned Sparrow (*Aimophila ruficeps*)	X	X	X	
Black-throated Sparrow (*Amphispiza bilineata*)				X
Field Sparrow (*Spizella pusilla*)		X	X	
Clay-colored Sparrow (*Spizella pallida*)				X
Chipping Sparrow (*Spizella passerina*)		X	X	
Grasshopper Sparrow (*Ammodramus savannarum*)	X	X	X	
Le Conte's Sparrow (*Ammodramus leconteii*)				X
Savannah Sparrow (*Passerculus sandwichensis*)		X	X	

Vesper Sparrow (*Pooecetes gramineus*)		X	X	
Lark Sparrow (*Chondestes grammacus*)	X	X	X	
Harris's Sparrow (*Zonotrichia querula*)				X
White-throated Sparrow (*Zonotrichia albicollis*)		X	X	
White-crowned Sparrow (*Zonotrichia leucophrys*)		X	X	
Song Sparrow (*Melospiza melodia*)		X	X	
Lincoln's Sparrow (*Melospiza lincolnii*)		X	X	
Dark-eyed Junco (*Junco hyemalis*)				X
Western Meadowlark (*Sturnella neglecta*)		X	X	
Eastern Meadowlark (*Sturnella magna*)		X	X	
Brown-headed Cowbird (*Molothrus ater*)	X	X		
Bronzed Cowbird (*Molothrus aeneus*)				X
Common Grackle (*Quiscalus quiscula*)				X
Great-tailed Grackle (*Quiscalus mexicanus*)				X
Bullock's Oriole (*Icterus bullockii*)	X			
Baltimore Oriole (*Icterus galbula*)				X
Orchard Oriole (*Icterus spurius*)	X			
House Finch (*Haemorhous mexicanus*)	X	X		
Lesser Goldfinch (*Spinus psaltria*)	X	X		
American Goldfinch (*Spinus tristis*)		X		
House Sparrow (*Passer domesticus*)				X
Total: 139 species				

APPENDIX B. All breeding bird abundance counts at Freeman Center using 100 m fixed radius point count surveys in grazed and ungrazed sites between March 2014 and May 2015.

Breeding Birds	2014	2015	Mar	Apr	May	Jun	Jul	Grazed	Ungrazed
Turkey Vulture	7	0	0	0	1	6	0	4	3
Black Vulture	6	0	0	0	0	6	0	5	1
Cooper's Hawk	0	1	1	0	0	0	0	0	1
Red-shouldered Hawk	0	1	1	0	0	0	0	1	0
Red-tailed Hawk	1	0	0	0	1	0	0	1	0
Crested Caracara	1	0	0	0	1	0	0	0	1
Northern Bobwhite	43	1	0	2	16	22	4	30	14
Wild Turkey	2	21	15	6	0	0	2	21	2
Mourning Dove	95	65	33	41	31	35	20	87	73
White-winged Dove	7	7	1	6	5	2	0	2	12
Inca Dove	2	0	0	0	0	2	0	0	2
Common Ground-Dove	31	7	0	9	8	13	8	22	16
Yellow-billed Cuckoo	34	3	0	3	18	14	2	22	15
Greater Roadrunner	5	1	0	2	2	1	1	6	0
Chimney Swift	1	0	0	0	0	0	1	1	0
B-c / R-t Hummingbird	10	3	1	2	2	6	2	6	7
G-f Woodpecker	5	3	3	1	0	3	1	5	3
L-b Woodpecker	28	14	8	10	4	14	6	25	17
Eastern Phoebe	1	6	6	0	1	0	0	5	2
Vermillion Flycatcher	0	2	0	2	0	0	0	2	0
Ash-throated Flycatcher	12	9	1	8	2	9	1	12	9
Western Kingbird	6	1	0	1	3	3	0	4	3
Scissor-tailed Flycatcher	15	6	2	4	7	6	2	12	9
White-eyed Vireo	28	16	8	10	7	14	5	29	15
Western Scrub-Jay	7	4	3	2	1	4	1	9	2
Purple Martin	2	0	0	0	0	2	0	0	2
Barn Swallow	6	0	0	0	0	5	1	1	5
Black-crested Titmouse	61	68	35	39	26	26	3	64	65
Carolina Chickadee	16	20	9	12	8	5	2	20	16
Verdin	45	51	28	25	11	23	9	51	45
Carolina Wren	32	11	4	7	8	14	10	35	8
Bewick's Wren	124	143	76	78	39	53	21	161	106
Canyon Wren	0	2	0	2	0	0	0	2	0
Blue-gray Gnatcatcher	7	16	2	14	3	4	0	8	15
Eastern Bluebird	5	19	11	9	1	3	0	7	17
Northern Mockingbird	119	97	44	60	33	59	20	125	91
European Starling	0	1	1	0	0	0	0	0	1
Northern Parula	1	0	0	1	0	0	0	1	0
Golden-cheeked Warbler	1	1	0	2	0	0	0	2	0

