

# Chihuahuan Desert Grassland Bird Conservation Plan

*Version 1.0*



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## **Rocky Mountain Bird Observatory**

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**Mission:** To conserve birds and their habitats

**Vision:** Native bird populations are sustained in healthy ecosystems

**Core Values:** (Our goals for achieving our mission)

1. **Science** provides the foundation for effective bird conservation.
2. **Education** is critical to the success of bird conservation.
3. **Stewardship** of birds and their habitats is a shared responsibility.

**RMBO accomplishes its mission by:**

- **Monitoring** long-term bird population trends to provide a scientific foundation for conservation action.
- **Researching** bird ecology and population response to anthropogenic and natural processes to evaluate and adjust management and conservation strategies using the best available science.
- **Educating** people of all ages through active, experiential programs that create an awareness and appreciation for birds.
- **Fostering** good stewardship on private and public lands through voluntary, cooperative partnerships that create win-win situations for wildlife and people.
- **Partnering** with state and federal natural resource agencies, private citizens, schools, universities, and other non-governmental organizations to build synergy and consensus for bird conservation.
- **Sharing** the latest information on bird populations, land management and conservation practices to create informed publics.
- **Delivering** bird conservation at biologically relevant scales by working across political and jurisdictional boundaries in western North America.

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**Cover Photo:** Loggerhead Shrike (*Lanius ludovicianus*) atop a fence post near Rancho el Uno. This ranch and biological preserve lies on the northwest boundary of the Rio Grande Joint Venture in the Janos Grassland Priority Conservation Area. Photo by Greg Levandoski.

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Photo credits: Doug Backlund (Chestnut-collared Longspur, Sprague's Pipit), Steve Berardi (Loggerhead Shrike), Jose Hugo Martinez (Baird's Sparrow, Lark Bunting, Sprague's Pipit), Bill Schmoker (Chestnut-collared Longspur).

## Executive Summary

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North American Bird Habitat Joint Ventures are responsible for providing science-based guidance to mitigate declines in wild bird populations through habitat protection, restoration and improvement. To guide these activities, the Rio Grande Joint Venture (RGJV) commissioned the Rocky Mountain Bird Observatory (RMBO) to develop conservation plans for five species of grassland birds. RMBO added the collection of habitat parameters to their grassland bird surveys conducted from 2009 to 2011. The addition of these data allowed RMBO to develop habitat-specific relationships to bird density for the Grassland Priority Conservation Areas (GPCA).

This conservation plan is an addition to the current RGJV implementation plan. We formatted this plan in a manner where new species may be added in sections without the need to revisit previous sections of the document.

In order to use the best information possible, we asked conservation, wildlife, and research entities that work within or with interest in the Chihuahuan Desert to share or provide guidance to GIS data sources for bird habitat management and modeling use. Specific requests identified the need to delineate the level of shrub encroachment in grasslands. This request was met with echoes of similar need for these data. We found limited sources of this data type at a sufficient scale for inclusion. The 2003 INEGI data set had significant flaws in grassland delineations. A prerelease version of the 2010 INEGI land classification data was used. Grassland classifications in the 2010 INEGI still contained many non-grassland areas, and shrub components were not sufficiently segregated based on the species-habitat relationships identified in the research underlying this plan. The US portion was dated and inconsistent for developing a reasonable cross-walk table for a reliable cross-border land cover product. The best sources of information we were able to identify were the USGS GAP data sets and the 2008 Landfire data set from the US Forest Service. Landfire data have classification, height, and fuel model parameters which were used as a proxy for shrub encroachment. The state of Texas is conducting a statewide series of classifications from remote sensing. The delivery of Texas data for the RGJV area is scheduled for later in 2012. These data are based on the Natural Heritage Program classifications.

RMBO transect data were used to estimate species density by GPCA. These data account for a range of environmental and habitat conditions. The transects are located in areas of grassland habitat with less than 25% shrub cover and reasonable access for survey crews. Detection distances to all birds were collected along one-kilometer transects and habitat information was collected using 10 circular plots along each transect at 100-meter interval spacing and data collected at both 5- and 50-meter radii. A hierarchical modeling approach was applied to all available transect data in the region to assess the contribution of location (GPCA) and habitat variables to species density.

Density estimates were extrapolated into carrying capacity estimates for each GPCA and all of the Chihuahuan Desert. Grassland cover estimates from the 2010 INEGI Landcover GIS were corrected using RMBO transect elimination data. These corrected data were used in a

moving window analysis that applied the parameters from the hierarchical output to pixel-based grass cover estimates. Finally, transect averages were used for the other vegetation covariables where the GIS did not have adequate resolution. Based on these estimates, we calculated the approximate potential target population levels for 11 GPCAs under optimal conditions with the current habitat base.

We provide species-habitat relationships for Baird's Sparrow, Sprague's Pipit, Chestnut-collared Longspur, Lark Bunting, and Loggerhead Shrike, all species on the USFWS Birds of Conservation Concern (BCC) list for Bird Conservation Region (BCR) 35. Along with species-habitat relationships, the report includes tools for habitat treatment for each species' optimal response. Inter-species comparisons are also provided. These graphics indicate the likely impacts, positive or negative, for the other four species based on beneficial actions for target species.

Ultimately, these bird-habitat models can help us to predict avian winter distribution throughout the Chihuahuan Desert, as well as provide a baseline for the species' response to future vegetation changes due to land use and climate change. These data can be instrumental for development of conservation designs to guide conservation actions with greater geographic specificity. This report identifies density (birds per hectare) and capacity (number of birds within a defined area) with a geographic focus and guidance to applying conservation actions to meet the needs of particular bird species.

Technical guidance (in English) on grassland management and conservation for the five species listed above is provided for grassland managers in the Chihuahuan Desert portion of the RGJV region. The grassland management and conservation recommendations include specific quantitative guidance on increasing/decreasing vegetation parameters and the expected response in species' abundance. Conservation actions may include protection of functioning grasslands, shrub removal in appropriate areas, alteration of grazing regimes, and restoration of degraded lands. We adapted this information where possible to provide more specific regional guidance within and outside the Chihuahuan Desert. Non-technical guidance is currently being developed by RMBO and other RGJV partners (in Spanish) for ranchers, ejidatarios, and range extensionists in the western Chihuahuan Desert in Mexico. The existing Spanish-language non-technical Chihuahuan Grassland Best Management Practices (BMP) utilizes results only from the 2008 bird-habitat relationship analyses, whereas the RGJV technical guidance in this document on management utilizes results from these previous analyses plus the 2009-2011 datasets.

## Resumen Ejecutivo

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Las *Joint Ventures* de América del Norte hábitat son responsables de proporcionar guías con base científica para mitigar las disminuciones poblacionales de aves silvestres a través de la protección, restauración y mejoramiento del hábitat. Para guiar estas actividades, el *Río Grande Joint Venture* (RGJV) comisionó a *Rocky Mountain Bird Observatory* (RMBO) para desarrollar planes de conservación para cinco especies de aves de pastizal. RMBO añadió la colección de parámetros del hábitat a sus conteos de aves de pastizal realizados entre 2009 y 2011. La adición de estos datos permitió a RMBO desarrollar relaciones de hábitat específicas para predecir la densidad de aves en las Áreas Prioritarias para la Conservación de los Pastizales (APCP).

Este plan de conservación es una adición al plan de implementación del RGJV actual. Le dimos el formato a este plan de manera que nuevas especies pueden ser añadidas en las secciones, sin la necesidad de revisar las secciones anteriores del documento.

Pedimos a las entidades dentro o con interés en el Desierto Chihuahuense compartir o proporcionar datos de SIG para el manejo de hábitats de aves y su uso en modelación. Solicitudes específicas identificaron la necesidad de delimitar el nivel de invasión de arbustos en los pastizales. Esta solicitud fue recibida con ecos de la necesidad de estos datos. Existen pocas fuentes de este tipo de datos, ninguno de los cuales se encontraban en una escala suficiente para su inclusión. El conjunto de datos de INEGI (2003) tenían defectos significativos en las delimitaciones de los pastizales. Utilizamos la información de la futura versión de los datos del INEGI (2010), aunque las clasificaciones de pastizales aún contenían muchas áreas que no eran pastizales y los matorrales no estaban suficientemente capturados. La parte de EE.UU. tenía datos antiguos e inconsistentes como para traducirlos a un confiable producto binacional de cobertura de suelo. La mejor fuente de información que pudimos identificar fueron los conjuntos de datos de LANDFIRE (2008) del Servicio Forestal de los EE.UU. Estos datos contienen la clasificación, la altura y parámetros de modelos de combustible que se utilizaron como medida del grado de invasión de arbustivas. Entregas futuras de datos para la parte de Texas de la zona RGJV se han programado a partir de finales de 2012. Estos datos se basan en las clasificaciones del Programa de Patrimonio Natural.

Los datos de los transectos de conteos de aves de RMBO fueron utilizados para estimar la densidad de las especies por cada APCP. Estos datos representan una gama de condiciones ambientales y de hábitat. Los transectos se encuentran en áreas de hábitat de pastizales con menos del 25% de cobertura de arbustos y acceso razonable para el personal de los conteos. Distancias de detección a todas aves fueron obtenidas a lo largo de los transectos y se colectó información del hábitat en 10 parcelas circulares a lo largo de cada transecto de 5 y 50 metros de radio. Un enfoque de modelado jerárquico se aplicó a todos los datos de los transectos disponibles para evaluar la contribución de la ubicación (APCP), y las variables de hábitat en la densidad de las especies.

Extrapolamos las estimaciones de densidad en estimaciones de capacidad para cada APCP y todo el Desierto Chihuahuense. Las estimaciones de la cubierta de pastizales del GIS de

cubierta vegetal del INEGI (2010) se corrigieron con los datos de eliminación de transectos de RMBO. Estos datos corregidos se utilizaron en un análisis de ventana móvil que aplicaron los parámetros de los modelos jerárquicos a las estimaciones de cobertura de pastos basadas en píxeles y los promedios registrados en los transectos fueron utilizados para las otras variables de la vegetación en las que el GIS no cuenta con la resolución adecuada. Con base en estas estimaciones se calcularon los niveles aproximados potenciales para la población objetivo de 11 APCPs en condiciones óptimas con la base del hábitat actual.

Describimos relaciones hábitat-especies para el gorrión de Baird, la bisbita llanera, el escribano de collar castaño, el gorrión ala blanca, y el alcaudón verdugo, todas las especies en la lista BCC del USFWS para el BCR 35. Junto con las relaciones especies-hábitat, este informe incluye herramientas para el manejo del hábitat para la respuesta óptima de las especies. Comparaciones entre especies también se proporcionan. Estos gráficos indican los posibles efectos, positivos o negativos, para las otras cuatro especies sobre la base de acciones beneficiosas para la especie objetivo.

En última instancia, estos modelos aves-hábitat nos pueden ayudar a predecir la distribución de invierno de aves a través del Desierto Chihuahuense, así como proporcionar una base para la respuesta de las especies a los cambios de vegetación en el futuro debido al cambio de uso del suelo y al cambio climático. Estos datos pueden ser fundamentales para el desarrollo de diseños de conservación para guiar a las medidas de conservación con un mayor enfoque espacial. Este informe identifica la densidad y la capacidad poblacional de aves con un enfoque geográfico con orientación a la aplicación de las medidas de conservación a las necesidades de especies de aves en particular.

Proporcionamos orientación técnica (en inglés) en la gestión de los pastizales y la conservación de las cinco especies mencionadas anteriormente para los administradores de pastizales en la parte del Desierto Chihuahuense de la región RGJV. Las recomendaciones de manejo de pastizales y de conservación incluyen la orientación cuantitativa específica al aumento/disminución de los parámetros de la vegetación y la respuesta esperada en su abundancia. Las acciones de conservación pueden incluir acciones tales como la protección de pastizales funcionales, la eliminación de arbustos, la modificación de los regímenes de pastoreo, y la restauración de tierras degradadas. Hemos adaptado esta información siempre que sea posible para proporcionar orientación regional más específica dentro y fuera del Desierto Chihuahuense. Orientación no técnica está siendo desarrollada por RMBO y otros socios de la RGJV (en español) para los ganaderos, los ejidatarios y los extensionistas en el oeste del Desierto de Chihuahua en México. El manual de mejores prácticas para el Desierto Chihuahuense en español utiliza sólo los resultados de los análisis de 2008 de la relación de hábitat de aves, mientras que la orientación técnica sobre orientación técnica del RGJV en este documento utiliza los resultados de éstos, además de los conjuntos de datos de 2009-2011.

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## Introduction

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Like most of North America's grasslands, the Rio Grande Joint Venture (RGJV) Chihuahuan Desert grasslands face continued degradation and alteration. Gaining a better understanding of the ability of current habitat conditions to support birds is a necessary first step for future grassland bird planning. Justification for this process is clearly articulated by the RGJV Management Board and is used as a performance metric with the U.S. Fish and Wildlife Service's Division of Bird Habitat Conservation in their annual reporting requirements for Joint Ventures. This approach to reporting ensures that the primary outcomes of partner investments are measured with reference to impact on wildlife rather than historic output measures of dollars and acres. Understanding how a landscape contributes to a species' viability and what changes to that landscape mean in terms of that species' population health are vital to developing strategies and programs that truly effect sustainable bird conservation.

This document is produced with the intent to supplement and extend the recent RGJV Implementation Plan approved in 2010. The Implementation Plan thoroughly describes the Joint Venture landscapes, risks, and priority species. The intent of this document is to build a scalable document to add additional guidance for five species included in the Implementation Plan as species of conservation concern. Each species will be addressed with a stand-alone section describing estimated bird densities, relationships of bird density to key habitat structure variables, and what, depending on current conditions, is the most beneficial change in habitat to effect a positive response in terms of species density. Because managers strive to understand the repercussions of actions, we have also included some guidance on the potential impact of management for one species on densities of the other four species included in these analyses. This information is not intended to circumvent decisions on habitat treatments for any given species but is provided to inform trade-offs in the decision-making process.

In addition to the above steps, we implemented a process for gross and cell-based capacity estimates in the overall process of developing bird plans. Gross capacity estimates provide an overview of the landscape to attract birds. These gross estimates do not imply that, just because a piece of habitat exists, a bird will be present. Gross capacity does however indicate the scale at which species can be served by the landscape. The cell-based capacity estimates carry similar caveats, but have the potential to highlight specific geographies. However, to accomplish cell-based capacity estimates at a finer level than presented here, the RGJV will require more detailed habitat classifications. The process has been demonstrated here and provides an indication of how many birds the Grassland Priority Conservation Areas (GPCA) can support under the best of conditions, as demonstrated over the sampling period. These data were necessary to provide context to the Joint Venture's responsibilities and contributions to continental-scale populations and reporting.

Finally, this exercise has exposed the authors to the range of data and research available in these habitats for use in conservation guidance. The vetting and use of these data have led to multiple caveats about their use and insights into data that need to be replaced, developed, and improved to provide greater confidence in and functionality of the models and processes implemented to develop this report. The authors provide a list of next steps and summary justifications at the end of this report.

## Methods

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### Study area

We implemented avian and habitat surveys in 11 current or proposed GPCAs in northern Mexico and western Texas in the winters of 2007–2011 in cooperation with the Universidad Autónoma de Nuevo León (UANL) and Sul Ross State University (SRSU) (Levandoski et al. 2009, Panjabi et al. 2010). These GPCAs were identified through a tri-national series of workshops involving regional experts from all parts of North America's central grasslands. GPCAs in our study included Cuatro Ciénegas, Cuchillas de la Zarca, Janos, Lagunas del Este, Malpaís, Mapimí, Marfa, El Tokio, Valles Centrales, Valle Colombia, and Sonoita (Figure 1).

### Sampling design

We overlaid a grid of 18 x 18 km<sup>2</sup> cell blocks across the Chihuahuan Desert and Sierra Madre Oriental Bird Conservation Regions to create a sampling frame for desert grasslands within GPCAs. Potential samples were cells that intersected with GPCAs and had at least 5 km of road access to grasslands as identified in the GIS (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 boundaries of the GPCA. This sampling design was described in detail by Panjabi et al. (2006), with modifications by Levandoski et al. (2009). We added additional GPCAs to the sampling frame in 2008 and 2009, as described by Panjabi et al. (2010), and the Malpaís grasslands in southeastern Durango in 2010 (Figure 1). In each sampling block we established randomly numbered points at 500 m intervals along roads intersecting grasslands, and established six paired 1-km line transects in each block, starting at the three lowest-numbered points that met habitat requirements for native grasslands with <25% shrub cover.

### Species and habitat data selection

Prior to initiation of this plan, in consultation with the Joint Venture Coordinator, we evaluated the amount of data we had on various species and whether those species were of conservation concern in the RGJV Implementation Plan. We settled on five species for the initial planning, analysis, and reporting. Between the five species, a wide geography of grasslands is encompassed and these species are also of conservation concern to northern Joint Ventures. We proceeded with the analysis of survey data collected on Chihuahuan Desert grassland transects for the five species: Baird's Sparrow (*Ammodramus bairdii*), Sprague's Pipit (*Anthus spragueii*), Chestnut-collared Longspur (*Calcarius ornatus*), Lark Bunting (*Calamospiza melanocorys*), and Loggerhead Shrike (*Lanius ludovicianus*).

The GPCAs (Table 1) and survey transects are distributed across the geography of the RGJV (Figure 1). Not all transects fall within GPCAs and not all transects have been surveyed at least three years. These data were collected as portions of other projects but built upon a common scalable sampling framework. Due to the adherence to a Grid Based Sampling (Panjabi et al. 2006) design, these data were able to be used in concert to evaluate species densities in the RGJV portion of the Chihuahuan Desert. Along with the collection of distance-based bird transect sampling, technicians collected vegetation data on a large portion of the transects over the last

three years. The simultaneous collection of these data provides the basis for investigating species-habitat correlations and relationships.

GIS data layers available for the RGJV area focus on coarse-cover type differentiations. Grassland and shrublands are difficult to distinguish yet are vital to avian applications. None of the available data sets provided the necessary classes for fine-scale application of species habitat models, for highlighting spatial variability, or targeting of programs beyond the GPCA scale. INEGI is scheduled to release their 2010 version of their land cover analysis in 2012. Until then the best available data for the Mexican portion of the Chihuahua Desert is still the 2005 INEGI data product. The 2010 data should replace existing data in RGJV member GIS databases when released. Analyses in this plan used a prerelease evaluation version of INEGI 2010 data. These data were still coarse with regard to grass-shrub differentiation. However, the new data excludes some areas of grassland conversion to crop and urban. The GAP data products are still the most consistent and widely used for large landscapes in the US and are fairly consistent with the quality of the INEGI data. GAP data was used but should be replaced with the Landfire 2010 data set once it is validated with transect data for accuracy.



**Figure 1.** Grassland Priority Conservation Areas in the Chihuahuan Desert (CEC and TNC 2005, Pool and Panjabi 2011) and wintering grassland bird sampling blocks surveyed in 2011. Green shading shows the extent of desert grasslands.

## **Bird surveys**

Our bird survey methodology followed Buckland et al. (2001), modified slightly for this study (Panjabi et al. 2006, Levandoski et al. 2009, Panjabi et al. 2010). We initiated surveys in most GPCAs in early January and completed surveys on or before March 5, with the exception of Marfa, where transects were conducted through March, and in Malpaís, which was surveyed in mid-December 2009. Each pair of 1-km line transects started from a randomly selected point along a road and headed in opposite directions perpendicular to the road. In a few instances where available grasslands were limited within the survey block, we split paired transects to start from different random points. During the course of the day, each pair of technicians surveyed the six transects in each block starting at sunrise and continuing until completion, which was generally before 13:00 hours. Finishing some transects within six hours was not possible due to weather, road conditions, and variability in the time needed to complete both bird and vegetation surveys. We recorded start and end times for each transect survey. We used Beaufort scales to categorize atmospheric conditions (sky, wind, and precipitation) at the start and end of each transect. We did not conduct surveys during winds higher than category 4 (20-29 km/hr) or during any precipitation greater than drizzle. We noted incidental observations of a subset of priority species observed in between transects in each survey block in order to provide a more complete inventory of grassland birds in each survey block (see Levandoski et al. 2009).

From each starting point, technicians used Garmin E-trex Vista GPS units to establish the end point of the transect 1000 m away and maintain their position on the line while conducting the survey. Observers used a sighting compass to help select a point on the horizon that corresponded with the direction of the transect end point, and used this bearing to help visualize the transect line in front of them. Observers recorded all birds detected during each survey and used laser rangefinders to estimate lateral distances from the transect line to each bird or bird cluster detected. Bird clusters were defined as groups of two or more individuals of the same species occurring within 25 m of the first individual detected. We recorded the cluster size, detection method (visual, song, call, wing-noise, pecking/drumming, or other), and transect segment where each cluster was located (0–250 m, 250–500 m, 500–750 m, or 750–1000 m). 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 m) of non-grassland habitat, they turned the transect 90° in a randomly chosen direction to avoid the obstacle.

## **Vegetation sampling protocol**

Vegetation survey protocol has varied slightly over the years. In 2008, we used a modified line-intercept approach described by Levandoski et al. (2009). But due to time constraints for data collection, we sampled ground- and shrub-cover parameters using ocular estimates in 2009-2011. In order to minimize potential bias and calibrate observers' estimation skills, we trained observers in estimating vegetation cover on plots where all parameters had been either measured directly or estimated through quantitative sampling. An analysis of grass-cover estimates from 2011 obtained through point-grid sampling of ground cover photos vs. ocular estimates on the same plots showed a strong correlation between the two approaches ( $r=.92$ ). Another comparison of ocular vs. quantitative sampling methods for the same ground and shrub cover parameters in shortgrass prairie in Colorado found that ocular sampling provides similar results (i.e., within 2%) as quantitative sampling for grass and shrub cover, whereas ocular estimates of bare ground were 2-5% higher than quantitative estimates and ocular estimates of "other" cover were 6-7%

lower than quantitatively sampled estimates (RMBO unpublished data). These findings suggest that ocular sampling of vegetation cover parameters provide a reasonably accurate assessment of grassland vegetation conditions.

We estimated vegetation parameters at 10 sub-sampling stations at 100 m intervals along each 1-km bird transect in 2009 and 2010. These surveys were conducted immediately following each bird survey. At each sub-sampling station, we made ocular estimates of ground cover within 5-m radius circular plots. To estimate ground cover, technicians looked directly down to the ground out to 2 meters in four cardinal directions, estimated the percent cover in each direction, averaged these, and then extrapolated the estimate out to 5 m, adjusting it for obvious variances. Ground cover estimates were broken down into five categories: woody shrubs/trees, bare ground, grass, and herbaceous. Average height was recorded for grass and herbaceous cover, with assistance of 30-cm rulers. Shrub cover was also estimated within 50 m of each sampling station using a similar approach. The habitat assessment also included characterizations of landscape-level site attributes including general topography (flatland, rolling hills, foothills, montane valleys, desert valleys, steep slopes, and mesa top), adjacent habitats, landownership, and dominant grassland type. Grassland types followed the classification by INEGI (2003) which includes natural, halophytic, gypsophytic, introduced or exotic grasslands. Gypsophytic and halophytic grasslands are defined by soil characteristics, whereas natural grasslands include all other native grasslands apart from halophytic and gypsophytic grasslands.

