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# Influences of spatial variation in vegetation on avian richness and abundance vary by season in the Chihuahuan Desert

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ABSTRACT

Changes in the structure, composition, and distribution of desert vegetation have resulted in altered desert bird communities. One of the most well-known influences on bird diversity and abundance in these ecosystems is the degree of woody shrub dominance. While the influence of vegetation structure and composition gradients on Chihuahuan Desert bird communities of North America has received valuable attention, seasonal variation in these influences is poorly understood. Our goal was to understand how vegetation gradients across space influence bird communities over four seasonal periods. We employed three years of avian survey data and static, spatial vegetation data in generalized linear mixed-effects models, identifying effects of (1) shrub cover in predicting shrubland bird species richness and abundance, (2) grass cover in predicting grassland bird abundance, and (3) grass height in predicting grassland and shrubland species richness and abundance. Effect sizes varied by season, with grass heights exhibiting (1) greatest positive effects on grassland species in the breeding season and (2) greatest negative effects on shrubland species in the winter. In targeting management for birds of the Chihuahuan Desert and other arid regions, managers should consider both bird-habitat associations and the variation in these relationships between seasons.

## 1. Introduction

Heterogeneity in the composition and distribution of North American desert vegetation provides for diverse bird communities (Macías-Duarte et al., 2009; Tomoff, 1974). The composition of these bird communities is not static (Lopez de Casenave et al., 2008; Maurer, 1985), with within-year variation due to migrating species (Isacch et al., 2005) and between-year dynamics shaped by the varying responses of species to weather, resource availability, and other factors (Marone, 1992). Similarly, desert bird communities may by altered through space briefly or over long periods by factors such as fire (Bock and Block, 2005), grazing (Merola-Zwartjes, 2005), invasive species (Steidl et al., 2013), or climate change (Friggens and Finch, 2015).

Among North American desert vegetation communities, grasslands of the Chihuahuan Desert were identified by the World Wildlife Fund as areas of high conservation importance (Ricketts et al., 1999). These areas provide habitat for the largest remaining Black-tailed Prairie Dog (*Cynomys ludovicianus*) towns on the continent and winter habitat for several significantly declining bird species (e.g., Mountain Plover [*Charadrius montanus*], Ferruginous Hawk [*Buteo regalis*] and Baird's Sparrow [*Ammodramus bairdii*]). Over 80% of grassland bird species that breed in western North America (i.e., western Great Plains to the Pacific Ocean) winter in these areas (Panjabi et al., 2010). Much of the attention given to Chihuahuan Desert grasslands has followed rapid conversion to cropland (Pool et al., 2014). Occurring at slower rates, yet inducing notable structural and compositional changes to vegetation communities, is the encroachment of woody shrubs and small trees (Goslee et al., 2003; Laliberte et al., 2004). This longer-term process has garnered attention due to its impacts on the composition of bird and other animal communities (Brennan and Kuvlesky, 2005; Pool et al., 2014) and generated interested in the efficacy of management approaches for maintaining or restoring grass dominance (Coffman et al., 2014).

Due to the differing life histories of grassland and non-grassland birds, studies of Chihuahuan Desert bird communities predict major restructuring following projected losses of grasslands or more subtle changes to grassland structure and composition (Mason et al., 2005; Pidgeon et al., 2001). The majority of avian community studies in the Chihuahuan Desert have focused on a single season (e.g., wintering or breeding; Desmond, 2004; Pidgeon et al., 2001), illuminating intraspecific and habitat-fitness relationships (e.g., Kozma and Mathews, 1997). Other studies incorporating year-round sampling (Macías-

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Duarte et al., 2009; Manzano-Fischer et al., 2006) have revealed complex patterns of seasonal bird community composition across vegetation communities.

Both within and beyond the Chihuahuan Desert, the maintenance of species richness and related community metrics is typically a priority for land managers, often with a focus on protecting rare communities. In light of documented and predicted climate impacts to desert ecosystems of the Southwest (Gherardi and Sala, 2015; Gremer et al., 2015; Gutzler, 2013), it is crucial for managers, agencies, and governments to understand the relationships among vegetation changes and grassland and shrubland bird communities. Understanding these relationships is challenging, however, due to temporal variation in the relationships between indices of biological communities and the habitats that support them (Hagan and Able, 2008; Yee and Juliano, 2007) with variation arising due to habitat associations among locally resident or migratory species (Bestelmeyer et al., 2003). This variation is seldom addressed in studies of seasonal community change and has not been explicitly addressed in Chihuahuan Desert bird communities but is necessary for effective habitat management.

To address shortcomings in our understanding of how gradients of vegetation structure and composition influence avian communities within the Chihuahuan Desert over annual cycles, we initiated a multi-year avian monitoring effort on Holloman Air Force Base, New Mexico, U.S.A. (hereafter HAFB). Our goals in this study were to (1) describe relationships between avian community metrics (richness and abundance) and several vegetation gradients, (2) assess seasonal variation in relationships between avian community metrics and vegetation gradients, and (3) provide management recommendations based on modeling results for these and similar areas undergoing environmental change. We pursued this goal in two guilds of bird species (grass-associated vs. shrub-associated) and by considering variation in vegetation effects during winter, spring migration, the breeding season, and fall migration. We expected to confirm positive associations between guilds and vegetation characteristics (e.g., grass-associated birds and grass cover) but wished to understand how these relationships might vary seasonally.