Yellow-breasted Chat	1	0	0	0	1	0	0	0	1
Summer Tanager	6	4	0	4	2	3	1	7	3
Northern Cardinal	128	154	86	80	44	45	27	171	111
Blue Grosbeak	0	2	0	2	0	0	0	0	2
Painted Bunting	112	28	0	28	29	57	26	83	57
Dickcissel	1	0	0	0	1	0	0	1	0
Rufous-crowned Sparrow	21	25	11	15	7	11	2	25	21
Grasshopper Sparrow	0	3	1	2	0	0	0	0	3
Lark Sparrow	36	37	15	27	4	11	16	55	18
Brown-headed Cowbird	64	37	12	35	14	27	13	69	32
Bullock's Oriole	0	1	0	1	0	0	0	1	0
Orchard Oriole	0	4	0	4	0	0	0	2	2
House Finch	4	4	2	2	0	2	2	3	5
Lesser Goldfinch	13	18	10	8	7	6	0	6	25

APPENDIX C. Breeding bird analyses data by survey site, collected during the breeding seasons of 2014 and 2015 in grazed and ungrazed pastures to assess the influence of grazing on the avian community at Freeman Center in the Balcones Canyonlands of Central Texas.

Site	Pasture	Grazed?	Date	Abundance	Richness	H'	Evar
fp-3	FP	n	5/8/2014	11	7	1.846	0.884
fp-2	FP	n	5/8/2014	15	13	2.523	0.960
fp-4	FP	n	5/8/2014	9	5	1.479	0.883
fp-1	FP	n	5/8/2014	7	6	1.748	0.958
fp-5	FP	n	5/8/2014	5	4	1.332	0.943
f-2	Fer	n	5/20/2014	18	14	2.476	0.915
f-1	Fer	n	5/20/2014	18	14	2.582	0.938
f-5	Fer	n	5/20/2014	20	10	2.151	0.831
f-4	Fer	n	5/20/2014	16	10	2.056	0.810
f-3	Fer	n	5/20/2014	14	10	2.228	0.927
fp-5	FP	n	6/12/2014	23	12	2.295	0.791
fp-1	FP	n	6/12/2014	11	8	2.020	0.929
fp-4	FP	n	6/12/2014	11	10	2.272	0.972
fp-2	FP	n	6/12/2014	16	10	2.220	0.897
fp-3	FP	n	6/12/2014	14	9	2.144	0.925
f-5	Fer	n	6/13/2014	16	12	2.426	0.932
f-2	Fer	n	6/13/2014	19	12	2.302	0.849
f-1	Fer	n	6/13/2014	22	14	2.563	0.905
f-4	Fer	n	6/13/2014	24	14	2.477	0.825
f-3	Fer	n	6/13/2014	11	6	1.673	0.844
fp-4	FP	n	6/29/2014	9	7	1.831	0.907
fp-1	FP	n	6/29/2014	7	7	1.946	1.000
fp-5	FP	n	6/29/2014	23	14	2.510	0.862
fp-3	FP	n	6/29/2014	19	12	2.406	0.901
fp-2	FP	n	6/29/2014	17	12	2.425	0.926
f-5	Fer	n	6/30/2014	15	11	2.303	0.930
f-2	Fer	n	6/30/2014	16	11	2.314	0.901
f-4	Fer	n	6/30/2014	17	12	2.425	0.926
f-1	Fer	n	6/30/2014	14	12	2.441	0.958
f-3	Fer	n	6/30/2014	15	6	1.488	0.693
cn-5	CN	y	4/3/2014	17	8	1.770	0.846
cn-1	CN	y	4/3/2014	16	12	2.387	0.913
cn-4	CN	y	4/3/2014	16	9	2.047	0.832
cn-2	CN	y	4/3/2014	31	13	2.288	0.701
cn-2	CN	y	5/30/2014	23	13	2.450	0.865
cn-4	CN	y	5/30/2014	23	13	2.450	0.865
cn-6	CN	y	5/30/2014	18	12	2.370	0.879
cn-5	CN	y	5/30/2014	21	11	2.293	0.868