### Statistical analysis

We used the hierarchical modeling approach (Royle and Dorazio 2008) of distance sampling (Buckland et al. 2001) to estimate parameters for bird abundance (density) models that account simultaneously for imperfect detection and the effect of habitat structure characteristics. We used the Bayesian estimation paradigm to compute model parameters. In this regard, density ( $D$ , number of individuals per unit of area) for line transects may be estimated from:

$$D = \frac{E(n) \cdot f(0) \cdot E(s)}{2L} \quad \text{Eq(1)}$$

where  $E(n)$  is the mean number of groups detected,  $E(s)$  is the mean number of individuals per detection (cluster size),  $L$  is the total transect length and  $f(0)$  is the probability density function of perpendicular distances evaluated at zero distance. Equation (1) links the state process (factors driving density) to the observation process (detections at transects) and explicitly provides their components that can be conveniently modeled as function of covariates. Our sampling unit for this study was the transect and therefore the random variables  $E(n)$  and  $L$  in Eq(1) are indexed over all transects ( $i = 1, 2, \dots$ )

### Detection component

We used a half-normal detection function to model the distribution of perpendicular detection distances, whose probability density function  $f(y)$  is given by

$$f(y) = \frac{1}{\sigma} \left( \frac{2}{\pi} \right)^{\frac{1}{2}} e^{-y^2/2\sigma^2}$$

We modeled the effect of weather on detection probability by making parameter  $\sigma$  a function of temperature ( $x_t$ ), wind speed ( $x_w$ ), and sky condition ( $x_s$ ). In this way,  $\sigma$  at the  $i$ -th transect becomes

$$\sigma_i(x_{ti}, x_{wi}, x_{si}) = e^{\beta_0 + \beta_t x_{ti} + \beta_w x_{wi} + \beta_s x_{si}}$$

where  $\beta_0$ ,  $\beta_t$ ,  $\beta_w$ , and  $\beta_s$  are regression parameters to be estimated from the data. We used  $f(0)$  in Eq(1) as the average of the estimated  $f(0)$  across all transects accounting for weather variables, i.e.

$$\hat{f}(0) = \frac{1}{N} \left( \frac{2}{\pi} \right)^{\frac{1}{2}} \sum_{i=1}^N \frac{1}{\hat{\sigma}_i}$$

### Observation component

We assumed that the random variable number of detections for the  $i$ -th transect ( $n_i$ ) followed a Poisson distribution with parameter  $E(n_i)$ , i.e.,  $n_i \sim \text{Poi}(E(n_i))$ . Rearranging Eq(1), we have that the Poisson parameter  $E(n_i)$  relates to density, our unobserved variable of interest, by

$$E(n_i) = \frac{2 \cdot L_i \cdot D_i}{E(s) \cdot \hat{f}(0)}$$

where  $L_i$  and  $D_i$  are the length of and the density at the  $i$ -th transect. We modeled density as a function of habitat structure variables grass cover ( $x_{GC}$ ), grass height ( $x_{GH}$ ), shrub cover ( $x_{SC}$ ), shrub height ( $x_{SH}$ ), forb cover ( $x_{FC}$ ), and forb height ( $x_{FH}$ ). We also included the random GPCA-by-year effects nested within the levels of random GPCA effects. Density at the  $i$ -th transect in the  $k$ -th GPCA and year ( $D_{j(ik)}$ ) then becomes:

$$D_{j(ik)} = e^{\beta_{D0} + \beta_1 x_{GCi} + \beta_2 x_{GCi}^2 + \beta_3 x_{GHi} + \beta_4 x_{GHi}^2 + \beta_5 x_{SCi} + \beta_6 x_{SCi}^2 + \beta_7 x_{SHi} + \beta_8 x_{SHi}^2 + \beta_9 x_{FCi} + \beta_{10} x_{FCi}^2 + \beta_{11} x_{FHi} + \beta_{12} x_{FHi}^2 + \beta_{GPCA_j} + \beta_{GPCA \times YEAR_k}}$$

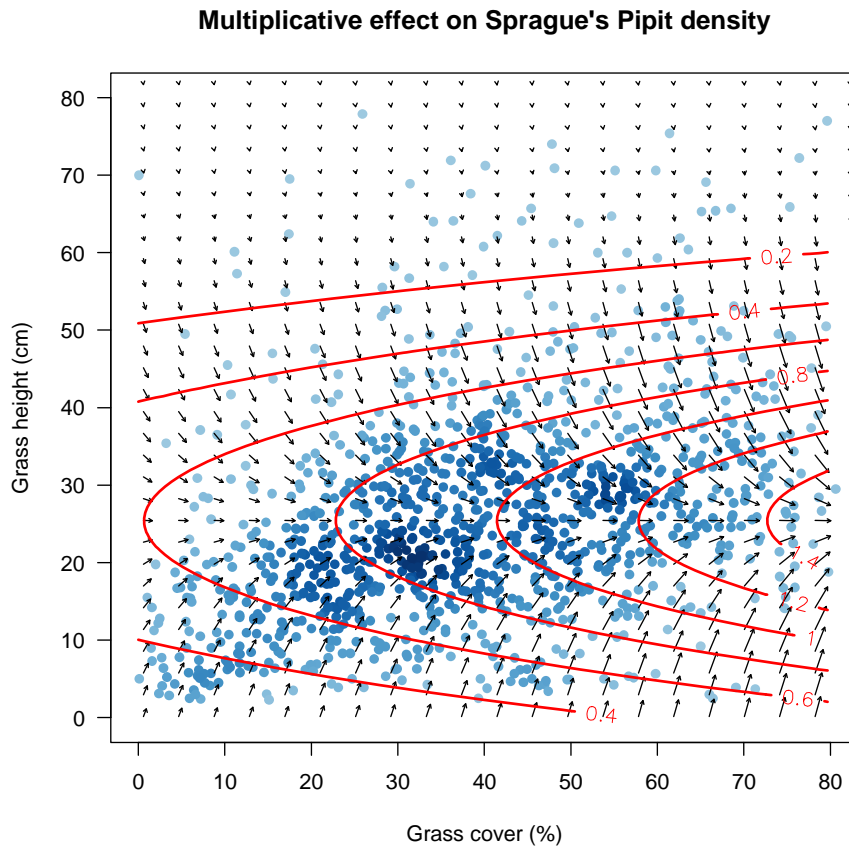
$$\beta_{GPCA_j} \sim N(\mu, \zeta)$$

$$\beta_{GPCA \times YEAR_k} \sim N(\eta, \xi)$$

where each  $\beta$  is a regression parameter, and  $\mu$ ,  $\zeta$ ,  $\eta$ , and  $\xi$  are hyperparameters for GPCA and GPCA  $\times$  year random effects. Prior distributions for all  $\beta_m \sim N(0, 1)$ . Estimations of overall and annual bird density illustrated on maps and boxplots (e.g., Fig. 7) represent the implementation of the model for bird density ( $D$ ) above with the GPCA and GPCA  $\times$  year only. We implemented this model because we had detection-distance data available back to 2007 in many instances and we thereby intended to provide a better characterization of the spatio-temporal variation in bird density. We used BUGS language (Spiegelhalter et al. 1996) to construct the likelihood function for each of the five priority species and to specify a prior distribution for each parameter in the model. We implemented the BUGS language using program WinBUGS 1.4 (Lunn et al. 2000) through program R (R Development Core Team 2009) with package R2WinBUGS (Sturtz et al. 2005). Markov Chain Monte Carlo (MCMC) runs consisted of three chains with a burn-in of 10,000 samples, and a posterior distribution based on 20,000 samples for each chain.



We built 2-dimensional plots to illustrate the effects of habitat management on bird species density (Fig. 2). We built contour level plots for the function  $f(x_i, x_j) = e^{\beta_1 x_i + \beta_2 x_i^2 + \beta_3 x_j + \beta_4 x_j^2}$ , for vegetation structure variables  $x_i$  and  $x_j$  (e.g., grass cover and grass height, Fig. 2) and their respective mean posterior regression parameters as described above. The function  $f(x_i, x_j)$  is the multiplicative factor on bird species baseline density as a function of vegetation structure variables  $x_i$  and  $x_j$ . We also plotted the gradient of  $f(x_i, x_j)$  over a grid on the plot. The gradient at a given point is a vector whose direction leads to the steepest ascent in  $f(x_i, x_j)$  or steepest increase in bird density and is given by  $\nabla f(x_i, x_j) = \frac{\partial f}{\partial x_i} \mathbf{e}_i + \frac{\partial f}{\partial x_j} \mathbf{e}_j$ , where  $\mathbf{e}_i$  and  $\mathbf{e}_j$  are unit vectors in the direction of  $x_i$  and  $x_j$  axes, respectively.



**Figure 2.** Plots are used throughout this document to illustrate the effects of habitat management on bird species density (e.g., Sprague’s Pipit). The  $x$ -axis and  $y$ -axis denote two vegetation variables that were important in determining the density of the bird species according to our hierarchical analysis. Red lines show the set of vegetation variables’ values that will produce the labeled multiplicative effect on density. The direction of the arrows (gradient) show the change in both variables that will produce the greatest increase in bird density. The length of the arrow is proportional to the magnitude of this change in bird density. Blue dots show the average levels found at bird transects surveyed throughout all Grassland Priority Conservation Areas. Blue dots become darker in areas around more frequent levels in both vegetation characteristics.

## Results

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### Priority and protected areas

The landscape of the Rio Grande Joint Venture area is composed of a variety of habitats including grasslands, which are among the most at risk to degradation and destruction. The CEC and TNC have already identified a series of GPCAs. These areas comprise some of the largest blocks of contiguous grassland habitat for priority species. Though they have been identified, these grasslands are still at risk of conversion to other land uses. Of the 4.9 million hectares of protected area in the RGJV, only 1,141,723 ha are protected in GPCAs (Table 1) based on the CEC 2010 protected areas data (<http://www.cec.org/Page.asp?PageID=924&ContentID=2979>) base plus The Nature Conservancy (TNC) boundary file for the UNESCO (United Nations Education, Scientific and Cultural Organization) Janos Biosphere Reserve not included in the CEC database. These international data do not include all private conservation easements due to sharing practices and many government managed lands, such as the US Forest Service or Bureau of Land Management because these lands are still capable of transfer to private ownership and congressional or administrative rules on land use practices. The biological value of many of these lands are still at risk from alterations due to acceptable practices such as mineral exploration and extraction.

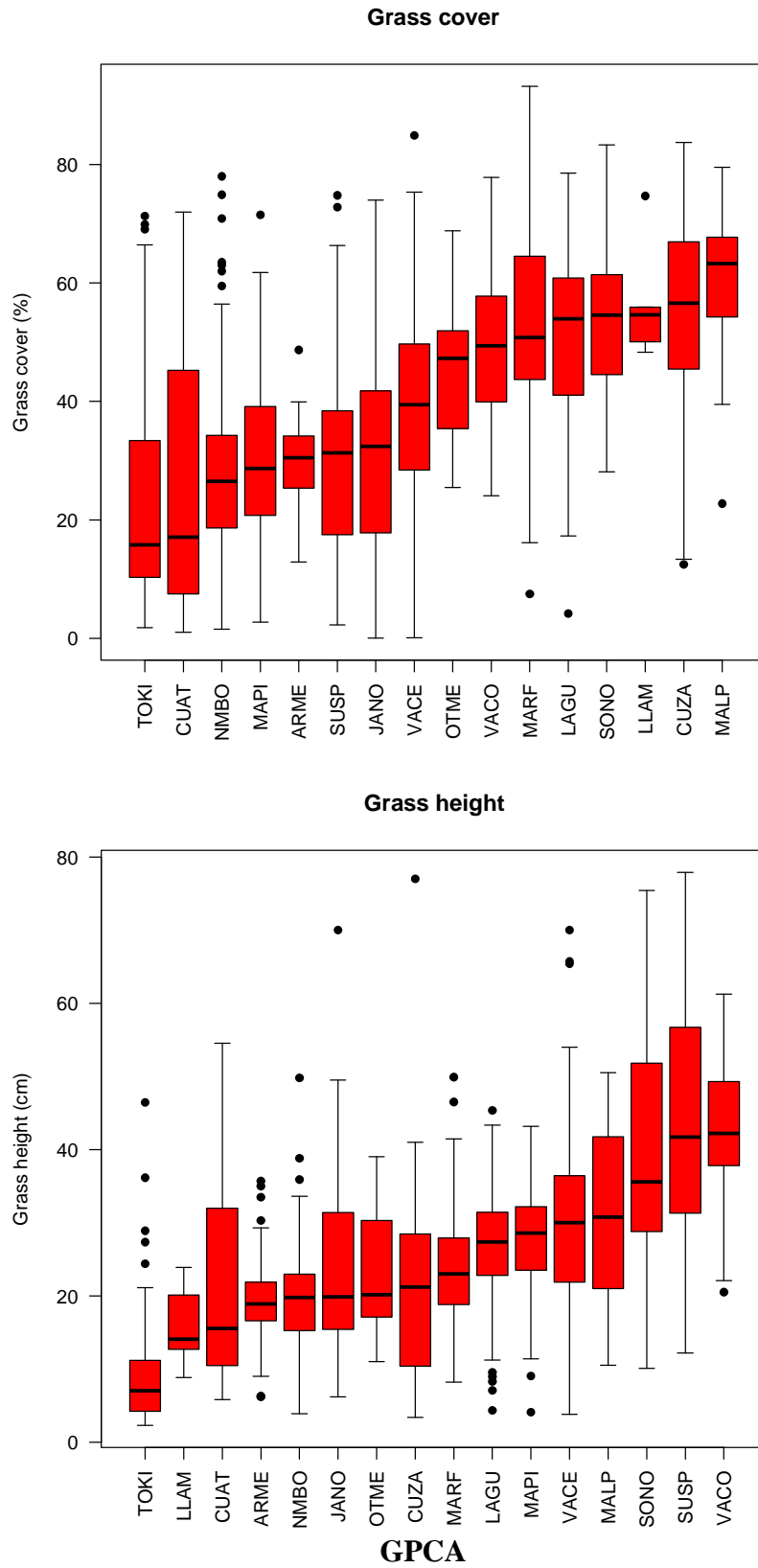
The GPCAs of the RGJV range in size from the 2.7 million ha Valles Centrales to the 153,098 ha Cuatro Ciénegas. The level of protection varies from zero protection in Valles Centrales to nearly all of Cuatro Ciénegas having a protected status. The network of GPCAs comprise nearly 16.5 million ha of which only 5% or 816,358 ha is protected.

**Table 1.** GPCA areas and CEC 2010 protected areas database from the National Atlas with the addition of Janos Biosphere Reserve.

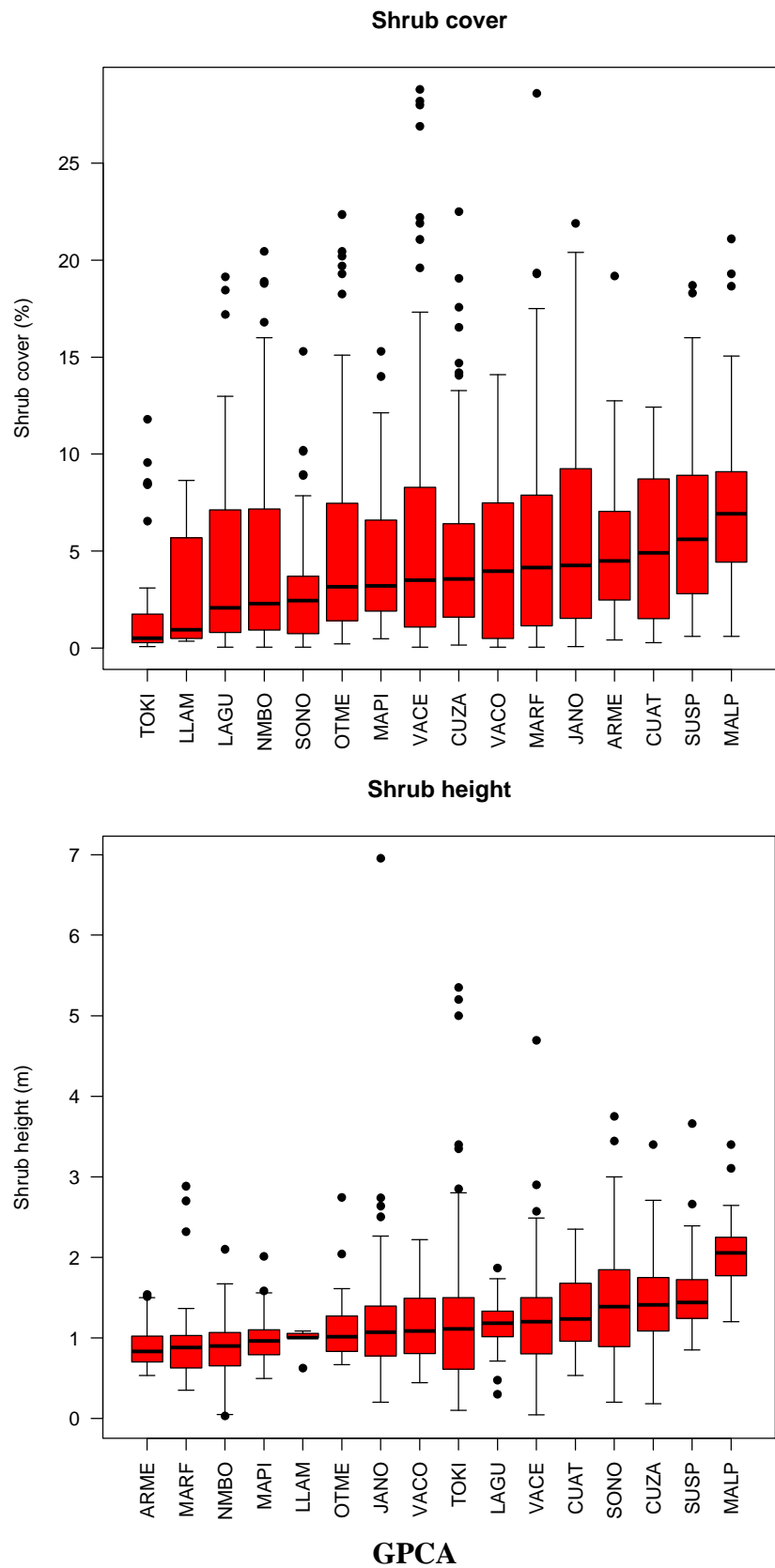
<b>GPCA Name (acronym)</b>	<b>Area (ha)</b>	<b>Grassland area (ha)</b>	<b>Percent low shrub grassland</b>	<b>Area (ha) of low shrub grassland (* MX only)</b>	<b>Area (ha) protected in each GPCA</b>
Alto Conchos (ALCO)	1,474,910	1,100,754	No Correction data	No data	No data
Cuatro Cienegas (CUAT)	153,098	22,440	No Correction data	No data	152,362
Cuchillas de la Zarca (CUZA)	1,158,844	904,277	61.2%	709,509	
Janos (JANO)	1,400,027	805,304	40.5%	566,695	345,620
Laguna del Este (LAGU)	896,707	413,226	46.1%	413,225	
Llano Las Amapolas (LLAM)	193,090	150,631	78.0%	150,630	2,326
Malpais (MALP)	2,619,151	1,129,774	43.1%	1,129,774	
Mapimi (MAPI)	896,582	221,401	6.1%	54,816	295,874
New Mexico Bootheel (NMBH)	1,445,450	31,818	2.1%	*30,030	2,302
Sonoita (SONO)	643,390	186,729	18.1%	*116,518	
Tokio (TOKI)	2,309,889	184,491	3.3%	75,512	48,558
Valle Colombia (VACO)	544,166	200,132	35.6%	193,877	294,681
Valles Centrales VACE)	2,694,326	1,230,564	21.2%	571,617	
Total	16,429,631	6,581,540		4,012,203	1,141,723

## **Vegetation characteristics across Grassland Priority Conservation Areas**

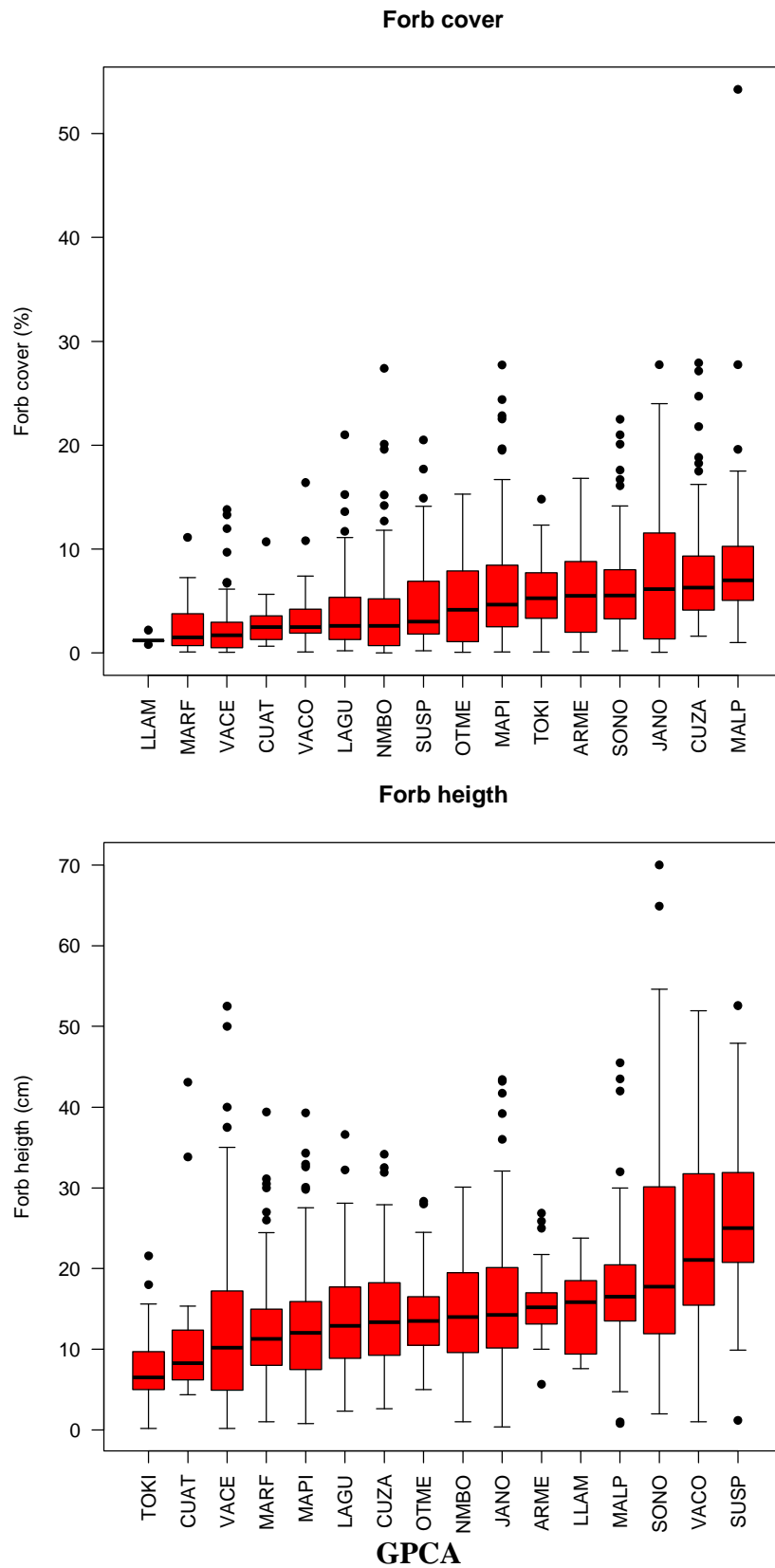
Grass vegetation shows an overall variability among GPCAs in both cover and height, although high variability within GPCAs (large overlap in interquartile ranges) obscures these differences, especially for grass cover (Fig. 3). Gypsophilic grasslands at Tokio in the southeastern Chihuahuan Desert are considerably shorter than the rest of the desert grasslands, although these differences in grass height do not translate into a large difference in grass cover (Fig. 3). Cuchillas de la Zarca and Malpais, which rank high in avian biodiversity among GPCAs (Macias-Duarte et al. 2012), ranked high in grass cover among all GPCAs. Shrub and forb vegetation characteristics tend to be more homogenous throughout GPCAs (Figs. 4 and 5). Therefore, the relative homogeneity in habitat structure conditions across GPCAs and the large variation within GPCAs suggests that general prescriptions for vegetation management to enhance habitat for any bird species can be applied to most grasslands throughout the Chihuahuan Desert. Furthermore, relationships between vegetation structure variables are important considerations to implement habitat improvement actions. Grass cover is highly correlated to grass height, despite the fact that the latter may be subject to large variations due to cattle and wildlife utilization. In addition, grass height is correlated to forb height. Correlation between any pairwise comparisons of vegetation structure variables is low (due to a lack of linear trends as seen in the scatterplots, Fig. 6). These low correlations show that grasslands are diverse in their physiognomy across the Chihuahuan Desert, spanning the spectrum of gradients of grass and shrub vegetation (e.g., dense grass within scattered shrubs and dense grass within shrub-free grasslands). It is feasible to modify vegetation characteristics in areas to improve or restore habitat to reach target vegetative conditions.