## 2. Methods

### 2.1. Study area

HAFB is a 21,281-ha military installation within the Tularosa Basin of the Mexican Highland section of the Basin and Range Province of western North America in the northern Chihuahuan Desert (Fig. 1). The basin generally receives less than 25 cm of precipitation per year with most falling during short, intense summer storms. Most (81%, 17,314 ha) of the land cover on HAFB was classified as grassland and shrubland vegetation classes (Muldavin et al., 1997). Grassland classes at the time of classification comprised 5803 ha, or one-third of the total area classified as grassland or shrubland. Shrubland classes at the time of classification comprised 11,511 ha (Fig. 1). Based on our field assessment (see Methods, below), approximately 9% of areas converted from grassland-dominated to shrubland-dominated since vegetation was classified by Muldavin et al. (1997), a percent change consistent with historical grassland-to shrubland-transformation elsewhere in the Chihuahuan Desert (Pidgeon et al., 2001; Yanoff and Muldavin, 2008).

### 2.2. Field sampling

#### 2.2.1. Transects

Using the delineated vegetation classes from Muldavin et al. (1997) and a 50-m majority filter applied to these data (using ArcMap; ESRI, 2014) to allow easier identification of the dominant vegetation classes in local areas, we established 80 candidate transects with over 50% cover in four major grassland and shrubland vegetation classes (Alkali Sacaton [*Sporobolus airoides*] Grassland, Gyp Dropseed [*Sporobolus nealleyi*] Grassland, Fourwing Saltbush [*Atriplex canescens*]/Alkali Sacaton Shrubland, and Fourwing Saltbush/Gyp Dropseed Shrubland). In March 2011, we ground-truthed 70 of the 80 transects to confirm the mapped vegetation categories were still correct. Ten were inaccessible due to distance (1) or military activities (9). At each transect, we estimated cover of the dominant cover types (grass, shrub, bare ground) and assigned the current class based on cover percentages in map unit descriptions for the original map. We changed five transects from shrubland to grassland types and 11 from grassland to shrubland types. To achieve a sample of transects balanced across major vegetation types and areas of the base, we omitted another 34 transects. We retained 36, 400-m transects: 10 in Alkali Sacaton Grassland, 13 in Fourwing Saltbush/Alkali Sacaton Shrubland, and 13 in Fourwing Saltbush/Gyp Dropseed Shrubland.

#### 2.2.2. Avian surveys

We surveyed all transects twice in each of four focal seasons: winter (January 10–February 1), spring migration (April 25–May 10), breeding (May 22–June 7), and fall migration (September 13–October 13). Twice per season, we conducted visual and auditory surveys for birds soon after dawn until approximately 3 h after sunrise. We did not survey during rain or when wind speed was more than ~25 km $h^{-1}$. We walked transects at approximately 3 km $h^{-1}$, stopping every 100 m to scan with binoculars and listen for vocalizing birds. All individual birds seen or heard to an unlimited distance were recorded, as was information on perpendicular distance (using bins in 50-m increments to a maximum distance of 1000 m) and whether birds were seen flying over. We varied the order of transects to ensure they were not visited in the same order or at the same time of day. When possible, we alternated the four observers among transects within the two surveys per season. Funding delays resulted in a discontinuous series of survey seasons between summer 2013 and spring 2014, but each season was surveyed in three years. Each transect was thus surveyed 24 times for a total sample of 864 surveys.

#### 2.2.3. Vegetation sampling

We established four 10 × 10 m vegetation sampling plots on each of the 36 bird sampling transects. Vegetation plots were spaced at 100-m intervals along each transect, with the two end plots placed 50 m from the ends of transects. Plots were situated 5 m from the transect line, on alternating sides of transects (Fig. 1). Inside these sampling plots, we estimated average plant height and made ocular estimates of the percent cover contributed by the three most dominant species in shrub, grass, and forb categories. Shrubs are those plants with multiple woody stems above ground, and forbs are non-grass plants without woody growth above ground. Vegetation sampling was conducted in fall 2011 (a relatively dry summer) following the July–September rainy season. To test for consistency in relative measures of vegetation (see section 2.3.1 below), a second round of vegetation sampling was conducted in fall 2014 (a relatively wet summer).

### 2.3. Model covariates

#### 2.3.1. Vegetation covariates

We calculated covariates describing vegetation characteristics meeting two criteria; (1) growth forms (e.g., shrub, grass, or forb) contributing over an average 5% to total cover, and (2) having notable variation (coefficient of variation > 30%) across transects. Three vegetation characteristics (shrub cover, grass cover, and grass height) met these criteria. Cover of shrubs and grasses was calculated from the sum of cover of all plant species in each growth form category. Grass height was calculated by a weighted average for each plot;

$$\frac{\sum_{i=1}^{N}(c_i h_i)}{\sum_{i=1}^{N}(c_i)},$$