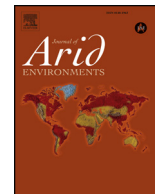




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Fall vegetative cover and summer precipitation predict abundance of wintering grassland birds across the Chihuahuan desert

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ABSTRACT

Local winter abundance of grassland passerines is highly variable throughout the Chihuahuan Desert among years. The objective of this study is to determine if plant biomass in grasslands and precipitation are predictors of bird abundance in space and time through Chihuahuan Desert. We conducted avian surveys in 17 Grassland Priority Conservation Areas (GPCA) in northern Mexico and southwestern United States in the winters of 2007–2011. We used distance sampling on line transects to estimate annual winter bird density in all GPCAs. We used a hierarchical model of distance sampling to estimate the effect of summer precipitation and vegetative cover during the fall on bird density for 10 grassland species. We used the MODIS NDVI at a pixel resolution of 231.5 m as a measure of plant biomass. Grasshopper Sparrow, Baird's Sparrow, Savannah Sparrow, Vesper Sparrow, and Eastern Meadowlark showed a strict positive response to NDVI, while Horned Lark, Sprague's Pipit, Chestnut-collared Longspur and Lark Bunting did not show a strictly-positive response to NDVI. Our results provide a valuable tool for the conservation of declining migratory birds on their wintering grounds by identifying a wildlife-habitat relationship using a remotely-sensed and readily available index of vegetative growth.

1. Introduction

Deserts are by definition ecosystems where biological processes, including wildlife population dynamics, are ultimately limited by water. Relatively few Nearctic migratory birds overwinter in arid lands, preferring instead less water-limited tropical and subtropical environments. The overwintering of migratory grassland birds in arid lands warrants attention given that populations of North American grassland birds continue to decline at alarming rates (Sauer et al., 2017) and the drivers of these declines remain poorly understood for most species. The ongoing loss of grasslands throughout Canada and the United States since the 19th century (White et al., 2000) suggests that loss and deterioration of breeding habitat is a common factor. However, grassland birds that overwinter in the Chihuahuan Desert grasslands of Mexico and the southwestern USA have declined by twice as much as those wintering elsewhere (North American Bird Conservation Initiative, 2016). As in other guilds of migratory birds, increasing evidence suggests factors in the non-breeding (wintering) season can strongly influence population trends (Calvert et al., 2009). Grassland

birds that largely depend on Chihuahuan Desert grasslands are threatened by conversion of wintering habitat to farmland (Macías-Duarte et al., 2009; Pool et al., 2014), overgrazing (Curtin et al., 2002), invasive grasses (Sánchez-Muñoz, 2009) and woody plant encroachment (Van Auken, 2000). The extent to which grassland birds will be able to adapt to the loss and deterioration of wintering habitat depends on the suitability of the remaining habitat and the capability of these birds to track resources at a broad scale, especially in light of profound changes in temperature and precipitation projected in arid lands as a consequence of climate change (Seager et al., 2007).

Local winter abundance of grassland passerines is highly variable throughout the Chihuahuan Desert among years (Macías-Duarte et al., 2011). For instance, winter density of passerine birds can reach a 50-fold difference between two years (0.63 vs. 31.82 birds·ha⁻¹) in desert grasslands of central Chihuahua in a 9-year period (Macías-Duarte et al., 2009), and in some years a species may be completely absent from a region where it normally occurs (Macías-Duarte et al., 2011). This extreme temporal variation in local abundance of wintering grassland passerines in the Chihuahuan Desert may reflect the ability of

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populations to ‘shift’ their distributions to alternate locations with better conditions. More precisely, we hypothesize that spatio-temporal variation of abundance of wintering grassland birds in the Chihuahuan Desert follows the ideal free distribution model (Fretwell, 1972), i.e., grassland birds are able to track the spatial distribution of resources (ideal) and can move without constraints (free) throughout their winter range so that individual birds can maximize their intake rate of resources. This phenomenon has been documented in Palearctic migratory birds on their wintering grounds of the Sahel, a similarly arid environment, and has been called “itinerancy” (Kristensen et al., 2013) or nomadism (Andersson, 1980).

Quantifying the spatio-temporal covariation of bird abundance and environmental factors throughout the Chihuahuan Desert may reveal factors limiting winter survival. Because most grassland passerines are granivorous in winter, feeding on grass and forb seeds, it is likely that the annual production and availability of these foods affects winter distribution and survival. In addition, grass and forb biomass are important components of habitat quality, providing protection from low temperatures at night (Macías-Duarte et al. in review) and from predation (Macías-Duarte and Panjabi, 2013). Therefore, tracking changes in vegetation biomass in this desert environment may lead to being able to predict abundance, distribution and even survival of grassland birds in winter.