cn-1	CN	y	5/30/2014	14	8	2.008	0.901
nc-5	NC	y	5/31/2014	15	11	2.311	0.908
nc-3	NC	y	5/31/2014	26	13	2.395	0.809
nc-4	NC	y	5/31/2014	27	11	2.260	0.811
nc-2	NC	y	5/31/2014	22	12	2.297	0.857
nc-1	NC	y	5/31/2014	15	11	2.338	0.930
cn-1	CN	y	6/15/2014	17	11	2.232	0.847
cn-5	CN	y	6/15/2014	23	12	2.389	0.878
cn-2	CN	y	6/15/2014	19	12	2.333	0.852
cn-4	CN	y	6/15/2014	12	8	1.979	0.890
cn-6	CN	y	6/15/2014	13	8	2.032	0.929
nc-1	NC	y	6/18/2014	24	14	2.474	0.841
nc-5	NC	y	6/18/2014	22	13	2.453	0.863
nc-3	NC	y	6/18/2014	19	12	2.191	0.880
nc-2	NC	y	6/18/2014	25	14	2.432	0.801
nc-4	NC	y	6/18/2014	24	13	2.402	0.820
cn-1	CN	y	7/1/2014	23	12	2.050	0.741
cn-5	CN	y	7/1/2014	20	10	2.011	0.758
cn-2	CN	y	7/1/2014	24	13	2.441	0.849
cn-6	CN	y	7/1/2014	19	11	2.215	0.818
cn-4	CN	y	7/1/2014	21	11	2.279	0.838
nc-1	NC	y	7/2/2014	18	12	2.322	0.856
nc-4	NC	y	7/2/2014	23	12	2.303	0.811
nc-2	NC	y	7/2/2014	25	10	2.124	0.752
nc-5	NC	y	7/2/2014	13	8	1.885	0.818
nc-3	NC	y	7/2/2014	24	12	2.323	0.823
fp-5	FP	n	3/13/2015	15	9	2.026	0.927
fp-1	FP	n	3/13/2015	8	5	1.494	0.869
fp-4	FP	n	3/13/2015	7	4	1.154	0.780
fp-2	FP	n	3/13/2015	16	9	1.993	0.796
fp-3	FP	n	3/13/2015	15	10	2.211	0.897
f-3	Fer	n	3/15/2015	7	4	1.352	0.943
f-4	Fer	n	3/15/2015	8	5	1.560	0.927
f-1	Fer	n	3/15/2015	10	8	1.973	0.916
f-2	Fer	n	3/15/2015	10	7	1.887	0.925
f-5	Fer	n	3/15/2015	4	3	1.040	0.932
fp-5	FP	n	3/27/2015	13	9	2.098	0.896
fp-1	FP	n	3/27/2015	9	6	1.735	0.924
fp-4	FP	n	3/27/2015	5	4	1.332	0.943
fp-2	FP	n	3/27/2015	15	9	2.119	0.897
fp-3	FP	n	3/27/2015	13	7	1.885	0.911
f-2	Fer	n	3/28/2015	12	8	2.023	0.924
f-5	Fer	n	3/28/2015	8	4	1.321	0.901