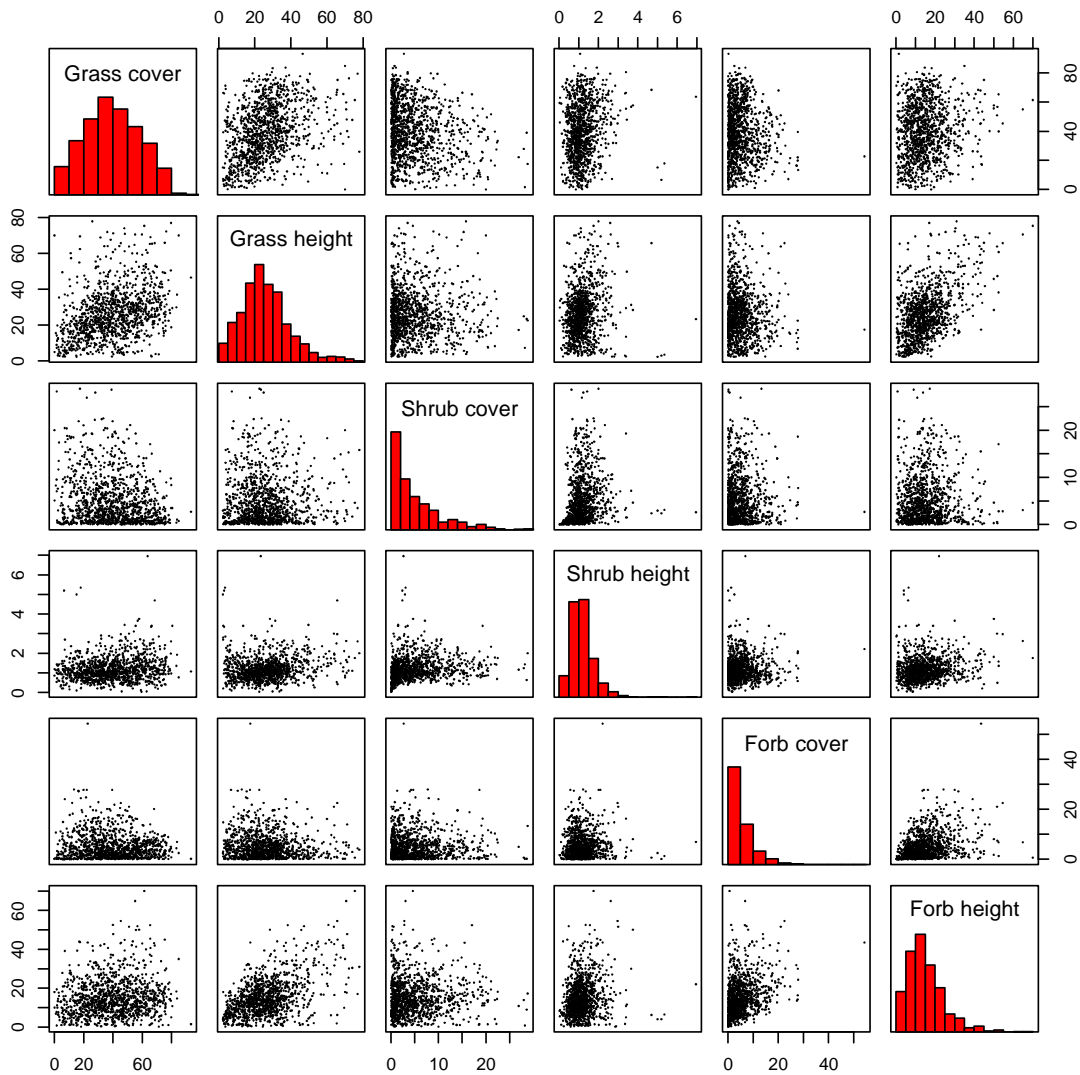
**Figure 3.** Distribution of grass cover and grass height in transects across Grassland Priority Conservation Areas (GPCA). See Table 1 for GPCA acronyms.



**Figure 4.** Distribution of shrub cover and shrub height in transects across Grassland Priority Conservation Areas (GPCA). See Table 1 for GPCA acronyms.



**Figure 5.** Distribution of forb cover and forb height in transects across Grassland Priority Conservation Areas (GPCA). See Table 1 for GPCA acronyms.



**Figure 6.** Scatterplot matrix of vegetation measurements in 16 Grassland Priority Conservation Areas (GPCA) in the Chihuahuan Desert. Each dot represents the average for a transect across years (2008-2011). Histograms in the diagonal plots show the marginal distribution of each variable across GPCAs. Horizontal axis units for **Cover** are in percent and **Height** is in centimeters. The vertical axis is percent or proportion of observations with values in the specified range.



## Baird's Sparrow

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Baird's Sparrow is an obligate grassland bird species (Vickery et al. 1999) whose breeding range is restricted to the upper Great Plains, encompassing the prairies of southern Alberta, southern Saskatchewan, southwestern Manitoba, North Dakota, and South Dakota (Green et al. 2003).

The species winters in Chihuahuan Desert grasslands from southeastern Arizona and northeastern Sonora, through the Mexican Central Plateau in southern New Mexico, southwestern Texas, Chihuahua, Coahuila, Durango, and northern Zacatecas (Howell and Webb 1995). The RGJV Implementation Plan (Rio Grande Joint Venture 2010) regards the Baird's



Sparrow as a near-endemic species for the winter in the Chihuahuan Desert BCR given its restricted winter range. The Baird's Sparrow, as with many other members in the grassland bird guild, has been declining since the onset of the North American Breeding Bird Survey with a 2.7% annual population decline or a 71% population decline from 1966 to 2010 (Sauer et al. 2011). Reduction of both suitable winter and breeding habitats by conversion of native prairie to cropland, invasion of exotic plant species, shrub encroachment, and poor range management is probably the underlying cause of this persistent decline. These threats have been documented on the wintering grounds of the Baird's Sparrow, where desert grasslands are being converted at an alarming rate in the last decade (Macias-Duarte et al. 2009, Ceballos et al. 2010). The contribution of winter survival to the decline of neotropical migratory birds is unknown but it is likely to be important (Sherry and Holmes 1996). Little is known about either the species' spatio-temporal patterns of abundance or its habitat requirements—two critical pieces of information needed to better guide conservation efforts on the wintering grounds. In this regard, this account provides the best characterization ever on the spatial and temporal variation in Baird's Sparrow density throughout the species' entire winter distribution within the Chihuahuan Desert, as well as the species' winter habitat characteristics.

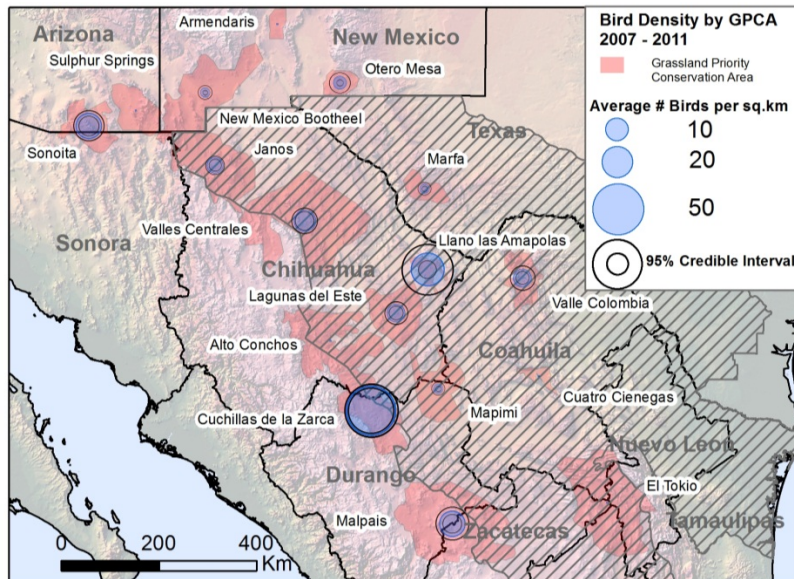
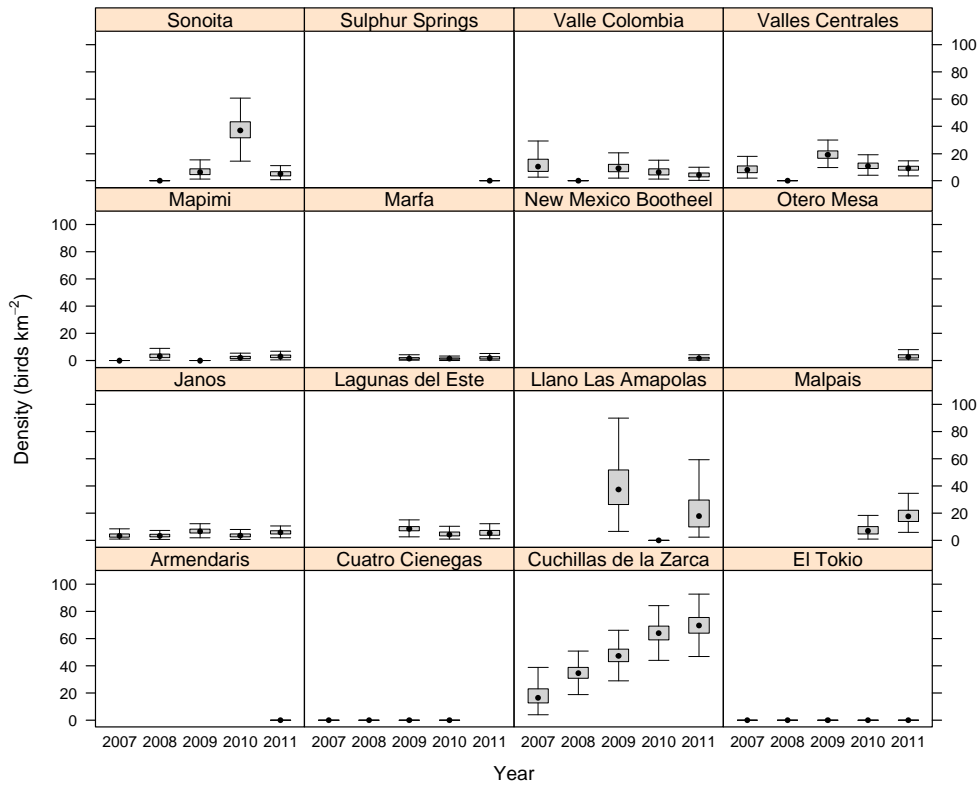
### **Abundance and distribution in the Chihuahuan Desert**

The abundance of Baird's Sparrow is not uniform throughout the Chihuahuan Desert (between-GPCA C.V. = 146%), being more abundant south of the Rio Grande towards the Sierra Madre Occidental (Fig. 7). Baird's Sparrows are more abundant in Cuchillas de la Zarca at the foothills of the Sierra Madre Occidental than anywhere else, reaching an average density of 47.0 birds km<sup>2</sup> (95% CRI 40.2-54.7 birds km<sup>2</sup>). Density of Baird's Sparrows may also be relatively high in Llano Las Amapolas, in high-elevation grasslands west of the Rio Grande (95th percentile = 51.3 birds km<sup>2</sup>, Fig. 7), but our estimation of density there is less precise given low sample size. Within the RGJV region, Valles Centrales, Janos, and Malpais are also important for the

conservation of the species given their moderate densities and the large extent of available habitat. In addition, our winter surveys show that Baird's Sparrows are absent from El Tokio and Cuatro Ciénegas in the eastern portion of the Chihuahuan Desert. We have no available information on Baird's Sparrow density for Alto Conchos, which, given its position at the Sierra Madre foothills north of Cuchillas de la Zarca, may harbor large winter populations of the species. Outside the RGJV region, Sonoita grasslands attain the highest density of Baird's Sparrows after Cuchillas de la Zarca and Llano Las Amapolas, with a mean annual density of 12.55 birds km<sup>-2</sup> (95% CRI 7.5-18.0 birds km<sup>-2</sup>), although with drastic annual variation. Baird's Sparrows are also absent from Armendaris and scarce in the New Mexico Bootheel region.

Annual changes in the abundance of Baird's Sparrows throughout the Chihuahuan Desert show different trends in different GPCAs. Baird's Sparrows have steadily and remarkably increased in Cuchillas de la Zarca since 2007, from 18.4 to 69.9 birds km<sup>-2</sup> (Fig. 7). The species' abundance had drastic changes in Llano Las Amapolas during the three years of monitoring. Densities remain relatively stable and low in the other surveyed areas. The RGJV region harbors a large portion of the winter population. Baird's Sparrows were found in relatively high densities outside the RGJV in Sonoita in 2010, reaching 37.7 birds km<sup>-2</sup> (95% CRI 21.2-56.9 km<sup>-2</sup>) suggesting intra Joint Venture responsibility for providing winter habitat.

### Baird's Sparrow



**Figure 7.** Abundance and distribution of Baird's Sparrow in GPCAs across the RGJV region demarcated by cross-hatching.

## Habitat relationships and habitat management

Baird's Sparrows are intrinsically related to grasslands in good condition with little woody vegetation in both the breeding grounds (Green et al. 2003) and the wintering grounds (Gordon 2000b, Macias-Duarte et al. 2009, Martinez-Guerrero et al. 2011). Baird's Sparrow winter density responds to habitat structure (Table 2). Our results show that the density of Baird's Sparrows is positively related to grass cover and negatively related to shrub cover throughout the Chihuahuan Desert (Fig. 8). Baird's Sparrows are also sensitive to vertical obstruction from grass and herbaceous vegetation. Baird's Sparrow density reaches its peak in grasslands around 38 cm high; extremes of either low or high grass vegetation have a strong negative effect on density (Fig. 8). This finding supports the observation by Gordon (2000a) that moderate cattle grazing may be compatible with the conservation of the species. Forb height also has an effect on Baird's Sparrow density, with an optimal height around 50 cm. Forb cover and shrub height show no tangible effect on density.

Most grasslands in the Chihuahuan Desert, under current range management, are below optimal conditions for Baird's Sparrows regarding grass vegetation (Fig. 9), where optimal conditions are reached at 80% grass cover and 38 cm grass height. Still, a large proportion of grasslands (those with grass cover >40%) could achieve the highest increases of Baird's Sparrow abundance by increasing grass cover; habitat management for Baird's Sparrow should focus on grasslands with these characteristics within GPCAs. Baird's Sparrows would also greatly benefit from less intense grazing in grasslands with <40% grass cover that promotes the existence of some tall grass stands. The response of the other four evaluated species to habitat management directed towards the enhancement of Baird's Sparrow density is positive (Fig. 9)—these species also benefit from increases in grass cover and intermediate grass height.

When we explore the joint effects of grass cover and shrub cover, it becomes evident that these variables are equally important across their ranges of variation to enhance habitat for Baird's Sparrows (Fig. 10). The greatest increase in Baird's Sparrow density will be achieved by decreasing shrub cover and increasing grass cover in grasslands with shrub cover <5% and grass cover >40%. Again, improvement focused on the best-managed grasslands will produce the greatest benefit. This habitat management is also favorable for the other four priority species, although Baird's Sparrow will benefit more from shrub control than from increases in grass cover.

The heights of grass and forb vegetation under current range management in most grasslands throughout the Chihuahuan Desert are suboptimal for the Baird's Sparrow (Fig. 11). Optimal grass height and forb height for the species are near 38 and 50 cm, respectively, with most sites having much lower levels. Baird's Sparrows will benefit from habitat management focused on increasing grass height. Since grass height and forb height are correlated throughout the Chihuahuan Desert (Fig. 6), promoting the presence of standing grass will likely enhance the effect on Baird's Sparrow density by also promoting forb height. Habitat management manipulating both grass height and forb height focused on the Baird's Sparrow may have slightly detrimental effects on the other four priority species, since their joint optimum levels are below those of the Baird's Sparrow. Existing grassland conditions appear more optimal for the other four species.

**Table 2.** Posterior distribution of model coefficients for the effect of habitat structure variables on the  $\log_e$  Density of Baird’s Sparrow in Chihuahuan Desert grasslands. Boldface rows indicate variables whose 95% credible interval excludes zero.

Variable	$\beta$	SD( $\beta$ )	2.50%	25%	50%	75%	97.50%
<b>Grass cover - 41.44</b>	<b>0.0227</b>	<b>0.0062</b>	<b>0.0108</b>	<b>0.0184</b>	<b>0.0228</b>	<b>0.0269</b>	<b>0.0348</b>
(Grass cover - 41.44) <sup>2</sup>	0.0000	0.0002	-0.0004	-0.0001	0.0000	0.0001	0.0003
<b>Shrub cover - 4.85</b>	<b>-0.1014</b>	<b>0.0241</b>	<b>-0.1479</b>	<b>-0.1182</b>	<b>-0.1007</b>	<b>-0.0846</b>	<b>-0.0545</b>
(Shrub cover - 4.85) <sup>2</sup>	0.0010	0.0030	-0.0057	-0.0009	0.0012	0.0031	0.0062
<b>Grass height - 25.44</b>	<b>0.0415</b>	<b>0.0076</b>	<b>0.0266</b>	<b>0.0366</b>	<b>0.0415</b>	<b>0.0464</b>	<b>0.0571</b>
<b>(Grass height - 25.44)<sup>2</sup></b>	<b>-0.0017</b>	<b>0.0004</b>	<b>-0.0024</b>	<b>-0.0019</b>	<b>-0.0017</b>	<b>-0.0014</b>	<b>-0.0010</b>
Shrub height - 1.22	-0.1398	0.1262	-0.3858	-0.2243	-0.1418	-0.0561	0.1105
(Shrub height - 1.22) <sup>2</sup>	-0.0138	0.0545	-0.1424	-0.0448	-0.0063	0.0251	0.0715
Forb cover - 5.66	0.0078	0.0167	-0.0268	-0.0031	0.0077	0.0193	0.0396
(Forb cover - 5.66) <sup>2</sup>	-0.0002	0.0008	-0.0018	-0.0007	-0.0001	0.0003	0.0011
<b>Forb height - 14.78</b>	<b>0.0311</b>	<b>0.0099</b>	<b>0.0117</b>	<b>0.0243</b>	<b>0.0312</b>	<b>0.0379</b>	<b>0.0506</b>
(Forb height - 14.78) <sup>2</sup>	-0.0004	0.0003	-0.0012	-0.0007	-0.0004	-0.0002	0.0002