In this context, the objective of this study is to determine if plant biomass in grasslands is a predictor of wintering bird abundance in space and time in Chihuahuan Desert grasslands. Grass biomass production in the Chihuahuan Desert is driven by seasonal precipitation (Khumalo and Holechek, 2005) and herbaceous plant growth is particularly synchronized with monsoonal summer rainfall (Moreno-de-las-Heras et al., 2015). A positive relationship between abundance of grassland birds during the winter and precipitation in the preceding summer has been documented in the Chihuahuan Desert at the local scale (Dunning and Brown, 1982; Gordon, 2000; Macías-Duarte et al., 2009), suggesting a direct link between plant biomass and bird abundance at the local scale. If this relationship between plant biomass in grasslands and bird abundance is also true at the regional scale, the information generated by this study could help inform conservation strategies for grassland birds, especially in light of projected increases in aridity in the Chihuahuan Desert due to climate change (Seager et al., 2007).

2. Methods

2.1. Study area

We conducted avian surveys in up to 17 Grassland Priority Conservation Areas (GPCA; CEC and TNC, 2005; Pool and Panjabi et al., 2010) in northern Mexico, southern Arizona, southern New Mexico and western Texas in winter from January 2007 to March 2011 (Levandoski et al., 2009; Macías-Duarte et al., 2011; Panjabi et al., 2010). GPCAs included in this study are Armendaris, Cuatro Ciénegas, Cuchillas de la Zarca, Janos, Lagunas del Este, Llano Las Amapolas, Malpaís, Mapimí, Marfa, New Mexico Bootheel, Otero Mesa, Sonoita, Sulphur Springs, El Tokio, Valles Centrales and Valle Colombia (Fig. 1).

2.2. Focal species

We focused this paper on winter abundance and distribution of the passerine component of the grassland bird guild, as defined by Sauer et al. (2011), whose winter distribution lies mostly in the Chihuahuan Desert and from which we had sufficient survey data to estimate model parameters (see 2.7. Hierarchical model). Our focal species included Horned Lark, Sprague's Pipit, Cassin's Sparrow, Vesper Sparrow, Lark Bunting, Savannah Sparrow, Grasshopper Sparrow, Baird's Sparrow, Chestnut-collared Longspur, and Eastern and Western meadowlark. We also included Brewer's Sparrow as a grassland facultative species, as it is

one of the most abundant bird species in Chihuahuan Desert grasslands (Desmond et al., 2005; Macías-Duarte et al., 2009; Manzano-Fischer et al., 2006). All these grassland species have undergone population declines on their breeding grounds in Canada and the USA (Sauer et al., 2011).

2.3. Sampling design

We overlaid a grid of roughly $18 \times 18 \text{ km}^2$ cell blocks across the Chihuahuan Desert and Sierra Madre Occidental Bird Conservation Regions to create a sampling frame for desert grasslands within GPCAs (Fig. 1). Eligible cells for sampling were those that intersected with GPCAs and had at least 5 km of road access to grasslands as identified using an intersect function and available GIS data (INEGI, 2003). Due to poor correspondence between some GPCA boundaries and actual locations of grassland in the vicinity of these GPCAs, we added additional cell blocks to the sampling pool that met the aforementioned criteria, but were outside the original GPCA boundaries. This sampling design is described in detail by Panjabi et al. (2007), with modifications by Levandoski et al. (2009). We added additional GPCAs to the sampling frame each year. In each sampling block we established randomly numbered points at 500 m intervals along roads intersecting grasslands. We chose the 3 lowest-numbered points that met habitat requirements for native grasslands with < 25% shrub cover, and established a pair of 1-km line transects at each of those 3 points. We used ArcGIS[®] 9.3 to implement the sampling design above.

2.4. Bird and vegetation surveys

We used distance sampling (Buckland et al., 2001) on line transects to estimate annual winter bird density in all GPCAs. We initiated surveys in early January and completed surveys by early March each winter. Each pair of 1-km line transects started from the road edge and headed in opposite directions perpendicular to the road. In a few instances (327 out of 3271 transects) where available grasslands were limited within the survey block, we split paired transects to start from different random points. Each pair of technicians surveyed the 6 transects in each block starting at sunrise and continuing until completion (273 out of 3271 before 13:00). Sometimes, due to weather, road conditions, and variability in the time needed to complete both bird and vegetation surveys, finishing all transects within 6 h was not possible. We did not conduct surveys during winds higher than category 4 in the Beaufort scale (20–28 kph) or during any precipitation greater than a drizzle.

From each starting point, technicians used Garmin E-trex Vista GPS units to walk towards the end point of the transect 1000 m away and maintain their position on the transect line while conducting the survey. Observers used a compass to select a point on the horizon that corresponded with the direction of the transect end point, and used this point and the bearing to it to visualize the transect line in front of them. Observers recorded the number of bird groups detected during each survey as well as group size (number of individuals) and perpendicular distance to the transect line for each bird group. Observers detected bird groups by detecting single individuals (group size of 1) or simultaneously detecting ≥ 2 individuals together. After an initial detection of a bird group, observers may have detected additional members of the group. Observers thus determined group size by adding all birds within a neighborhood of 25 m of an initial detection. Observers used both laser rangefinders and ocular estimates to obtain lateral distances from the transect line to each bird group. Birds can be detected as individuals or groups, the latter defined as 2 or more individuals of the same species occurring within 25 m of the first individual detected. In this context, we recorded the cluster size for each bird detection. If observers encountered a major obstacle (such as an international border, cliff or other impassable terrain) or if the transect would otherwise bisect a large area ($> 250 \text{ m}$) of non-grassland habitat,

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