f-1	Fer	n	3/28/2015	3	3	1.099	1.000
f-4	Fer	n	3/28/2015	8	7	1.906	0.963
f-3	Fer	n	3/28/2015	3	2	0.637	0.924
f-5	Fer	n	4/11/2015	5	5	1.609	1.000
f-4	Fer	n	4/11/2015	9	8	2.043	0.967
f-3	Fer	n	4/11/2015	2	2	0.693	1.000
f-1	Fer	n	4/11/2015	11	9	2.146	0.947
f-2	Fer	n	4/11/2015	11	8	2.020	0.929
fp-3	FP	n	4/15/2015	14	11	2.305	0.920
fp-5	FP	n	4/15/2015	17	10	2.170	0.843
fp-2	FP	n	4/15/2015	16	10	2.253	0.927
fp-1	FP	n	4/15/2015	5	5	1.609	1.000
fp-4	FP	n	4/15/2015	5	3	1.055	0.932
f-3	Fer	n	4/26/2015	8	7	1.906	0.963
f-2	Fer	n	4/26/2015	20	14	2.554	0.907
f-5	Fer	n	4/26/2015	9	6	1.677	0.879
f-1	Fer	n	4/26/2015	17	11	2.282	0.874
f-4	Fer	n	4/26/2015	15	9	1.987	0.824
fp-5	FP	n	4/27/2015	13	12	2.458	0.977
fp-1	FP	n	4/27/2015	7	7	1.946	1.000
fp-4	FP	n	4/27/2015	5	3	1.055	0.932
fp-2	FP	n	4/27/2015	14	9	2.144	0.925
fp-3	FP	n	4/27/2015	15	9	2.084	0.864
cn-1	CN	y	3/14/2015	9	8	2.043	0.967
cn-5	CN	y	3/14/2015	13	8	1.992	0.891
cn-2	CN	y	3/14/2015	11	5	1.547	0.898
cn-6	CN	y	3/14/2015	23	8	1.627	0.628
cn-4	CN	y	3/14/2015	8	4	1.321	0.901
nc-3	NC	y	3/16/2015	15	8	1.956	0.836
nc-5	NC	y	3/16/2015	9	6	1.677	0.879
nc-2	NC	y	3/16/2015	15	8	1.859	0.783
nc-4	NC	y	3/16/2015	12	7	1.699	0.797
nc-1	NC	y	3/16/2015	15	8	1.991	0.877
cn-4	CN	y	3/25/2015	11	7	1.846	0.884
cn-6	CN	y	3/25/2015	12	6	1.705	0.871
cn-2	CN	y	3/25/2015	11	7	1.846	0.884
cn-5	CN	y	3/25/2015	11	8	2.020	0.929
cn-1	CN	y	3/25/2015	8	4	1.321	0.901
nc-1	NC	y	3/29/2015	11	7	1.768	0.841
nc-4	NC	y	3/29/2015	10	7	1.887	0.925
nc-2	NC	y	3/29/2015	11	7	1.799	0.846
nc-5	NC	y	3/29/2015	10	7	1.834	0.889
nc-3	NC	y	3/29/2015	16	11	2.253	0.875