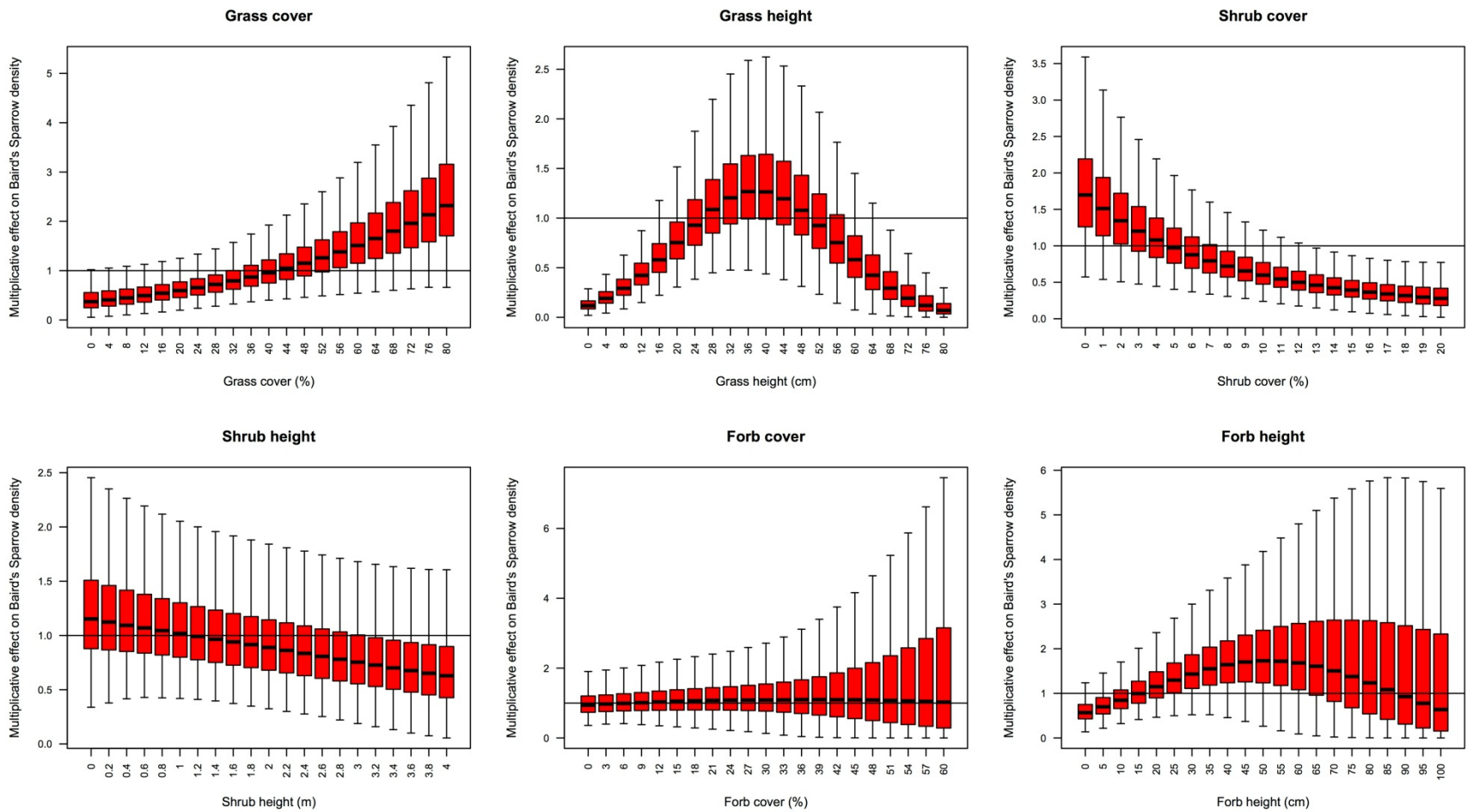
## Habitat management recommendations

Results from our hierarchical model for the Baird’s Sparrow suggest that management for habitat improvement should focus on increasing the regeneration of the grasses in grasslands near average condition (~40% cover) if the goal is to provide quality habitat in the short term. The gains in Baird’s Sparrow abundance associated with restored and improved habitat in degraded grasslands could be low. However, the effectiveness of treatments (such as resting, reseeding, soil erosion control, etc.) will likely be more viable in degraded lands in the long term than in preserved grasslands and must be considered as a long-term alternative for Baird’s Sparrow conservation. Thus restoration is prioritized over management of current grassland condition because restoration in effect adds to the basic capacity for the landscape to support Baird’s Sparrows and viable habitat is still the most influential parameter from the models for estimating carrying capacity. In addition, we recommend that potential Baird’s Sparrow habitat be moderately grazed and allow a standing grass vegetation of 30-50 cm. Shrub control for Baird’s Sparrow habitat must be performed only to restore grasslands from shrublands (>5% shrub cover), rather than performing shrub removal in areas already occupied by Baird’s Sparrows in the winter. Shrub removal creates more habitat, which is more efficient for increasing Baird’s Sparrow capacity than improvement of existing habitat, which targets density. Habitat

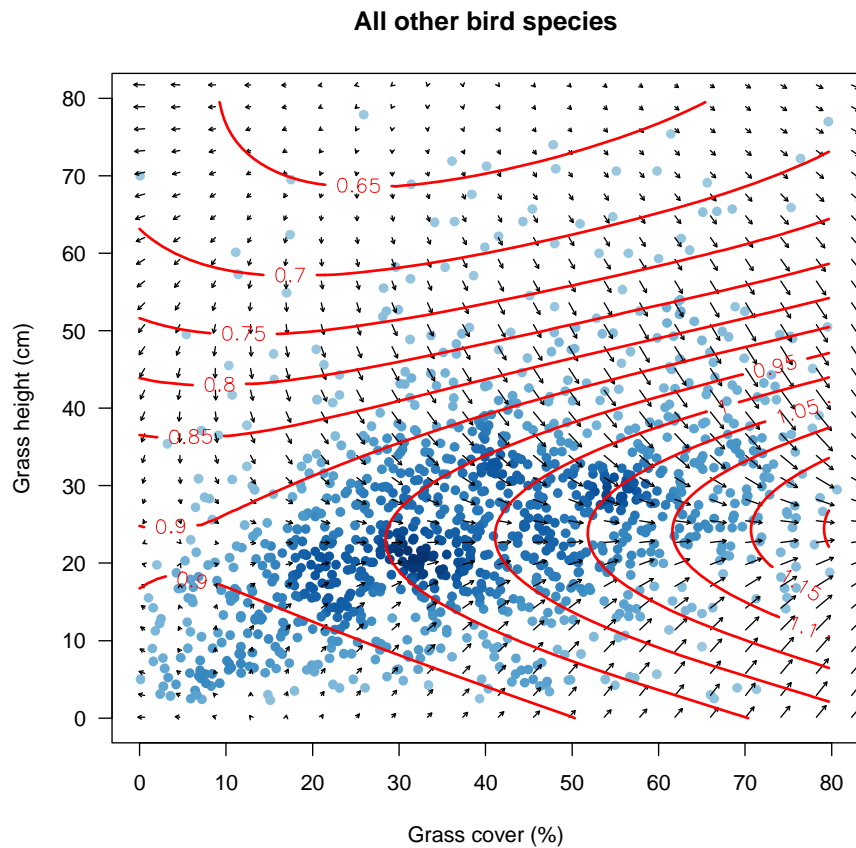
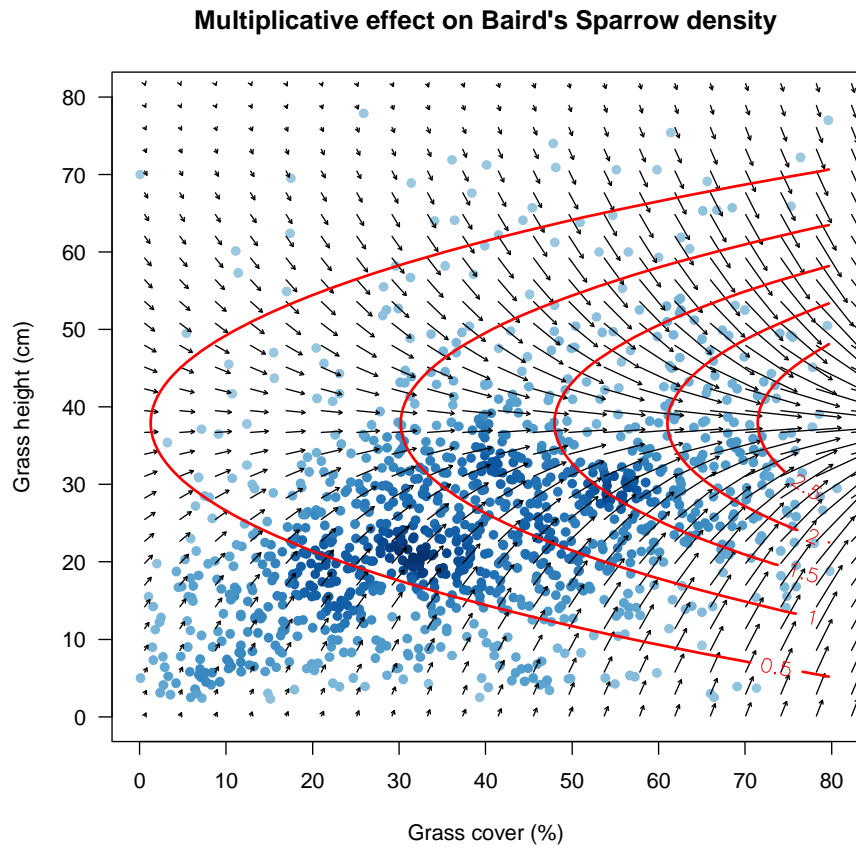
management for Baird's Sparrows will likely benefit numerous species (including the other four RGJV species).



Baird's Sparrow habitat in Durango, Mexico. (Photo: Jose Hugo Martinez Guerrero)

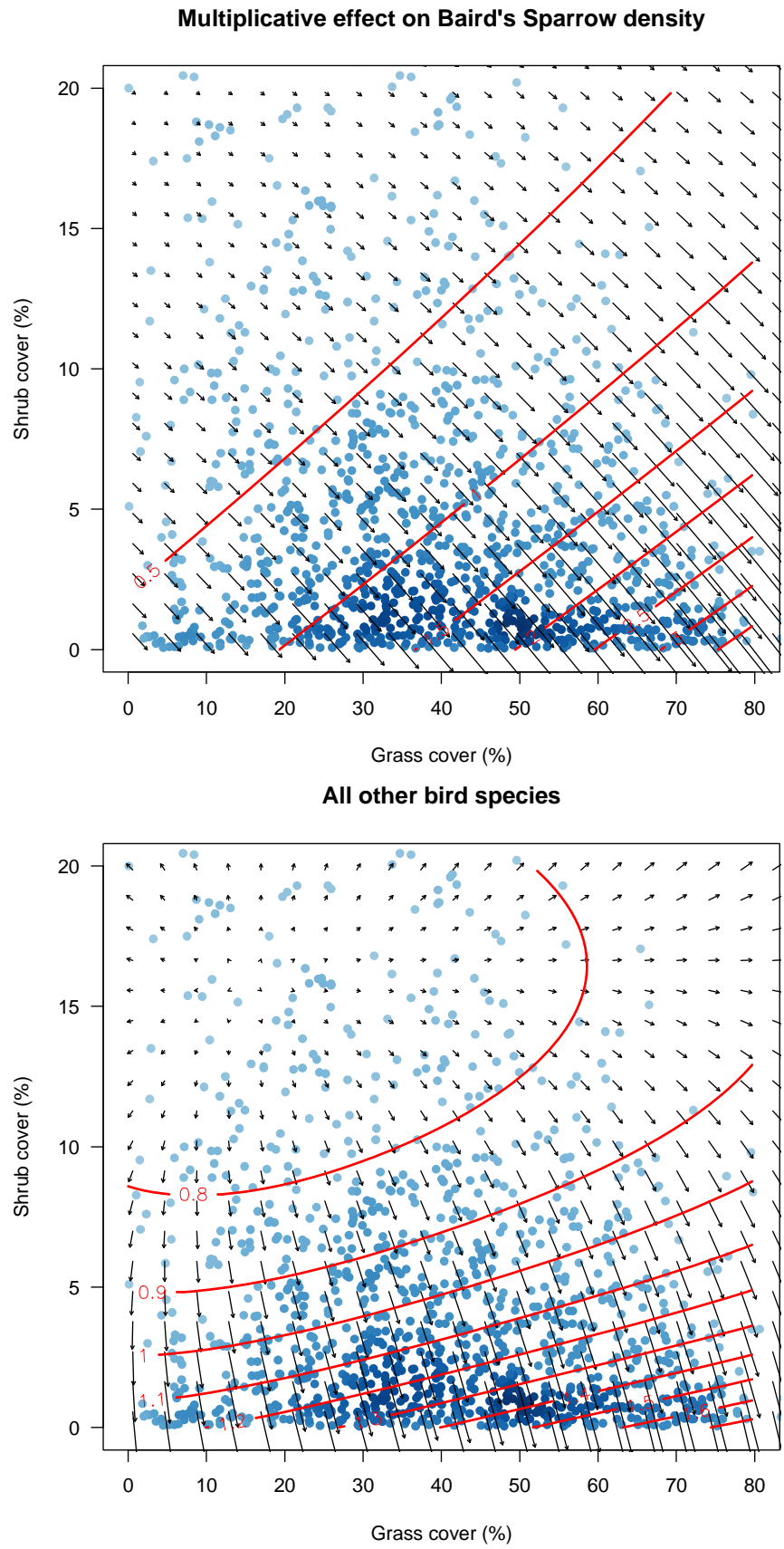


**Figure 8.** Multiplicative effect of habitat structure variables on baseline winter densities of Baird's Sparrow throughout Chihuahuan Desert grasslands.

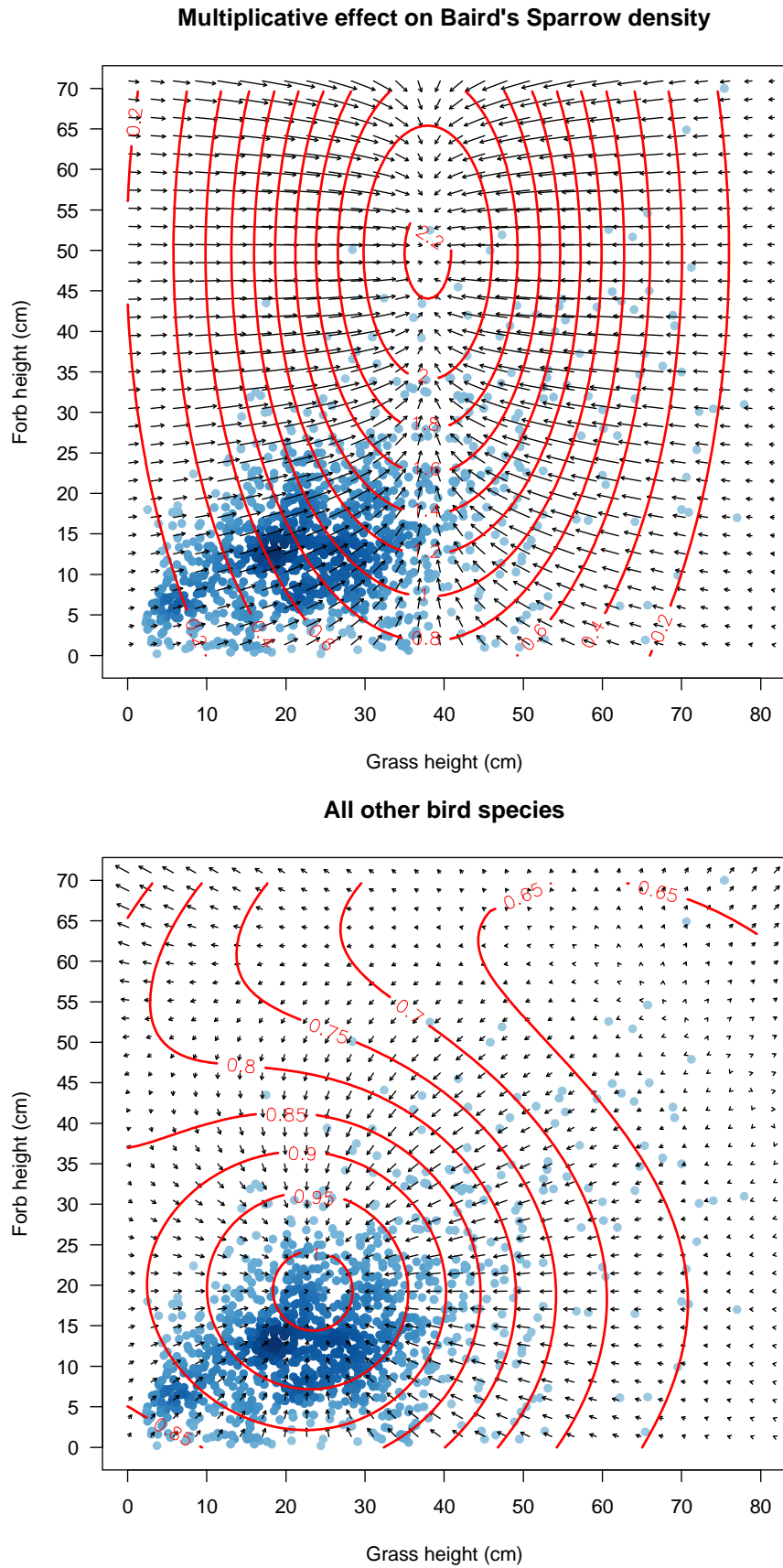


**Figure 9.** Effect of habitat management (grass cover and grass height) on Baird's Sparrows and the other four RGJV priority bird species in Chihuahuan Desert grasslands.





**Figure 10.** Effect of habitat management (grass cover and shrub cover) on Baird’s Sparrows and the other four RGJV priority bird species in Chihuahuan Desert grasslands.



**Figure 11.** Effect of habitat management (grass height and forb height) on Baird's Sparrows and the other four RGJV priority bird species in Chihuahuan Desert grasslands.

## Chestnut-collared Longspur

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Chestnut-collared Longspur is a grassland-endemic species whose breeding distribution is restricted to the short- and mixed-grass prairies in the northern Great Plains. The breeding range includes southern Alberta, Saskatchewan, and Manitoba in Canada, Montana, the Dakotas, and relict, local populations in Colorado, Nebraska, Wyoming, and Minnesota in the United States (Hill and Gould 1997). Conversion of native prairie to cropland and urban development has reduced much of the species' historical range, and population declines continue. The Chestnut-collared Longspur has suffered one of the steepest declines in the grassland bird guild, with 4.4% annual decline or 87% total decline from 1966 to 2010 (Sauer et al. 2011). The species' winter distribution extends from northern Arizona, north-central New Mexico, central Kansas, and west-central Oklahoma through northern Sonora, northwestern Texas (Hill and Gould 1997), and the Mexican Central Plateau from Chihuahua and Coahuila south to Zacatecas,



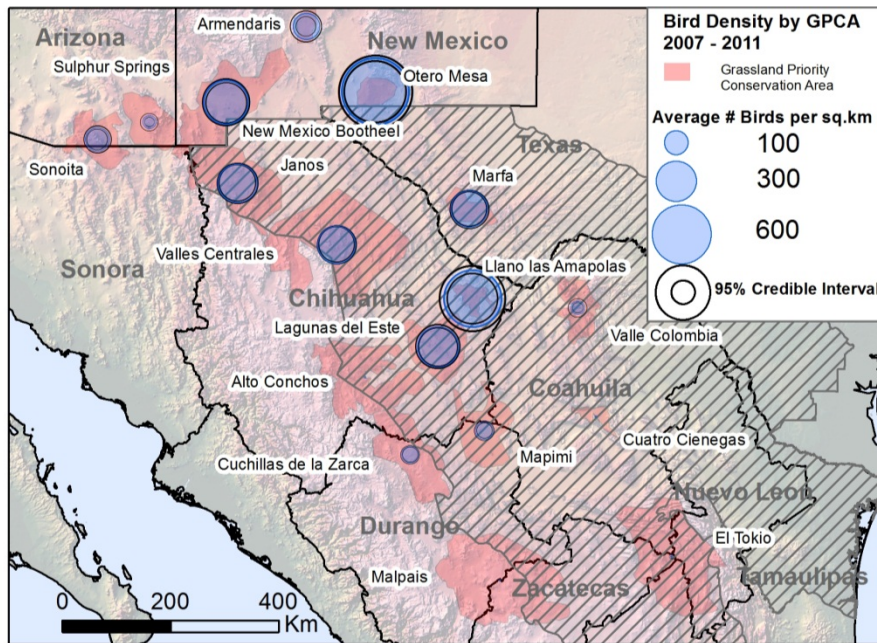
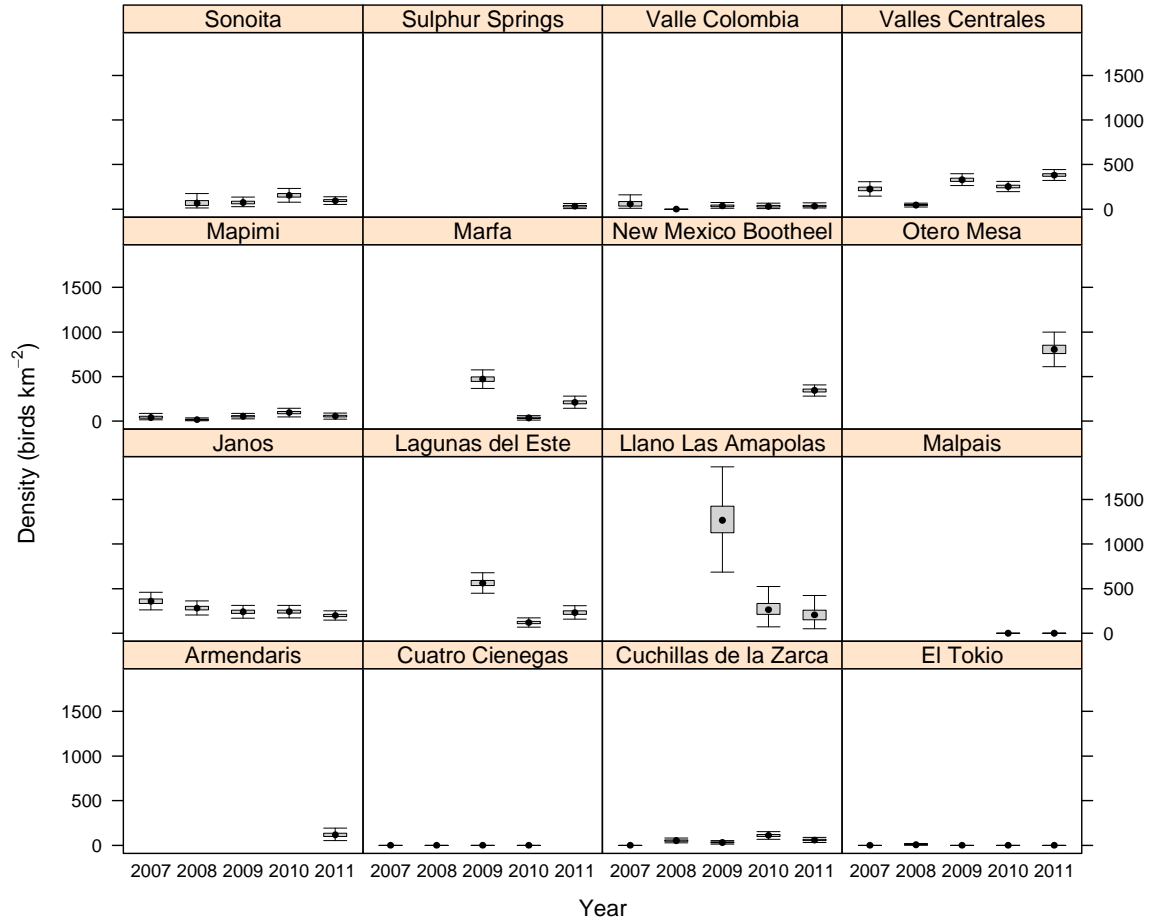
Aguascalientes, and San Luis Potosí (Howell and Webb 1995). Since Chestnut-collared Longspurs are also grassland specialists during the winter (Macias-Duarte et al. 2009), the species is highly susceptible to the effects of intense human activity on shortgrass prairies on the wintering grounds. As a consequence, contraction of wintering range in Texas may be caused by degradation of wintering habitat (Hill and Gould 1997). Therefore, identified research priorities for the Chestnut-collared Longspur (Hill and Gould 1997) include the study of migration and wintering biology (especially in Mexico), identification of key migration stopovers and wintering sites, threats to these areas, winter habitat requirements and preferences, and food sources and intake. This account provides the most extensive description of the abundance and distribution of Chestnut-collared Longspurs in the Chihuahuan Desert, winter habitat requirements, and vegetation management recommendations to enhance winter habitat capacity.