nc-1	NC	y	4/8/2015	15	6	1.679	0.806
nc-5	NC	y	4/8/2015	10	9	2.164	0.970
nc-3	NC	y	4/8/2015	20	10	2.224	0.883
nc-2	NC	y	4/8/2015	10	7	1.834	0.889
nc-4	NC	y	4/8/2015	19	11	2.306	0.880
cn-1	CN	y	4/12/2015	14	10	2.206	0.902
cn-5	CN	y	4/12/2015	7	5	1.550	0.927
cn-2	CN	y	4/12/2015	17	11	2.282	0.874
cn-6	CN	y	4/12/2015	11	4	1.264	0.797
cn-4	CN	y	4/12/2015	11	8	2.020	0.929
nc-2	NC	y	4/22/2015	16	9	2.079	0.866
nc-4	NC	y	4/22/2015	12	10	2.210	0.931
nc-1	NC	y	4/22/2015	13	7	1.885	0.911
nc-5	NC	y	4/22/2015	10	6	1.696	0.881
nc-3	NC	y	4/22/2015	9	7	1.889	0.938
nc-4	NC	y	4/25/2015	10	8	2.025	0.943
nc-6	NC	y	4/25/2015	15	9	2.084	0.864
nc-2	NC	y	4/25/2015	21	13	2.442	0.860
nc-5	NC	y	4/25/2015	15	10	2.211	0.897
nc-1	NC	y	4/25/2015	15	12	2.431	0.943

APPENDIX D. Wintering bird indices and ground foraging analyses data collected between October 2014 and March 2015 in grazed and ungrazed sites, used to assess the influence of grazing on the avian community at Freeman Center in the Balcones Canyonlands of Central Texas.

Site	Pasture	Date	Abundance	Richness	H'	Evar	Ground Foragers
f-5	Fer	10/24/2014	3	3	1.099	1.000	0
cn-1	CN	10/24/2014	12	10	2.254	0.951	1
cn-5	CN	10/24/2014	8	6	1.733	0.932	1
cn-2	CN	10/24/2014	23	12	2.303	0.811	1
cn-4	CN	10/24/2014	13	8	1.951	0.855	0
cn-6	CN	10/24/2014	27	10	2.085	0.718	0
f-1	Fer	10/24/2014	11	6	1.768	0.958	1
f-4	Fer	10/24/2014	4	4	1.386	1.000	0
f-3	Fer	10/24/2014	3	2	0.637	0.924	0
f-5	Fer	10/25/2014	3	3	1.099	1.000	1
fp-2	FP	10/25/2014	25	13	2.299	0.774	2
fp-4	FP	10/25/2014	11	8	1.972	0.899	1
fp-5	FP	10/25/2014	18	11	2.293	0.875	4
fp-3	FP	10/25/2014	13	5	1.264	0.643	2
fp-1	FP	10/25/2014	15	8	1.894	0.820	0
f-1	Fer	10/25/2014	3	2	0.637	0.924	1
f-4	Fer	10/25/2014	9	6	1.735	0.924	2
f-2	Fer	10/25/2014	9	4	1.273	0.850	3
nc-3	NC	10/27/2014	3	3	1.099	1.000	0
nc-1	NC	10/27/2014	13	10	2.205	0.914	2
nc-4	NC	10/27/2014	17	9	1.952	0.765	1
nc-2	NC	10/27/2014	13	8	1.992	0.891	0
nc-5	NC	10/27/2014	13	6	1.519	0.703	5
cn-6	CN	11/14/2014	7	6	1.748	0.958	0
f-4	Fer	11/14/2014	6	5	1.561	0.951	0
f-3	Fer	11/14/2014	0	0	0.000	0.000	0
f-1	Fer	11/14/2014	19	10	2.009	0.780	3
f-2	Fer	11/14/2014	4	3	1.040	0.932	2
f-5	Fer	11/14/2014	3	1	0.000	1.000	3
cn-1	CN	11/14/2014	2	2	0.693	1.000	1
cn-5	CN	11/14/2014	0	0	0.000	0.000	0
cn-2	CN	11/14/2014	13	8	1.951	0.855	1
cn-4	CN	11/14/2014	8	7	1.906	0.963	0
nc-1	NC	11/17/2014	12	2	0.693	1.000	12
nc-2	NC	11/17/2014	5	5	1.609	1.000	2
fp-1	FP	11/17/2014	0	0	0.000	0.000	0
fp-4	FP	11/17/2014	5	3	1.055	0.932	2

fp-2	FP	11/17/2014	9	4	1.149	0.738	5
fp-3	FP	11/17/2014	10	4	1.089	0.686	0
fp-5	FP	11/17/2014	7	2	0.598	0.868	7
nc-5	NC	11/17/2014	6	2	0.451	0.634	5
nc-3	NC	11/17/2014	10	4	1.221	0.799	5
nc-4	NC	11/17/2014	3	3	1.099	1.000	0
fp-1	FP	12/5/2014	23	11	2.163	0.759	5
fp-4	FP	12/5/2014	1	1	0.000	1.000	0
fp-2	FP	12/5/2014	14	7	1.730	0.772	6
fp-3	FP	12/5/2014	4	3	1.040	0.932	0
fp-5	FP	12/5/2014	3	3	1.099	1.000	0
cn-6	CN	12/5/2014	25	12	2.380	0.852	2
cn-4	CN	12/5/2014	2	2	0.693	1.000	0
cn-2	CN	12/5/2014	14	9	2.045	0.859	0
cn-5	CN	12/5/2014	20	8	1.878	0.752	8
cn-1	CN	12/5/2014	36	5	0.588	0.327	2
f-5	Fer	12/6/2014	16	8	1.646	0.715	0
f-2	Fer	12/6/2014	4	4	1.386	1.000	0
f-1	Fer	12/6/2014	18	9	2.062	0.824	3
f-4	Fer	12/6/2014	5	5	1.609	1.000	0
f-3	Fer	12/6/2014	2	2	0.693	1.000	0
nc-1	NC	12/8/2014	35	4	0.474	0.295	3
nc-4	NC	12/8/2014	12	8	1.907	0.854	0
nc-2	NC	12/8/2014	19	10	2.142	0.819	5
nc-5	NC	12/8/2014	12	5	1.424	0.762	3
nc-3	NC	12/8/2014	16	5	1.354	0.723	11
fp-1	FP	12/29/2014	5	4	1.332	0.943	0
fp-4	FP	12/29/2014	11	6	1.594	0.786	0
cn-6	CN	12/29/2014	3	3	1.099	1.000	0
cn-4	CN	12/29/2014	5	5	1.609	1.000	0
cn-2	CN	12/29/2014	13	9	2.098	0.896	2
cn-5	CN	12/29/2014	24	9	1.683	0.646	14
cn-1	CN	12/29/2014	10	8	2.025	0.943	6
fp-5	FP	12/29/2014	15	9	2.084	0.864	0
fp-3	FP	12/29/2014	6	2	0.637	0.924	0
fp-2	FP	12/29/2014	21	11	2.178	0.798	12
nc-2	NC	12/30/2014	11	9	2.146	0.947	0
nc-4	NC	12/30/2014	37	8	1.368	0.428	9
nc-3	NC	12/30/2014	5	5	1.609	1.000	0
nc-5	NC	12/30/2014	5	5	1.609	1.000	0
nc-1	NC	12/30/2014	2	2	0.693	1.000	0
f-3	Fer	12/30/2014	0	0	0.000	0.000	0
f-4	Fer	12/30/2014	8	6	1.733	0.932	4