## Abundance and distribution in the Chihuahuan Desert

The Chestnut-collared Longspur has a northerly distribution in the Chihuahuan Desert (Fig. 12), being more abundant in the lowlands of eastern Chihuahua, west Texas, and southern New Mexico. The Chestnut-collared Longspur attains its highest density in Otero Mesa in southern New Mexico, with 807.5 birds km<sup>-2</sup> (95% CRI 675.0-953.2 birds km<sup>-2</sup>) and then in Llano Las Amapolas in eastern Chihuahua, with 595.2 birds km<sup>-2</sup> (95% CRI 443.3-780.9 birds km<sup>-2</sup>). Density of Chestnut-collared Longspurs decreases towards the southeastern Chihuahuan Desert reaching almost zero density at El Tokio in southeastern Nuevo Leon and zero density at Cuatro Ciénegas in central Coahuila and Malpais. Density of Chestnut-collared Longspurs also decreases towards the northwestern Chihuahuan Desert of Arizona and Sonora and farther north into New Mexico (Fig. 12). Janos and Valles Centrales have intermediate-density levels of Chestnut-collared Longspurs (266.2 and 248.3 birds km<sup>-2</sup>, respectively) but given the relatively large areas of these GPCAs, Janos and Valles Centrales harbor the large winter populations and play a major role in the viability of the continental population. Therefore, recent conversion of approximately 69,000 ha of grassland to farmland in Valles Centrales likely exacerbates the negative trajectory of Chestnut-collared Longspur populations.

Annual trends in the species' winter abundance vary by GPCA, although all trends are obscured by the extreme magnitude of annual variation in density at Llano Las Amapolas where the species reached a maximum annual density of 1289.9 birds km<sup>-2</sup> in 2009 and then dropped to 215.1 birds km<sup>-2</sup> in 2011 (Fig. 12). Nevertheless, some trends are evident in other GPCAs. Density of Chestnut-collared Longspurs has steadily declined in Janos but increased in Valles Centrales from 2007, but no trends appear evident in the other GPCAs. Given the recent grassland losses in Valles Centrales, the increase in density may reflect increasing concentration of Chestnut-collared Longspurs in the remaining grasslands.

### Chestnut-collared Longspur



**Figure 12.** Abundance and distribution of Chestnut-collared Longspur in GPCAs across the RGJV region demarcated by cross-hatching.

## Habitat relationships and habitat management

Habitat structure is a strong predictor of abundance of Chestnut-collared Longspurs in the Chihuahuan Desert (Table 3). The habitat features that had the largest effects were shrub cover, shrub height, and forb height (Figure 13). Shrub cover has a negative effect on bird density: bird density is increased 94% over the baseline density at zero shrub cover, but decreases by 34% at 10% shrub cover. Chestnut-collared Longspur abundance shows an even stronger negative response to shrub height: grasslands with low shrubs (20 cm high) have 220% more birds than grasslands with shrubs at intermediate heights (1.2 m). Bird density shows a unimodal response to forb height, with the maximum density reached in grasslands with average forb height of 20 cm. Bird density decreases rapidly when average forb heights exceed 30 cm. These results confirm and extend upon the habitat relationships found for the species in Valles Centrales and Janos, where the probability of occurrence was negatively related to the density of low and high shrubs (Macias-Duarte et al. 2009) and abundance was also negatively related to shrub density (Desmond et al. 2005). Grass cover showed a weak relationship with the species' density, but the relationship was positive as suggested by previous studies (Desmond et al. 2005, Macias-Duarte et al. 2009).

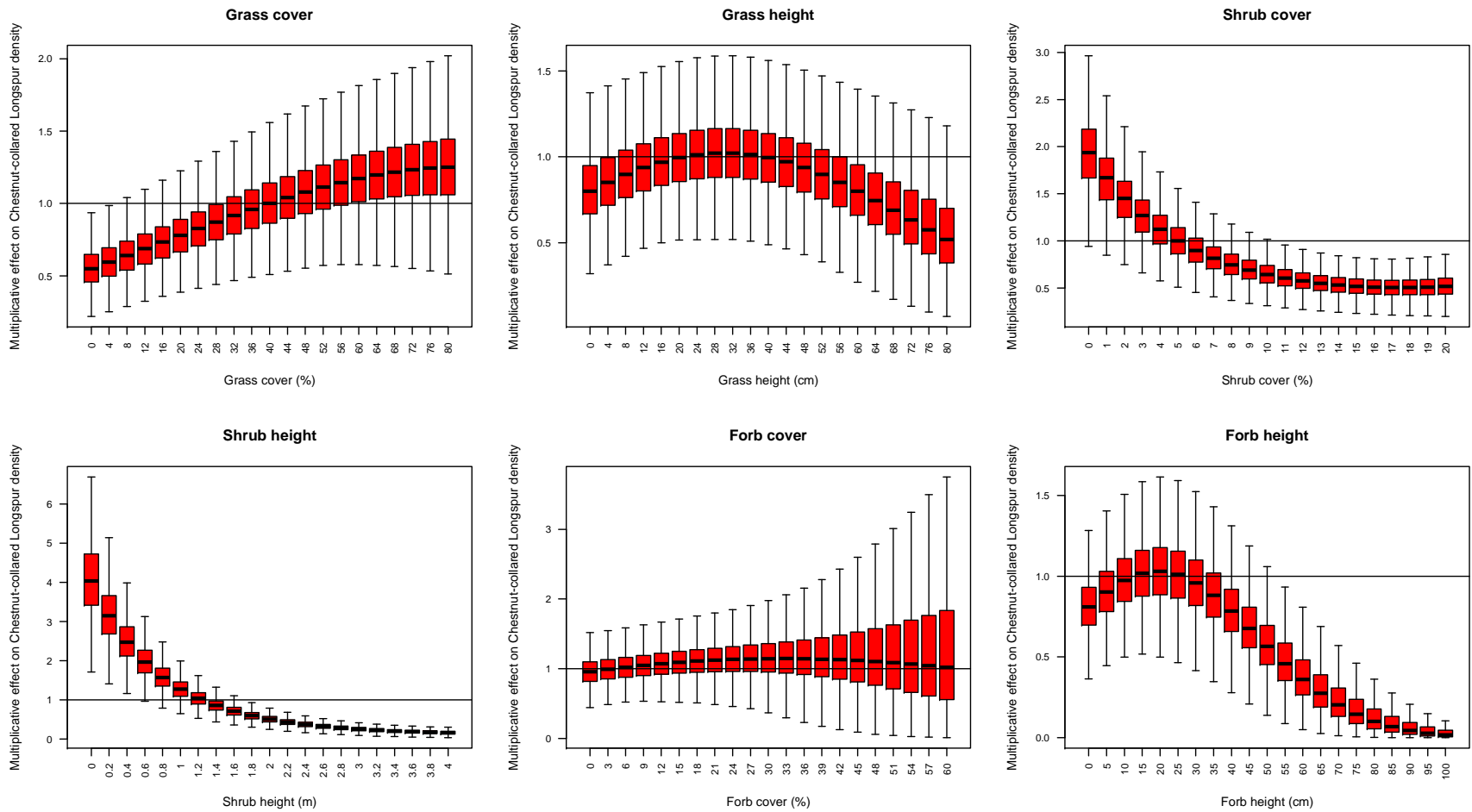
Visualizing the joint effect of shrub cover and forb height shows that the most efficient habitat management to increase Chestnut-collared Longspur densities in Chihuahuan Desert grasslands is to decrease simultaneously shrub cover and shrub height, especially in sites near to average baseline density (below the isoline = 1; Fig. 14), which depicts where the increase in bird density because of habitat management would be the greatest. Although most of our transects are in grassland that already has low shrub cover and shrub height, areas where Chestnut-collared Longspurs are below baseline density (sites above the isoline = 1; Fig. 14) may also be managed for higher density. This result highlights the strong negative effect that woody plant encroachment has on winter habitat suitability for the species. Habitat management directed to reduce shrub height and shrub cover to improve Chestnut-collared Longspur winter habitat will also benefit the other four priority species, especially in regards to the reduction of shrub cover (Fig. 14). In addition, although forb height also became an important predictor of Chestnut-collared Longspur density, the magnitude of this variable's effect on bird density is less evident than that for shrub cover for most sites (upper plot in Fig. 15). Forb heights greater than 40 cm have noticeable negative effects on Chestnut-collared Longspur abundance (Fig. 13), but few sites had forb vegetation with such height (upper plot in Fig. 15). Managing shrub cover and forb height to benefit Chestnut-collared Longspurs in the Chihuahuan Desert will also benefit the other four RGJV species because they share a similar joint response to these habitat variables (lower plot in Fig. 15).

**Table 3.** Posterior distribution of model coefficients for the effect of habitat structure variables on  $\log_e$  Density of Chestnut-collared Longspur in Chihuahuan Desert grasslands. Boldface rows indicate variables whose 95% credible interval excludes zero.

Variable	$\beta$	SD( $\beta$ )	2.50%	25%	50%	75%	97.50%
Grass cover - 41.44	0.0099	0.0019	0.0061	0.0086	0.0099	0.0112	0.0137
(Grass cover - 41.44) <sup>2</sup>	-0.0001	0.0001	-0.0002	-0.0002	-0.0001	-0.0001	0.0000
<b>Shrub cover - 4.85</b>	<b>-0.1111</b>	<b>0.0099</b>	<b>-0.1303</b>	<b>-0.1178</b>	<b>-0.1112</b>	<b>-0.1043</b>	<b>-0.0915</b>
<b>(Shrub cover - 4.85)<sup>2</sup></b>	<b>0.0044</b>	<b>0.0009</b>	<b>0.0027</b>	<b>0.0038</b>	<b>0.0044</b>	<b>0.0050</b>	<b>0.0060</b>
Grass height - 25.44	0.0023	0.0032	-0.0038	0.0001	0.0023	0.0044	0.0087
(Grass height - 25.44) <sup>2</sup>	-0.0003	0.0001	-0.0005	-0.0004	-0.0003	-0.0002	0.0000
<b>Shrub height - 1.22</b>	<b>-0.9809</b>	<b>0.0669</b>	<b>-1.1138</b>	<b>-1.0257</b>	<b>-0.9801</b>	<b>-0.9358</b>	<b>-0.8513</b>
<b>(Shrub height - 1.22)<sup>2</sup></b>	<b>0.1159</b>	<b>0.0263</b>	<b>0.0573</b>	<b>0.1003</b>	<b>0.1184</b>	<b>0.1343</b>	<b>0.1601</b>
Forb cover - 5.66	0.0094	0.0082	-0.0063	0.0038	0.0093	0.0148	0.0259
(Forb cover - 5.66) <sup>2</sup>	-0.0002	0.0004	-0.0010	-0.0004	-0.0002	0.0001	0.0006
Forb height - 14.78	0.0057	0.0041	-0.0023	0.0030	0.0057	0.0085	0.0138
<b>(Forb height - 14.78)<sup>2</sup></b>	<b>-0.0006</b>	<b>0.0002</b>	<b>-0.0011</b>	<b>-0.0008</b>	<b>-0.0006</b>	<b>-0.0005</b>	<b>-0.0002</b>



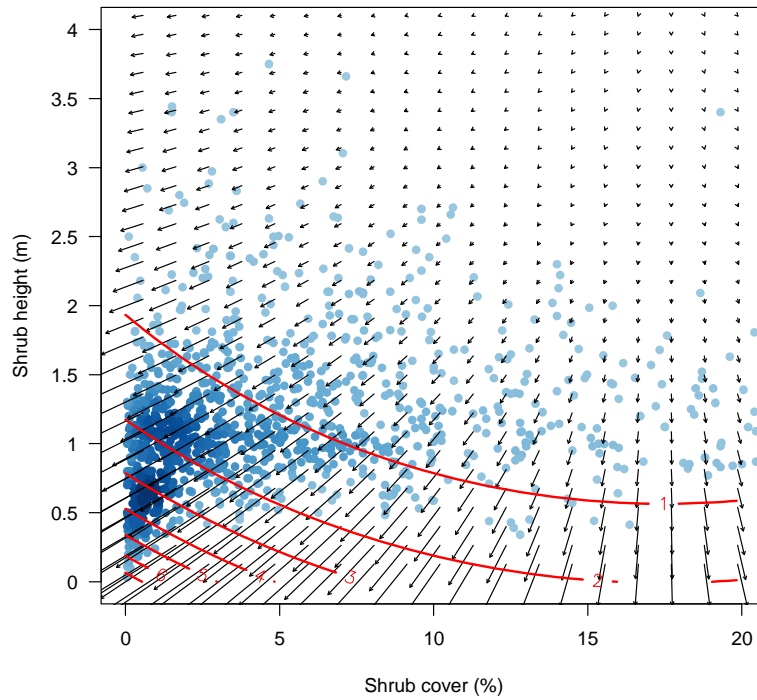
Chestnut-collared Longspur habitat in Chihuahua, Mexico.(Photo: Alberto Macias-Duarte)



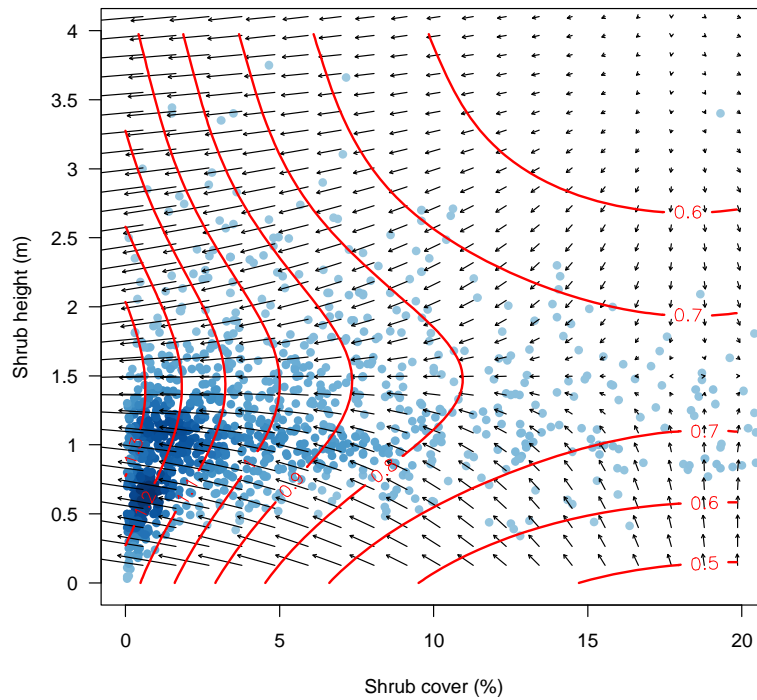
**Figure 13.** Multiplicative effect of habitat structure variables on baseline winter densities of Chestnut-collared Longspur throughout Chihuahuan Desert grasslands.



### Multiplicative effect on Chestnut-collared Longspur density

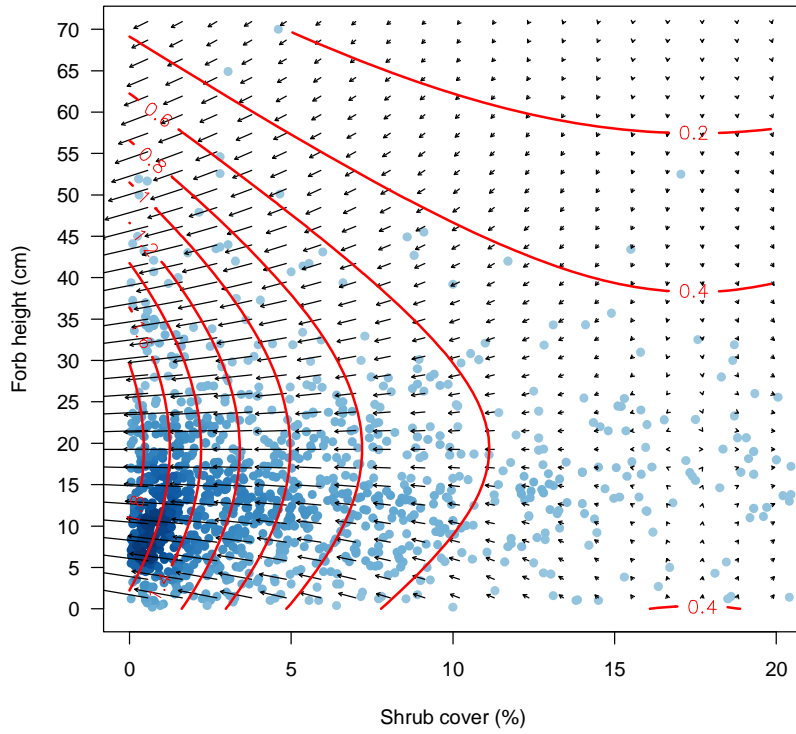


### All other bird species

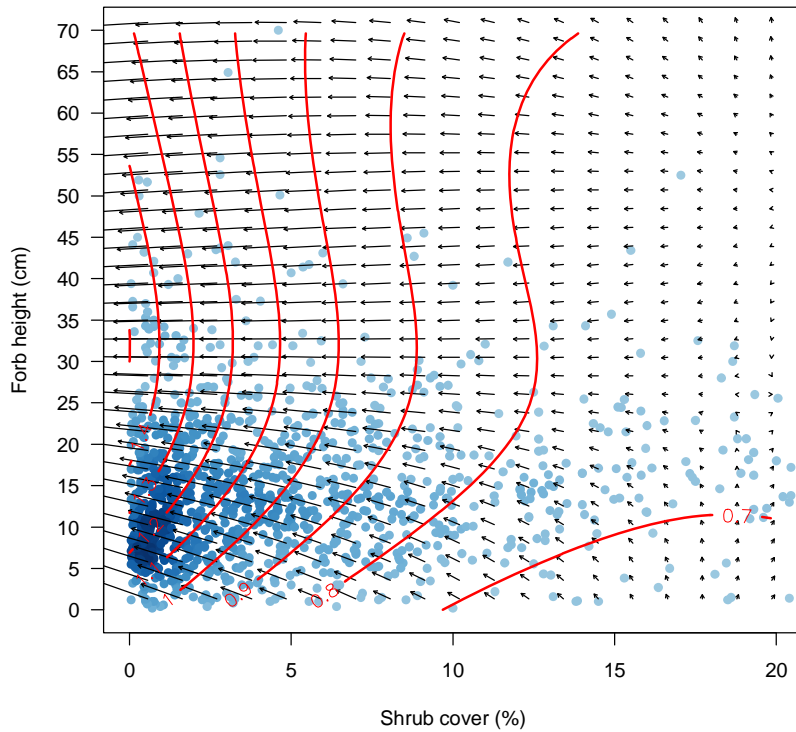


**Figure 14.** Effect of habitat management (shrub cover and shrub height) on Chestnut-collared Longspurs and the other four RGJV priority bird species in Chihuahuan Desert grasslands.

### Multiplicative effect on Chestnut-collared Longspur density



### All other bird species



**Figure 15.** Effect of habitat management (shrubs cover and forb height) on Chestnut-collared Longspurs and the other four RGJV priority bird species in Chihuahuan Desert grasslands.

## **Habitat management recommendations**

Results from the habitat analysis suggest that this grassland-endemic species is highly vulnerable to habitat loss by woody plant encroachment, a phenomenon currently prevalent in grasslands throughout the Chihuahuan Desert. Therefore, shrub-cover reduction by fire, mechanical, or chemical methods to  $\leq 5\%$  will likely restore suitable winter habitat for Chestnut-collared Longspurs. Further reductions of shrub cover will likely promote an even steeper increase in Chestnut-collared Longspur density. Grass and forb vegetation are also important components of the species' winter habitat and re-establishment and regeneration of this habitat component should be included as a part of shrub control programs. Our analyses show that habitat management to benefit Longspurs will benefit or not affect density levels for the other four RGJV priority species.

## Lark Bunting

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Lark Bunting is one of the few species endemic to the grasslands of North America (Shane 2000) whose current breeding distribution comprises the shortgrass and mixed-grass prairies and shrub-steppes of the Great Plains. This vast breeding range spans from the southern prairie provinces of Canada southwards to the Texas Panhandle and eastern New Mexico (Sauer et al. 2008). Lark Buntings winter from southwestern, central, and southern Arizona through southern and eastern New Mexico, the



Oklahoma and Texas Panhandles south to Rio Grande Valley, and west of the Brazos river (Shane 2000) in the US. In Mexico, Lark Buntings winter in Baja California, the coastal plains of Sonora and northern Sinaloa, the Mexican Plateau south to Guanajuato, and on the Atlantic slope of Tamaulipas (Howell and Webb 1995). The Lark Bunting is undergoing the steepest population decline in the grassland bird guild, a decline that ranks second (only after the Bank Swallow) among all birds recorded in the North American Breeding Bird Survey, with a 4.4% annual decline or 89% population decline from 1966 to 2010 (Sauer et al. 2011). Both the loss of breeding habitat (due to agriculture expansion and practices) and low fecundity (due to high predation and limited ability to double brood; Adams et al. 2007) in the Great Plains may contribute to the steep population declines. Other factors affecting survival on the wintering grounds may have not been evaluated but may also be important. The winter range of Lark Buntings includes a variety of ecosystems ranging from high-elevation desert grasslands to coastal shrublands in Sonora and Texas. The species is a habitat generalist on the winter grounds (Howell and Webb 1995, Macias-Duarte et al. 2009) and may be better adapted to cope with the destruction and deterioration of desert grasslands (Phillips et al. 1964, Macias-Duarte et al. 2009) on the wintering grounds. Further investigation may be required to assess winter survival in the variety of occupied habitats. This research provides an accounting of abundance and distribution, as well as habitat use, limited to the desert grasslands.

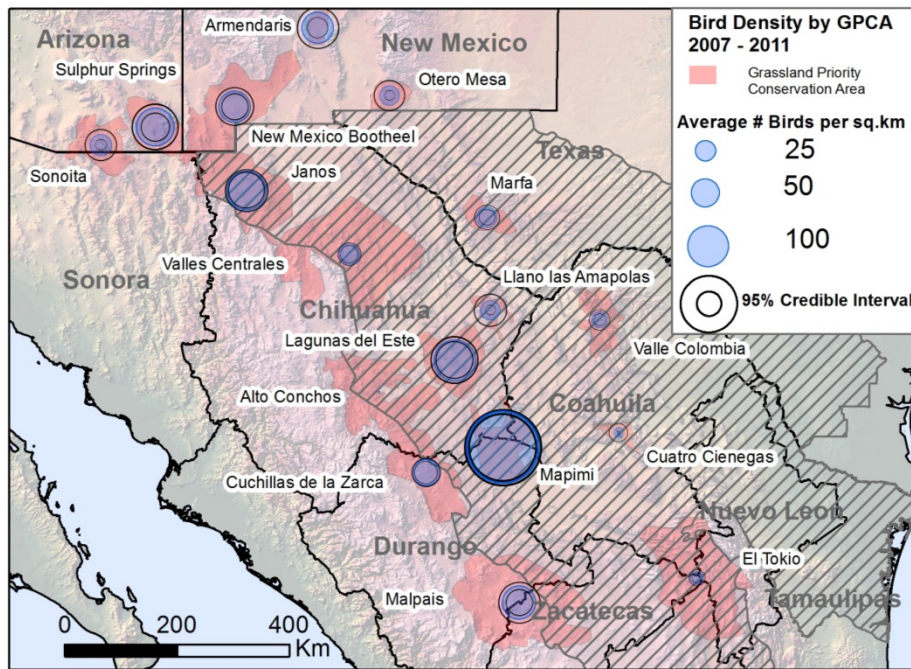
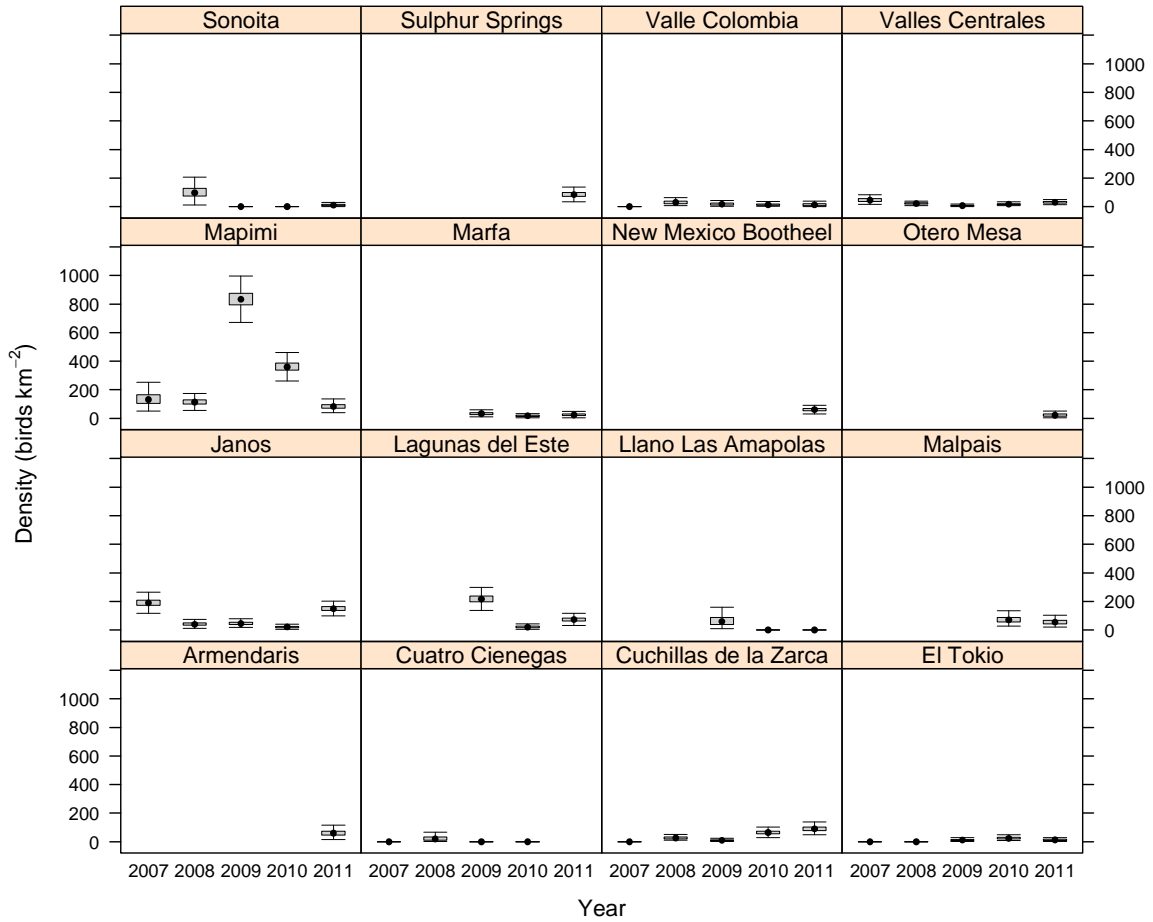
### **Abundance and distribution in the Chihuahuan Desert**

The Lark Bunting has a widespread distribution in the Chihuahuan Desert with varying mean densities among GPCAs but with two important discontinuities (Fig. 16). Lark Buntings reach their highest mean annual density at Mapimi, with 307.0 birds km<sup>-2</sup> (95% Credible Interval (CRI) 272.2-345.1 birds km<sup>-2</sup>), almost three times higher than the annual density found at the Lagunas del Este, which ranks second among GPCA in annual density. Lark Bunting densities reach their lowest density in the southeastern portion of the Chihuahuan Desert in the GPCAs of Cuatro Ciénegas (mean annual density 6.1 birds km<sup>-2</sup>) in central Coahuila, and El Tokio (mean annual

density 10.2 birds km<sup>-2</sup>). Lark Bunting density remains relatively high throughout the northwestern portion of the Chihuahuan Desert. Mapimi GPCA includes the smaller Mapimi biosphere reserve protected and managed by the Mexican federal government. This coincidence of active conservation management in the area of highest densities provides a valuable opportunity to enhance winter habitat for the species where the benefits may provide the best return in terms of birds. This reserve has a management advantage over most other GPCAs where there is less control over land management even though the majority of Mapimi grasslands are outside the reserve boundaries.

Temporal trends in annual Lark Bunting density throughout the Chihuahuan Desert grasslands are quite variable and obscured by the large annual variation in Mapimi. Lark Bunting density reached its recorded maximum in the winter of 2009 with 835.3 birds km<sup>-2</sup>, and then dropped by almost 10 times in 2011 (84.3 birds km<sup>-2</sup>, upper plot Fig. 16). Density also peaked at Lagunas del Este in 2009 with 218.4 birds km<sup>-2</sup>. Annual Lark Bunting densities fluctuate below 200 birds km<sup>-2</sup> in the rest of the GPCAs. In addition, the presence of Lark Buntings varies among GPCAs with relatively low density. Lark Buntings were not observed in 3 out of 4 (75%) winters at Cuatro Ciénegas, in 2 out of 4 (50%) winters at Sonoita, in 2 out of 5 (40%) winters at El Tokio, and in 1 out of 5 (20%) winters in Valle Colombia; Lark Buntings were present only in 2009 at Llano Las Amapolas when the species reached its peak annual densities in neighboring GPCAs Lagunas del Este and Mapimi.

## Lark Bunting



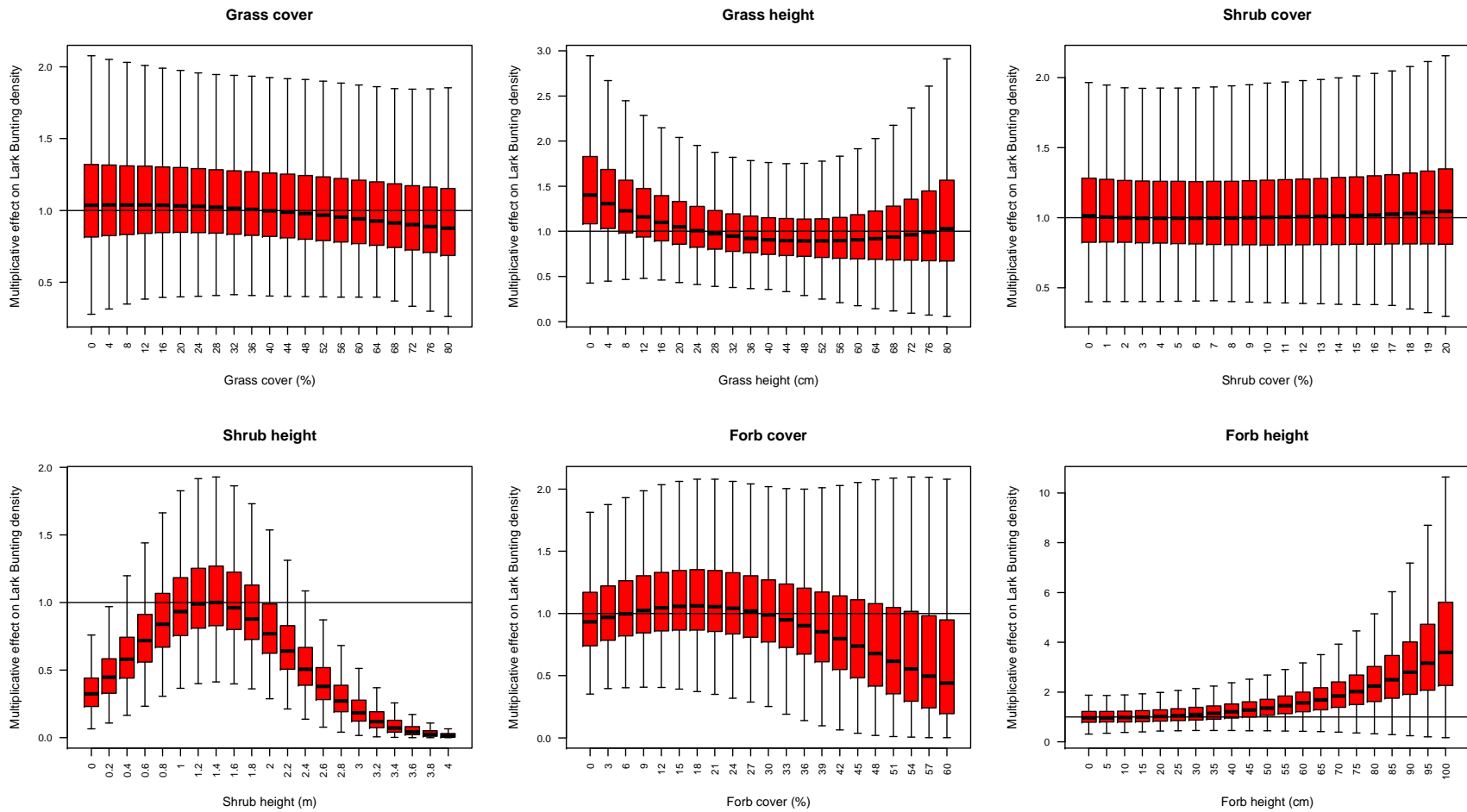
**Figure 16.** Abundance and distribution of Lark Buntings in GPCAs across the RGJV region demarcated by cross-hatching.

## Habitat relationships and habitat management

Lark Buntings are habitat generalists tolerating a broad range of conditions in grass, shrub, and forb vegetation (Fig. 17). Shrub height was the only significant vegetation parameter that affected the abundance of Lark Buntings within grasslands. Lark Bunting density had a unimodal response to shrub height, with the optimal shrub vegetation height at 1.4 m and bird density rapidly decreased for shrub vegetation <0.8 m and >2 m (Fig. 17). Grass vegetation did not show any effect on Lark Bunting density in any GPCA. Except for the response to shrub height, our results agree with those of Macias-Duarte et al. (2009) who found that the presence of Lark Buntings was not influenced by any habitat structure variable in desert grasslands based on two study areas in Valles Centrales.

**Table 4.** Posterior distribution of model coefficients for the effect of habitat structure variables on  $\log_e$  Density of Lark Bunting in Chihuahuan Desert grasslands. Boldface rows indicate variables whose 95% credible interval excludes zero.

Variable	$\beta$	SD( $\beta$ )	2.50%	25%	50%	75%	97.50%
Grass cover - 41.44	-0.0009	0.0016	-0.0041	-0.0020	-0.0009	0.0002	0.0020
(Grass cover - 41.44) <sup>2</sup>	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000
Shrub cover - 4.85	-0.0016	0.0155	-0.0312	-0.0122	-0.0016	0.0088	0.0293
(Shrub cover - 4.85) <sup>2</sup>	0.0003	0.0015	-0.0028	-0.0007	0.0004	0.0014	0.0032
Grass height - 25.44	-0.0050	0.0027	-0.0103	-0.0068	-0.0050	-0.0032	0.0003
(Grass height - 25.44) <sup>2</sup>	0.0001	0.0001	-0.0001	0.0000	0.0001	0.0001	0.0002
Shrub height - 1.22	0.0947	0.0725	-0.0442	0.0437	0.0952	0.1439	0.2385
<b>(Shrub height - 1.22)<sup>2</sup></b>	<b>-0.1990</b>	<b>0.0520</b>	<b>-0.3058</b>	<b>-0.2331</b>	<b>-0.1976</b>	<b>-0.1636</b>	<b>-0.1015</b>
Forb cover - 5.66	0.0136	0.0126	-0.0105	0.0049	0.0135	0.0220	0.0387
(Forb cover - 5.66) <sup>2</sup>	-0.0006	0.0007	-0.0020	-0.0011	-0.0006	-0.0002	0.0006
Forb height - 14.78	0.0027	0.0049	-0.0072	-0.0005	0.0027	0.0059	0.0125
(Forb height - 14.78) <sup>2</sup>	0.0001	0.0001	-0.0001	0.0000	0.0001	0.0001	0.0002



**Figure 17.** Multiplicative effect of habitat structure variables on baseline winter densities of Lark Buntings throughout Chihuahuan Desert grasslands.



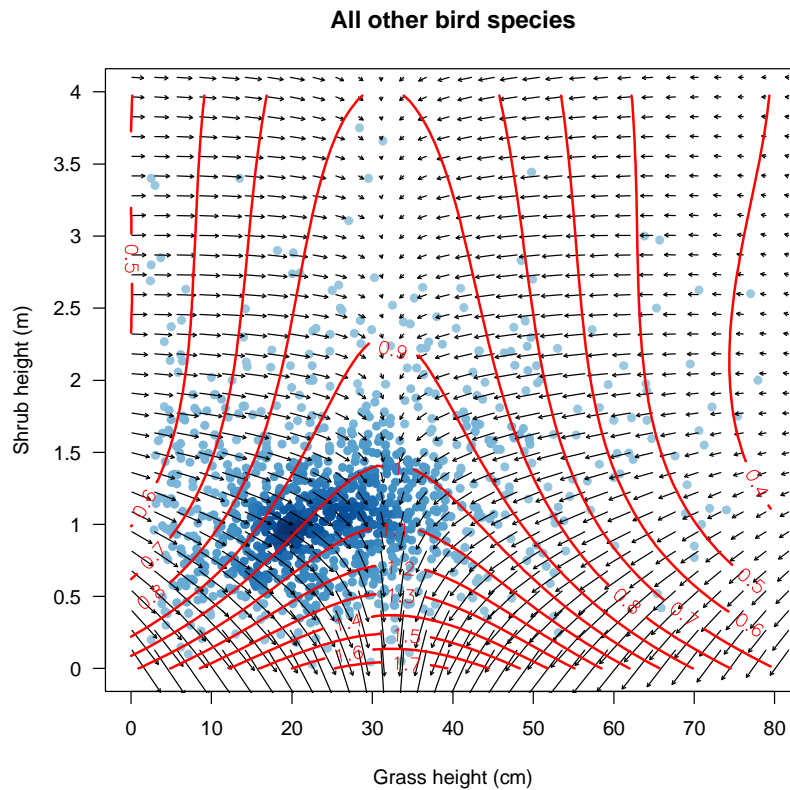
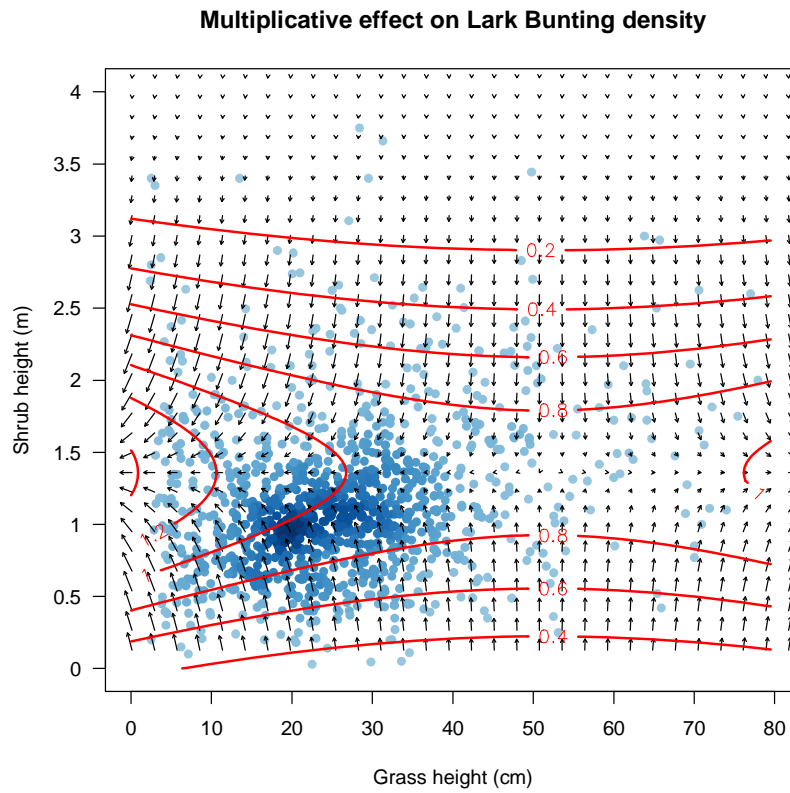
Plotting the joint effects of grass height and shrub height (Fig. 18) on Lark Bunting density, we observe that habitat management to benefit the species must focus on reducing grass height rather than shrub height for most grassland sites within GPCAs. Shrub height in most sites is near optimum levels (~1.4 m). For the other four RGJV priority species together, management for Lark Buntings is in the opposite direction of optimal change in habitat conditions needed to increase density levels with regard to grass height and shrub height. On average, the other four species require a reduction in shrub height and an increase in grass height in most sites within GPCAs.

## **Habitat management recommendations**

The hierarchical model for the Lark Bunting suggests that the species is a habitat generalist within grassland habitats in the Chihuahuan Desert, whose density levels in the region show no or little response to habitat structure. Since all our sampling locations met the condition of having <25% shrub cover, our results suggest that general sustainable range management practices will benefit the species during the winter, as well as promote the restoration of historical grasslands. Habitat management will be the most beneficial in Mapimi and Janos Biosphere Preserves, as well as in GPCA Lagunas del Este, where the species attains its highest density levels. Nevertheless, our hierarchical model suggests the existence of an optimal shrub height for the species on the wintering grounds. Most grasslands within GPCAs already have shrub height levels around the optimal value of 1.4 m (Figs. 4 and 18). Therefore, shrub removal programs for grassland restoration should consider retaining some sparse groups of tall woody plants, whose major function may be to provide perching sites for large flocks of Lark Buntings. Although this practice may affect the other four species (lower plot in Fig. 18), their negative effects on bird density are minor in general when shrub vegetation is near average levels (>1 m, lower plot of Fig. 18).



Lark Bunting habitat in Chihuahua, Mexico. (Photo: Arvind Panjabi)



**Figure 18.** Effect of habitat management (grass height and shrub height) on Lark Bunting density and other four RGJV priority bird species in Chihuahuan Desert grasslands.

## Loggerhead Shrike

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The Loggerhead Shrike inhabits open country with short vegetation and grasslands throughout North America, from the Great Plains of Canada through most of the United States, except the northeast and northwest regions, heavily forested areas, higher mountains, and higher elevation deserts (Yosef 1996). Loggerhead Shrikes also inhabit most of Mexico, except the southern Pacific coastal plains, the Atlantic Slope (where the species winters), and east of the Isthmus of Tehuantepec (Howell and Webb 1995).

The Loggerhead Shrike is resident throughout most of the southern part of its range, while northern populations are migratory. In spite of its widespread distribution across North America, Loggerhead Shrike populations throughout the continent have declined at an annual rate of 3.2% or 77% of the total population from 1966 to 2010 (Sauer et al. 2011). Changes in land use, pesticides, and competition with species more tolerant of human-induced changes appear to be major factors contributing to the population declines throughout North America, but determining their ultimate causation remains a research priority (Yosef 1996). The Chihuahuan Desert harbors both year-round resident and migratory populations, with an estimated 28% of migrants in the western part, and up to 73% of migrants east to the Sierra Madre Oriental (Perez and Hobson 2009). The contribution of habitat destruction and deterioration on the population trend is therefore less evident than for the other species covered by this plan, which have more restricted winter ranges within the Chihuahuan Desert. Still, the patterns of abundance, distribution, and habitat use of the Loggerhead Shrike through the grassland portions of the Chihuahuan Desert are documented in this section to provide a better assessment of the status of the species' population in Mexico where little information about the species exists.