f-1	Fer	12/30/2014	0	0	0.000	0.000	0
f-2	Fer	12/30/2014	3	3	1.099	1.000	0
f-5	Fer	12/30/2014	9	6	1.677	0.879	0
cn-1	CN	1/15/2015	15	4	1.083	0.542	13
cn-5	CN	1/15/2015	1	1	0.000	1.000	0
cn-2	CN	1/15/2015	14	9	2.107	0.893	3
cn-6	CN	1/15/2015	6	5	1.561	0.951	0
cn-4	CN	1/15/2015	2	1	0.000	1.000	0
nc-1	NC	1/15/2015	13	5	1.264	0.643	3
nc-2	NC	1/15/2015	9	5	1.581	0.951	3
nc-4	NC	1/15/2015	2	2	0.693	1.000	0
nc-5	NC	1/15/2015	5	5	1.609	1.000	0
nc-3	NC	1/15/2015	12	3	0.566	0.448	10
f-3	Fer	1/16/2015	8	7	1.906	0.963	1
f-4	Fer	1/16/2015	12	9	2.095	0.907	0
f-1	Fer	1/16/2015	9	6	1.677	0.879	0
f-2	Fer	1/16/2015	12	8	1.814	0.824	3
f-5	Fer	1/16/2015	3	3	1.099	1.000	0
fp-5	FP	1/16/2015	11	9	2.146	0.947	1
fp-3	FP	1/16/2015	6	4	1.330	0.924	2
fp-2	FP	1/16/2015	14	2	0.520	0.746	11
fp-1	FP	1/16/2015	0	0	0.000	0.000	0
fp-4	FP	1/16/2015	2	2	0.693	1.000	0
cn-6	CN	1/28/2015	4	3	1.040	0.932	0
fp-3	FP	1/28/2015	14	9	2.045	0.859	1
fp-1	FP	1/28/2015	8	6	1.667	0.894	3
fp-4	FP	1/28/2015	2	2	0.693	1.000	0
fp-2	FP	1/28/2015	35	13	1.967	0.609	26
fp-5	FP	1/28/2015	8	4	1.213	0.797	0
cn-1	CN	1/28/2015	45	8	1.626	0.439	16
cn-5	CN	1/28/2015	12	8	1.936	0.858	0
cn-2	CN	1/28/2015	16	8	1.715	0.715	0
cn-4	CN	1/28/2015	3	2	0.637	0.924	0
f-4	Fer	1/30/2015	9	7	1.831	0.907	0
f-3	Fer	1/30/2015	1	1	0.000	1.000	0
f-5	Fer	1/30/2015	2	2	0.693	1.000	0
f-2	Fer	1/30/2015	2	2	0.693	1.000	0
f-1	Fer	1/30/2015	2	2	0.693	1.000	0
nc-3	NC	1/30/2015	7	3	0.956	0.803	6
nc-5	NC	1/30/2015	9	4	1.149	0.738	4
nc-2	NC	1/30/2015	5	4	1.332	0.943	0
nc-4	NC	1/30/2015	5	2	0.500	0.715	0
nc-1	NC	1/30/2015	3	2	0.637	0.924	0

cn-6	CN	2/11/2015	6	4	1.330	0.924	0
cn-5	CN	2/11/2015	31	14	2.436	0.776	10
cn-1	CN	2/11/2015	39	15	2.310	0.669	22
cn-2	CN	2/11/2015	12	8	1.979	0.890	0
cn-4	CN	2/11/2015	7	4	1.352	0.943	2
f-5	Fer	2/13/2015	2	1	0.000	1.000	0
f-2	Fer	2/13/2015	16	9	2.101	0.873	0
f-1	Fer	2/13/2015	5	5	1.609	1.000	1
f-4	Fer	2/13/2015	6	5	1.561	0.951	0
f-3	Fer	2/13/2015	1	1	0.000	1.000	0
nc-5	NC	2/13/2015	18	5	1.274	0.667	11
nc-3	NC	2/13/2015	7	5	1.475	0.879	1
nc-2	NC	2/13/2015	18	9	2.091	0.862	4
nc-4	NC	2/13/2015	15	7	1.615	0.730	10
nc-1	NC	2/13/2015	4	3	1.040	0.932	1
fp-2	FP	2/14/2015	30	11	2.090	0.714	20
fp-5	FP	2/14/2015	18	9	2.058	0.852	1
fp-3	FP	2/14/2015	7	6	1.748	0.958	2
fp-1	FP	2/14/2015	5	5	1.609	1.000	0
fp-4	FP	2/14/2015	2	2	0.693	1.000	0
cn-1	CN	2/25/2015	37	11	1.876	0.605	24
cn-5	CN	2/25/2015	6	4	1.330	0.924	0
cn-2	CN	2/25/2015	31	6	1.381	0.488	21
cn-6	CN	2/25/2015	8	6	1.733	0.932	0
cn-4	CN	2/25/2015	5	5	1.609	1.000	0
f-1	Fer	2/27/2015	1	1	0.000	1.000	0
f-4	Fer	2/27/2015	8	6	1.733	0.932	1
f-3	Fer	2/27/2015	0	0	0.000	0.000	0
nc-4	NC	2/27/2015	16	5	1.127	0.556	11
nc-1	NC	2/27/2015	6	4	1.330	0.924	4
nc-2	NC	2/27/2015	14	5	1.438	0.789	10
nc-5	NC	2/27/2015	0	0	0.000	0.000	0
nc-3	NC	2/27/2015	11	3	0.600	0.478	9
f-5	Fer	2/27/2015	1	1	0.000	1.000	0
f-2	Fer	2/27/2015	2	2	0.693	1.000	0
fp-1	FP	3/1/2015	2	2	0.693	1.000	0
fp-4	FP	3/1/2015	8	4	1.321	0.901	3
fp-2	FP	3/1/2015	14	7	1.810	0.827	5
fp-3	FP	3/1/2015	6	5	1.561	0.951	3
fp-5	FP	3/1/2015	8	5	1.494	0.869	0
f-1	Fer	3/13/2015	6	3	1.011	0.871	1
f-4	Fer	3/13/2015	6	5	1.561	0.951	0
f-2	Fer	3/13/2015	9	8	2.043	0.967	0