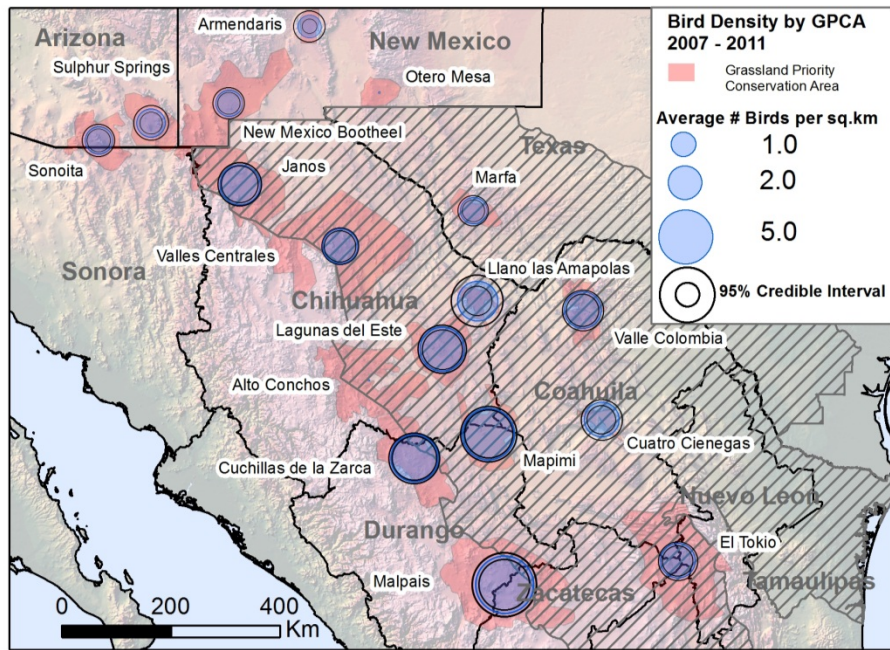
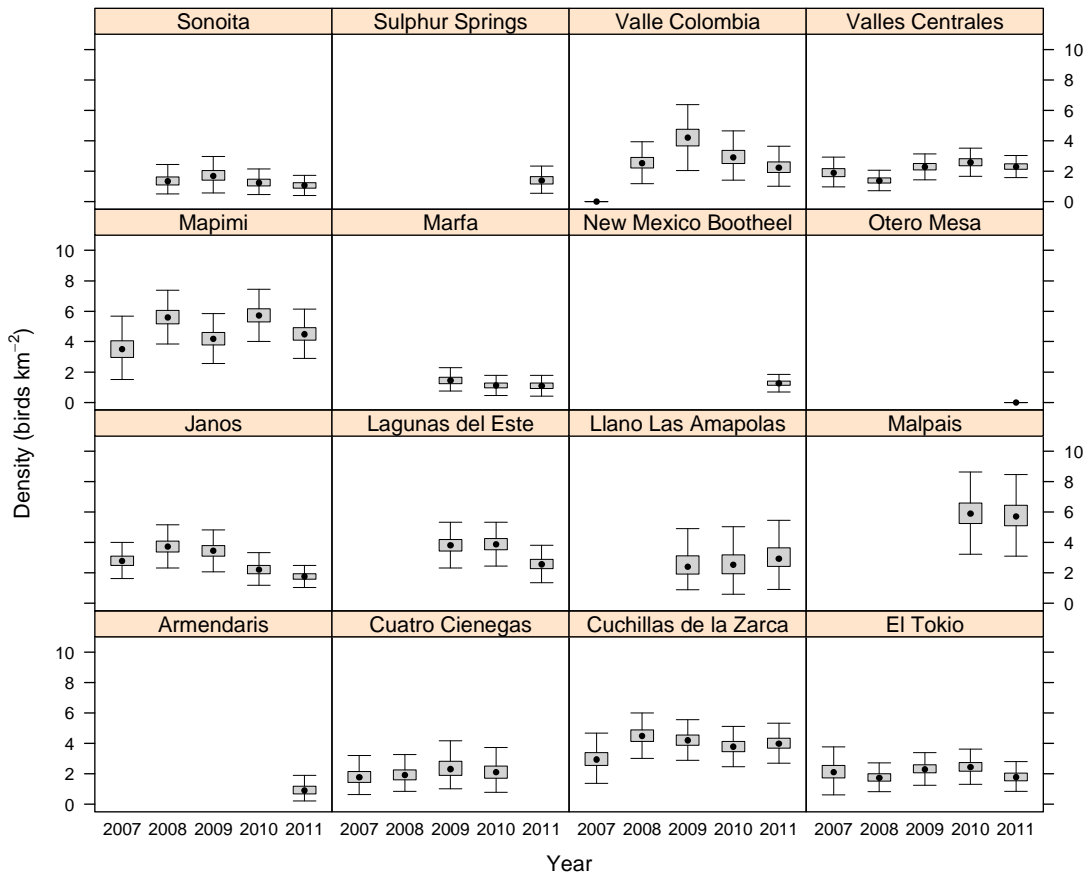
### **Abundance and distribution in the Chihuahuan Desert**

Loggerhead Shrikes have the most widespread and uniform distribution during the winter in Chihuahuan Desert grasslands among any of the species covered by this plan (between-GPCA CV = 67%, Fig. 19). Still, the Loggerhead Shrike tends to be more abundant in GPCAs in the western Chihuahuan Desert towards the Sierra Madre Occidental (Fig. 19), including Janos, Cuchillas de la Zarca, and Malpais. Loggerhead Shrikes reach their highest mean annual density at Malpais in the southern Sierra Madre foothills, with 5.9 birds km<sup>-2</sup> (95% CRI 4.5-7.4 birds km<sup>-2</sup>), followed by Mapimi, in the lower plains, with 4.7 birds km<sup>-2</sup> (95% CRI 4.1-5.4 birds km<sup>-2</sup>). Loggerhead Shrikes were not recorded in Otero Mesa in 2011 (the only year this GPCA was surveyed), or in Valle Colombia in 2007.

Temporal trends in Loggerhead Shrike abundance are remarkably uniform through the Chihuahuan Desert (Fig. 19, upper plot). Inter-annual variation in Loggerhead Shrike density within GPCAs is the lowest among the species covered by this plan, and winter population numbers remain quite constant among years. The coefficient of variation in annual Loggerhead Shrike density reaches its maximum in Valle Colombia with 12.4%, and its minimum in El Tokio with only 11.8%.

The spatio-temporal patterns in abundance and distribution found in this study have revealed winter population dynamics for the Loggerhead Shrike that are unique among the species covered by this plan. The Loggerhead Shrike is the only predatory species and the largest species among the five covered herein. This correspondence between winter population dynamics and intrinsic species' traits strongly suggest the need to account for the species' natural history in any demographic modeling attempt to explain the patterns of abundance and distribution in other migratory birds on the wintering grounds.

### Loggerhead Shrike



**Figure 19.** Abundance and distribution of Loggerhead Shrike in GPCAs across the RGJV region demarcated by cross-hatching.

## Habitat relationships and habitat management

Abundance of Loggerhead Shrike during the winter was weakly influenced by habitat structure in both grass and shrub vegetation (Fig. 20). Grass cover, shrub cover, and shrub height had a small but significant effect on Loggerhead Shrike density. Abundance of shrikes increased with shrub height, but slightly decreased with grass cover and shrub cover. Our results confirm and further extend the inference to the entire Chihuahuan Desert the preference of Loggerhead Shrikes for grasslands with sparse grasses and tall woody vegetation found by Macias-Duarte et al. (2004) in Valles Centrales. Forb cover had a marginal effect on shrike abundance, with a negative response for forb vegetation >12 cm.

**Table 5.** Posterior distribution of model coefficients for the effect of habitat structure variables on  $\log_e$  Density of Loggerhead Shrike in Chihuahuan Desert grasslands. Boldface rows indicate variables whose 95% credible interval excludes zero.

Variable	$\beta$	SD( $\beta$ )	2.50%	25%	50%	75%	97.50%
Grass cover - 41.44	-0.00086	0.00116	-0.00316	-0.00165	-0.00086	-0.00007	0.00141
<b>(Grass cover - 41.44)<sup>2</sup></b>	<b>0.00004</b>	<b>0.00002</b>	<b>0.00000</b>	<b>0.00003</b>	<b>0.00004</b>	<b>0.00005</b>	<b>0.00008</b>
<b>Shrub cover - 4.85</b>	<b>-0.02655</b>	<b>0.01174</b>	<b>-0.04955</b>	<b>-0.03445</b>	<b>-0.02639</b>	<b>-0.01865</b>	<b>-0.00365</b>
(Shrub cover - 4.85) <sup>2</sup>	0.00162	0.00097	-0.00034	0.00098	0.00163	0.00227	0.00346
Grass height - 25.44	0.00000	0.00208	-0.00409	-0.00140	0.00001	0.00142	0.00403
(Grass height - 25.44) <sup>2</sup>	0.00000	0.00004	-0.00009	-0.00003	0.00000	0.00003	0.00008
<b>Shrub height - 1.22</b>	<b>0.14973</b>	<b>0.04368</b>	<b>0.06491</b>	<b>0.12033</b>	<b>0.14934</b>	<b>0.17902</b>	<b>0.23615</b>
(Shrub height - 1.22) <sup>2</sup>	-0.01304	0.00735	-0.02849	-0.01772	-0.01270	-0.00793	0.00019
Forb cover - 5.66	0.00878	0.01128	-0.01323	0.00111	0.00871	0.01636	0.03065
(Forb cover - 5.66) <sup>2</sup>	-0.00096	0.00061	-0.00224	-0.00136	-0.00093	-0.00054	0.00012
Forb height - 14.78	-0.00454	0.00401	-0.01210	-0.00733	-0.00465	-0.00186	0.00359
(Forb height - 14.78) <sup>2</sup>	0.00002	0.00009	-0.00016	-0.00004	0.00003	0.00009	0.00020

Visualization of the joint effects of grass cover and shrub cover on Loggerhead Shrike density (Fig. 21) suggests that habitat management for the Loggerhead Shrike in Chihuahuan Desert grasslands requires reducing shrub cover in both areas with low grass cover (<30%) and high grass cover (>60%, lower plot in Fig. 22). Vegetation management to improve habitat for Loggerhead Shrikes is in the opposite direction of that required to improve the habitat for the other species covered by this plan in grasslands with grass cover < 60%. For shrub cover and shrub height, the majority of the grasslands with shrub cover > 5% have mean shrub height at suboptimal levels (below the isoline = 1.0, upper plot in Fig. 22). Therefore, habitat management

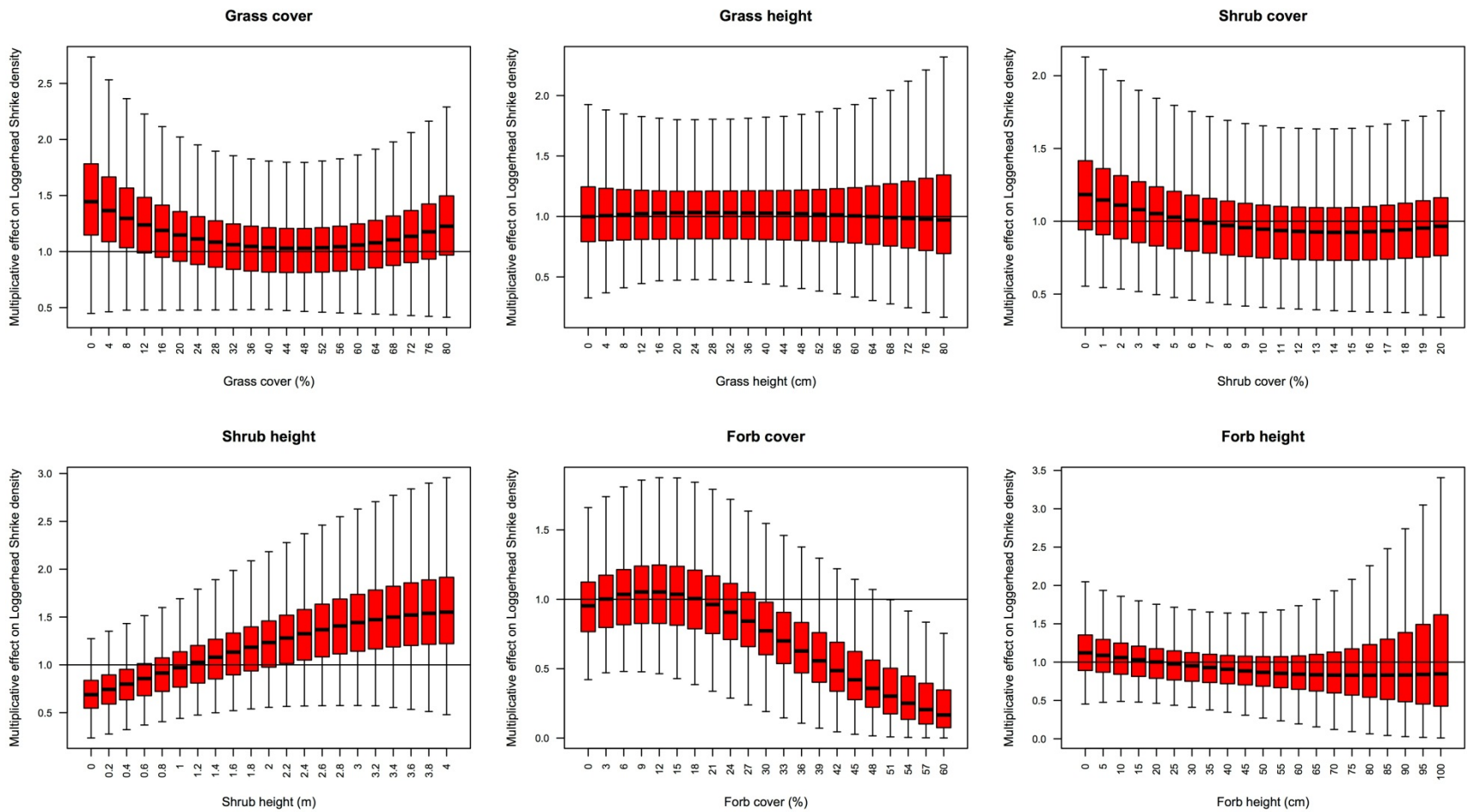
should focus on both reducing shrub cover and increasing mean height of woody vegetation elements. Again, habitat enhancement for the other four species requires the reduction of tall shrubs but supports the reduction of shrub cover.

## **Management recommendations**

The Loggerhead Shrike is a unique bird in its natural history compared to the other species covered herein. Hence, habitat management to improve conditions for Loggerhead Shrikes is usually contradictory to that for the other four species. As in the case of the Lark Bunting, tall woody plants are a key vegetation component for the Loggerhead Shrike's winter habitat. Shrub removal programs for grassland restoration must therefore consider retaining sparse groups of tall woody plants (>2 m high), whose major function may be to provide perching sites for hunting prey. Management of grass and forb vegetation, as well as the reduction of shrub cover, must be focused on the habitat requirements for the other four species, with only mild negative effects for shrikes.

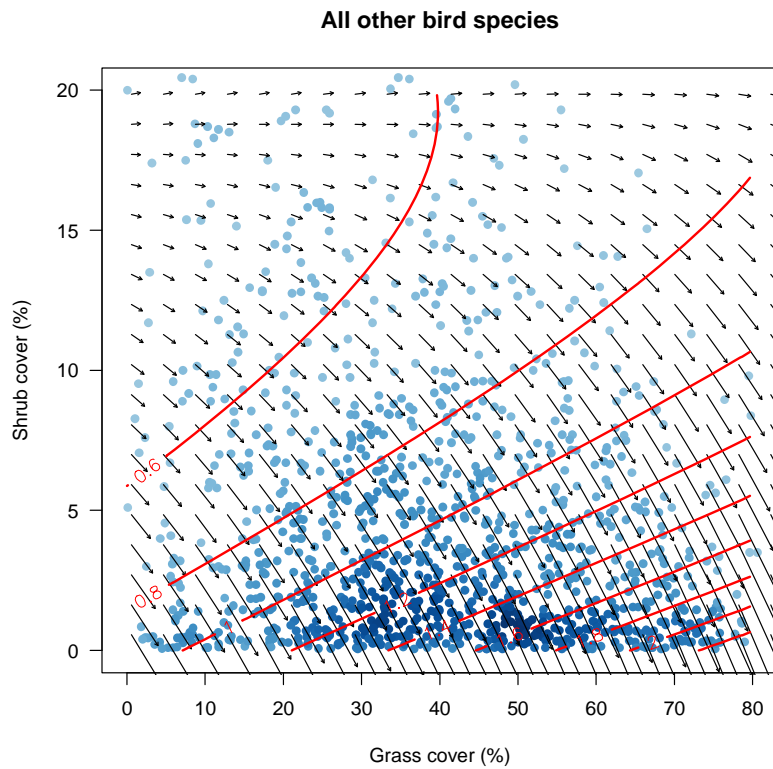
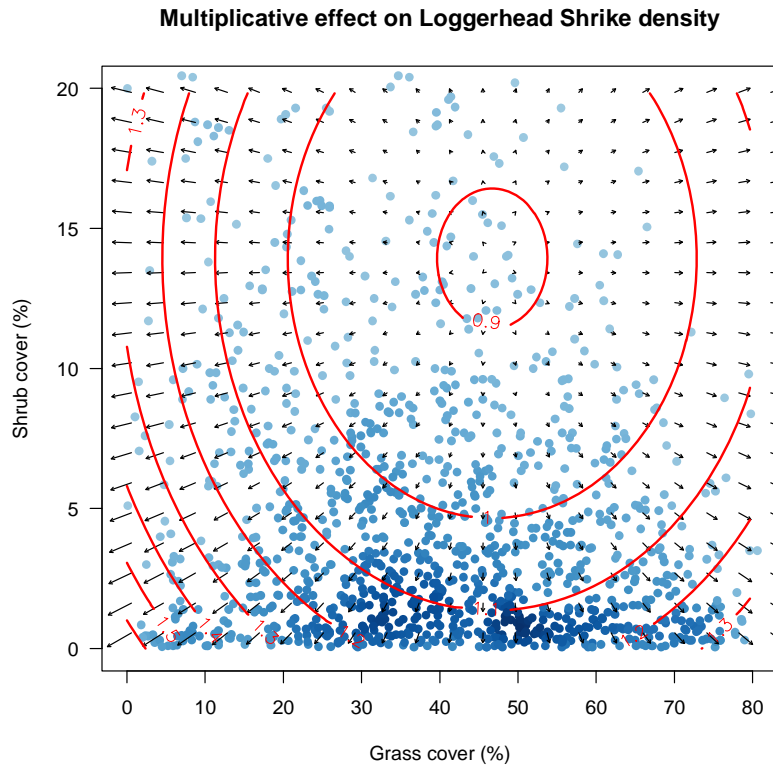


Loggerhead Shrike habitat in Chihuahua, Mexico.(Photo: Greg Levandoski)

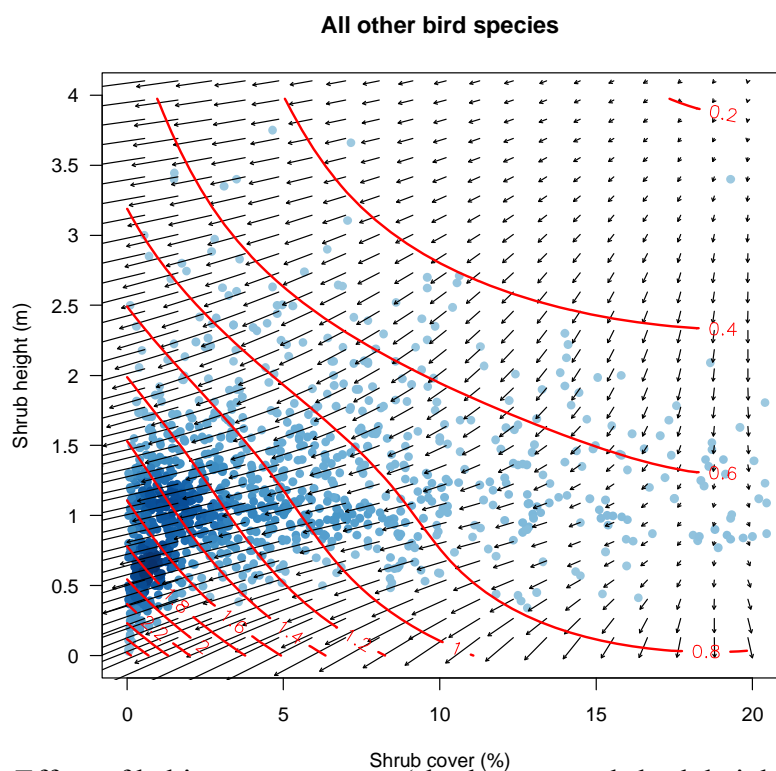
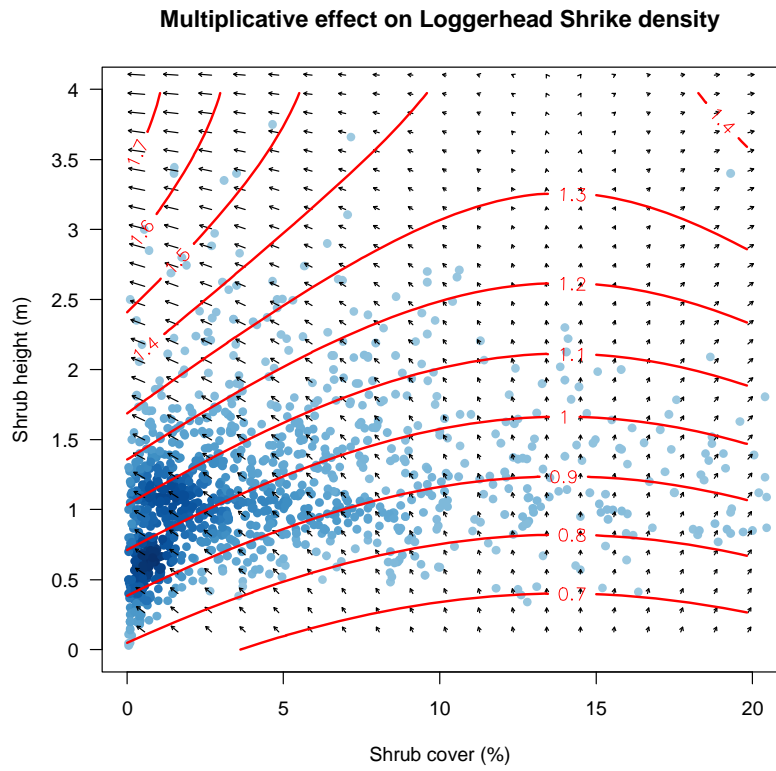


**Figure 20.** Multiplicative effect of habitat structure variables on baseline winter densities of Loggerhead Shrike throughout Chihuahuan Desert grasslands.





**Figure 21.** Effect of habitat management (grass height and shrub cover) for Loggerhead Shrike density and its effect on the other four RGJV priority bird species in Chihuahuan Desert grasslands.



**Figure 22.** Effect of habitat management (shrub cover and shrub height) for Loggerhead Shrike density and the other four RGJV priority bird species in Chihuahuan Desert grasslands.

## Sprague's Pipit

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Sprague's Pipit breeding distribution is limited to the native prairies of the northern Great Plains, including southeastern Alberta, southern Saskatchewan, and southwestern Manitoba, most of North Dakota, the northern edge of South Dakota, and the Great Plains in Montana (Robbins and Dale 1999). The species' winter distribution is more widespread than that of the Baird's Sparrow, extending from south-central and southeastern Arizona, the southern edge of New Mexico, Texas, southern Oklahoma, southern Arkansas, northwestern Mississippi, and southern Louisiana south into the Mexican Plateau down to the Trans-Mexican Volcanic Belt (Howell and Webb 1995).