f-5	Fer	3/13/2015	4	3	1.040	0.932	0
f-3	Fer	3/13/2015	8	5	1.494	0.869	0
cn-1	CN	3/14/2015	4	3	1.040	0.932	2
cn-5	CN	3/14/2015	5	4	1.332	0.943	0
cn-6	CN	3/14/2015	13	6	1.672	0.835	2
cn-4	CN	3/14/2015	7	6	1.748	0.958	0
cn-2	CN	3/14/2015	8	4	1.213	0.797	4
fp-5	FP	3/15/2015	3	2	0.637	0.924	0
f-2	Fer	3/15/2015	15	7	1.767	0.793	13
fp-1	FP	3/15/2015	2	2	0.693	1.000	0
fp-4	FP	3/15/2015	8	5	1.560	0.927	0
fp-2	FP	3/15/2015	10	6	1.498	0.780	0
fp-3	FP	3/15/2015	6	4	1.330	0.924	0
nc-3	NC	3/16/2015	10	4	1.168	0.709	0
nc-1	NC	3/16/2015	28	12	2.286	0.762	15
nc-4	NC	3/16/2015	10	7	1.748	0.853	0
nc-2	NC	3/16/2015	9	6	1.677	0.879	0
nc-5	NC	3/16/2015	10	5	1.471	0.833	5

APPENDIX E. Survey sites, corresponding pastures, and GPS coordinates in decimal degrees used to assess the influence of grazing on the avian community at Freeman Center in the Balcones Canyonlands of Central Texas. The Front pasture and Fernando were ungrazed while Crow's Nest and North Crawford were grazed pastures.

Survey Site	Pasture	Coordinates
fp - 1	Front	29.93439°, -98.01356°
fp - 2	Front	29.93650°, -98.01316°
fp - 3	Front	29.93807°, -98.01134°
fp - 4	Front	29.93477°, -98.01099°
fp - 5	Front	29.94005°, -98.01296°
f - 1	Fernando	23.93591°, -98.00221°
f - 2	Fernando	29.93615°, -98.00492°
f - 3	Fernando	29.93367°, -97.99760°
f - 4	Fernando	29.93436°, -98.00027°
f - 5	Fernando	29.93560°, -98.00803°
cn - 1	Crow's Nest	29.94055°, -97.98905°
cn - 2	Crow's Nest	29.93250°, -97.98495°
cn - 4	Crow's Nest	29.93254°, -97.97686°
cn - 5	Crow's Nest	29.93682°, -97.98241°
cn - 6	Crow's Nest	29.92957°, -97.97340°
nc - 1	North Crawford	29.92391°, -97.98357°
nc - 2	North Crawford	29.92826°, -97.99122°
nc - 3	North Crawford	29.92996°, -98.00678°
nc - 4	North Crawford	29.92462°, -97.99329°
nc - 5	North Crawford	29.92653°, -97.99869°

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