Sprague's Pipit is undergoing, as are many members of the grassland bird guild, persistent population declines on the breeding grounds, reaching a 2.4% annual decline, or a 66% total BBS population decline from 1966 to 2010 (Sauer et al. 2011). Sprague's Pipits are particularly susceptible to habitat alteration due to overgrazing and invasion by exotic plants, and habitat deterioration and destruction of Great Plains prairies may be related to the documented breeding population declines. In addition, Sprague's Pipit is a grassland specialist on the wintering grounds where the species inhabits grasslands with high grass cover and low shrub cover (Macias-Duarte et al. 2009). Desert grasslands in northern Mexico are undergoing desertification, largely as a consequence of overgrazing, and are being reduced by shrub encroachment and conversion of grasslands to farmland. Therefore, protection and restoration of winter habitat may currently be the best option available to reverse the documented population declines. This account provides the best and most extensive information available on the distribution of Sprague's Pipits in the Chihuahuan Desert and provides information to guide actions and prioritize areas that will have the highest impact for conservation of the species.

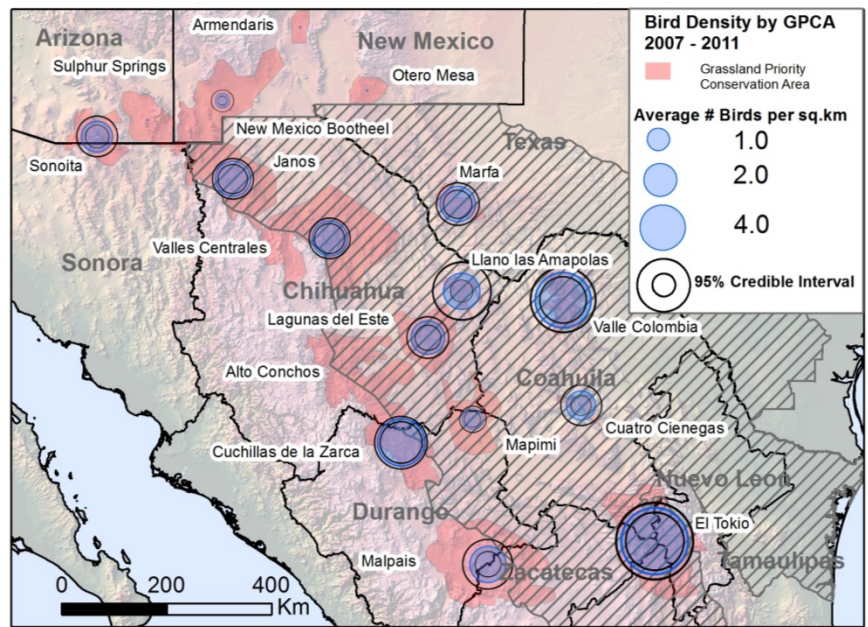
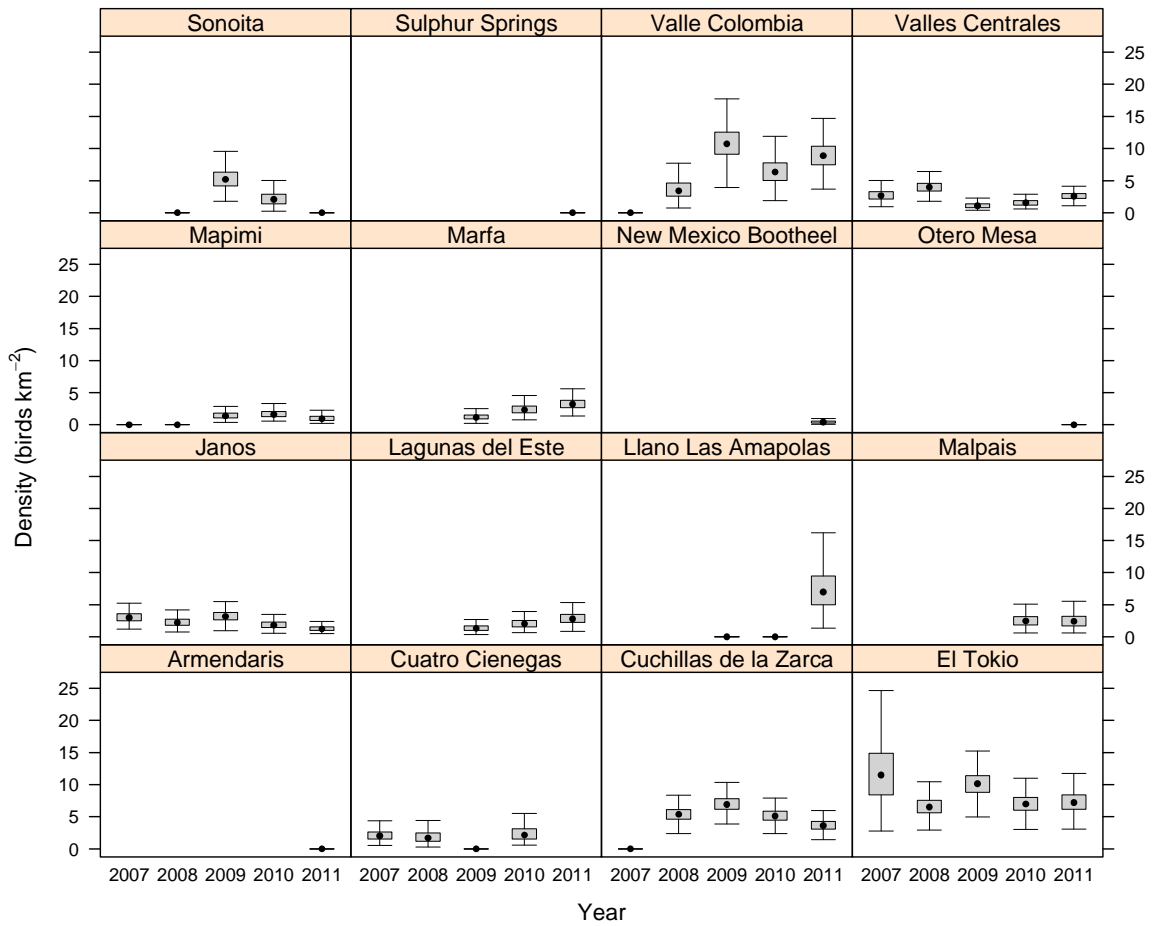
### **Abundance and distribution in the Chihuahuan Desert**

Sprague's Pipit is widely distributed in the Chihuahuan Desert with a relatively uniform distribution, with a between-GPCA CV in density of 97% (Fig. 23). Nevertheless, it tends to occur in higher density in the southeastern portion of the Chihuahuan Desert. Grassland Priority Conservation Areas with the highest Sprague's Pipit density levels are El Tokio (8.6 birds km<sup>-2</sup>, 95% CRI 6.3-11.3 birds km<sup>-2</sup>), Valle Colombia (6.0 birds km<sup>-2</sup>, 95% CRI 4.2-8.1 birds km<sup>-2</sup>), and Cuchillas de la Zarca (4.3 birds km<sup>-2</sup>, 95% CRI 3.4-5.3 birds km<sup>-2</sup>); this region of higher Sprague's Pipit density is fragmented by lower densities in Cuatro Cienegas, Mapimi, and Malpais. The species is particularly scarce in the northern Chihuahuan Desert. Sprague's Pipit occurred at its lowest density in New Mexico

Bootheel ( $0.4 \text{ birds km}^{-2}$ , 95% CRI  $0.2\text{-}1.0 \text{ birds km}^{-2}$ ) and was not sighted in our surveys during 2011 in Armendaris, Otero Mesa, and Sulphur Springs. Llano Las Amapolas could potentially be an important wintering area for the species, with annual density as high as  $19.0 \text{ birds km}^{-2}$ , but the low number of transects provide lower precision estimates of annual density.

Annual variation in Sprague's Pipit density within GPCAs, similar to those of Loggerhead Shrike, is relatively low compared to the sparrow species, with no noticeable trend for any GPCA, except for a minor increasing trend in Lagunas del Este, Marfa, and Valle Colombia (upper plot in Fig. 23). The highest winter density recorded was in El Tokio in 2007, with  $12.0 \text{ birds km}^{-2}$  (95% CRI  $4.5\text{-}22.3 \text{ km}^{-2}$ ). Sprague's Pipit density was also relatively high in Llano Las Amapolas in 2011 with  $7.8 \text{ birds km}^{-2}$  (95% CRI  $2.9\text{-}19.0 \text{ birds km}^{-2}$ ). Besides Valle Colombia and El Tokio, annual Sprague's Pipit density within GPCAs fluctuates at levels below  $10 \text{ birds km}^{-2}$ . Presence of Sprague's Pipit also varies among GPCAs. It was not recorded in Sonoita in 2008 and 2011, in Janos in 2007 and 2008, in Llano Las Amapolas in 2009 and 2010, or in Cuchillas de la Zarca in 2007.

### Sprague's Pipit



**Figure 23.** Abundance and distribution of Sprague’s Pipit in GPCAs across the RGJV region demarcated by cross-hatching.

## Habitat relationships and habitat management

The response of the Sprague's Pipit's abundance to habitat structure is remarkably similar to that of the Baird's Sparrow (Figs. 8 and 24). Sprague's Pipit inhabits open grasslands on both the breeding grounds and the wintering grounds (Macias-Duarte et al. 2009).

Sprague's Pipit winter density shows a strong response to most habitat structure variables (Table 6). Density of Sprague's Pipit is positively related to grass cover and negatively related to shrub cover throughout the Chihuahuan Desert (Fig. 24). Sprague's Pipits are also sensitive to vertical obstruction from grass and herbaceous vegetation. Sprague's Pipit density reaches its peak in grasslands around 28 cm high; either low or high grass vegetation has a strong negative effect on the species' density (Fig. 24). Forb height also has an effect on pipit density, with an optimal density at around 20 cm high. Shrub height shows no effect on the species' abundance. Forb height shows an extremely large effect at forb cover >40%, but with extremely low precision. Our findings confirm and extend to the entire Chihuahuan Desert similar responses of Sprague's Pipit abundance to habitat structure variables inferred by Macias-Duarte et al. (2009) in the Valles Centrales, where the species' presence was also positively related to grass cover and negatively related to shrub density and grass height.

Most grasslands in the Chihuahuan Desert under current range management are below optimal conditions for Sprague's Pipit for grass cover (Fig. 25), where optimal conditions are reached at 80% grass cover. However, average grass height across the Chihuahuan Desert is near the optimum level of 28 cm. Still, a large proportion of grasslands (those with grass cover >40%) could achieve the highest increases of Sprague's Pipit abundance by increasing grass cover. Therefore, habitat management for Sprague's Pipit should focus on grasslands with those characteristics within GPCAs. Sprague's Pipit would also benefit from the grazing of grasslands with >40% grass cover to promote the existence of shorter but denser grasses. The response of the other four species in this plan to habitat management directed towards the enhancement of Sprague's Pipit density is positive (Fig. 25)—the other species also benefit from increases in grass cover and intermediate values of grass height.

Visualizing the joint effects of grass cover and shrub cover, it becomes evident that these variables are equally important across their ranges of variation to enhance habitat for Sprague's Pipit (Fig. 26). The greatest increase in pipit density will be achieved by decreasing shrub cover and increasing grass cover in grasslands with shrub cover <5% and grass cover >40%. Again, improvement of the best-managed grasslands will produce the greatest benefit. This habitat management is also favorable for the other species covered in this plan, although the species will benefit more from shrub control than from increases in grass cover.

Under current range management, grass and forb heights in most grasslands of the Chihuahuan Desert are close to optimal for Sprague's Pipit density levels (Fig. 27). Optimal grass height and forb height for the species are around 28 and 20 cm, respectively, with most sites having habitat distributed around those levels. Since both grass height and forb height are correlated throughout the Chihuahuan Desert (Fig. 6), promoting the

presence of medium standing grass in some pastures will likely enhance its effect on Sprague’s Pipit density by also promoting the presence of forbs. Habitat management manipulating both grass height and forb height focused on the Sprague’s Pipit has slightly detrimental effects on the other species covered in this plan, since their joint optimum levels are above those of the Sprague’s Pipit.

## Habitat management recommendations

Results from our hierarchical model for the Sprague’s Pipit suggest that management for habitat improvement must focus on increasing the regeneration of the grasses in grasslands that are near average condition (~40%), if the goal is to provide quality habitat in the short term. The gains in Sprague’s Pipit abundance associated with restored and improved habitat in degraded grasslands could be low. However, the effectiveness of treatments (such as resting, reseeding, soil erosion control, etc.) will likely to be more evident in degraded lands in the long term than in preserved grasslands and must be considered as a long-term alternative for pipit conservation. In addition, we recommend that potential Sprague’s Pipit habitat be moderately or intensively grazed and allow for standing grass vegetation around 20 cm. Shrub control for pipit habitat should focus on restoring grasslands from shrublands (>5% shrub cover), rather than performing shrub removal in areas already occupied by pipits in the winter. Habitat management for Sprague’s Pipit will likely benefit numerous species (including the other species covered in this plan), especially the Baird’s Sparrow.

**Table 6.** Posterior distribution of model coefficients for the effect of habitat structure variables on  $\log_e$  Density of Sprague’s Pipit in Chihuahuan Desert grasslands. Boldface rows indicate variables whose 95% credible interval excludes zero.

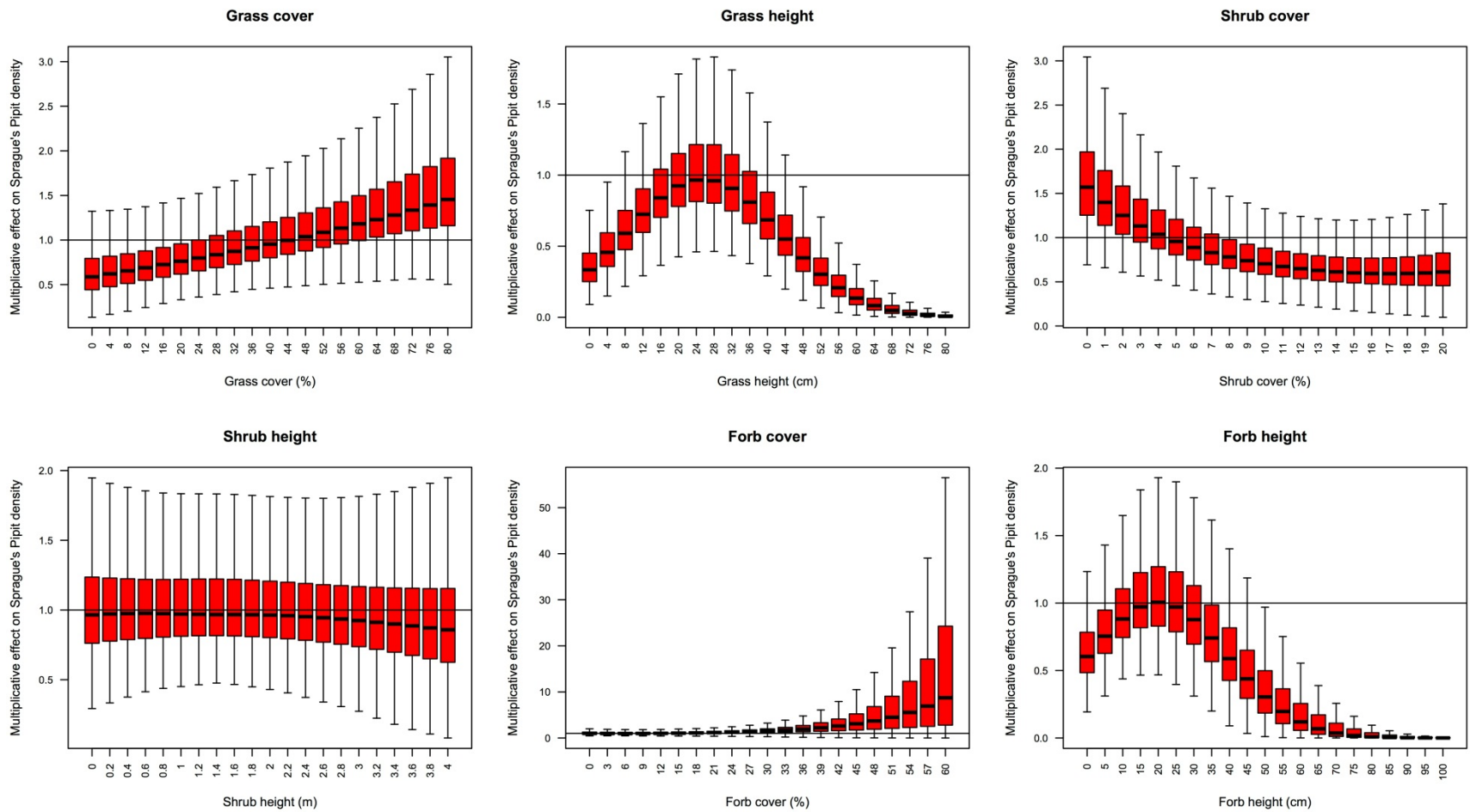
Variable	$\beta$	SD( $\beta$ )	2.50%	25%	50%	75%	97.50%
<b>Grass cover - 41.44</b>	<b>0.0115</b>	<b>0.0047</b>	<b>0.0022</b>	<b>0.0084</b>	<b>0.0116</b>	<b>0.0147</b>	<b>0.0207</b>
(Grass cover - 41.44) <sup>2</sup>	0.0000	0.0001	-0.0003	-0.0001	0.0000	0.0001	0.0003
<b>Shrub cover - 4.85</b>	<b>-0.0794</b>	<b>0.0210</b>	<b>-0.1210</b>	<b>-0.0938</b>	<b>-0.0786</b>	<b>-0.0653</b>	<b>-0.0389</b>
(Shrub cover - 4.85) <sup>2</sup>	0.0031	0.0020	-0.0011	0.0019	0.0032	0.0045	0.0066
Grass height - 25.44	-0.0001	0.0079	-0.0160	-0.0054	0.0001	0.0055	0.0148
<b>(Grass height - 25.44)<sup>2</sup></b>	<b>-0.0017</b>	<b>0.0004</b>	<b>-0.0025</b>	<b>-0.0020</b>	<b>-0.0017</b>	<b>-0.0014</b>	<b>-0.0009</b>
Shrub height - 1.22	-0.0039	0.1233	-0.2478	-0.0877	-0.0039	0.0823	0.2319
(Shrub height - 1.22) <sup>2</sup>	-0.0207	0.0489	-0.1330	-0.0489	-0.0146	0.0139	0.0577
Forb cover - 5.66	0.0004	0.0167	-0.0325	-0.0110	0.0001	0.0120	0.0327
(Forb cover - 5.66) <sup>2</sup>	0.0007	0.0007	-0.0008	0.0002	0.0007	0.0012	0.0019
Forb height - 14.78	0.0127	0.0100	-0.0071	0.0059	0.0128	0.0195	0.0318

Variable	$\beta$	SD( $\beta$ )	2.50%	25%	50%	75%	97.50%
<b>(Forb height - 14.78)<sup>2</sup></b>	<b>-0.0013</b>	<b>0.0006</b>	<b>-0.0025</b>	<b>-0.0017</b>	<b>-0.0013</b>	<b>-0.0009</b>	<b>-0.0003</b>

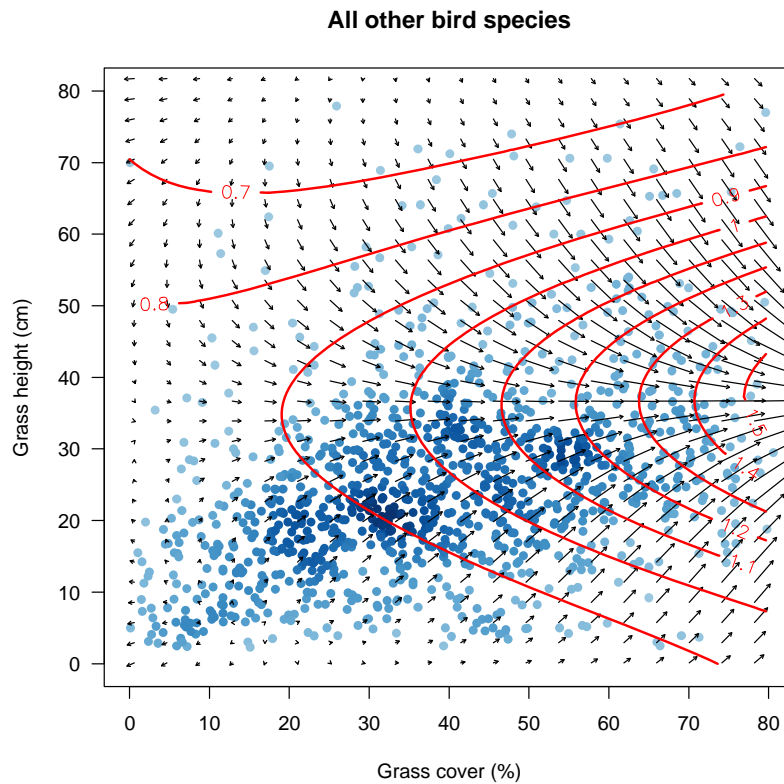
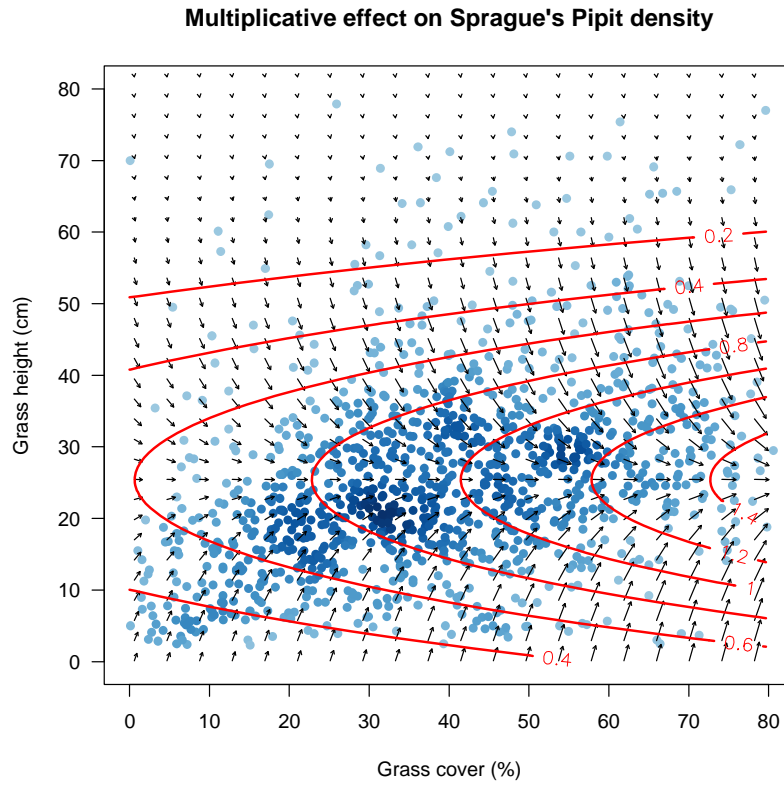


Sprague's Pipit habitat in Chihuahua, Mexico.(Photo: Alberto Macias-Duarte)

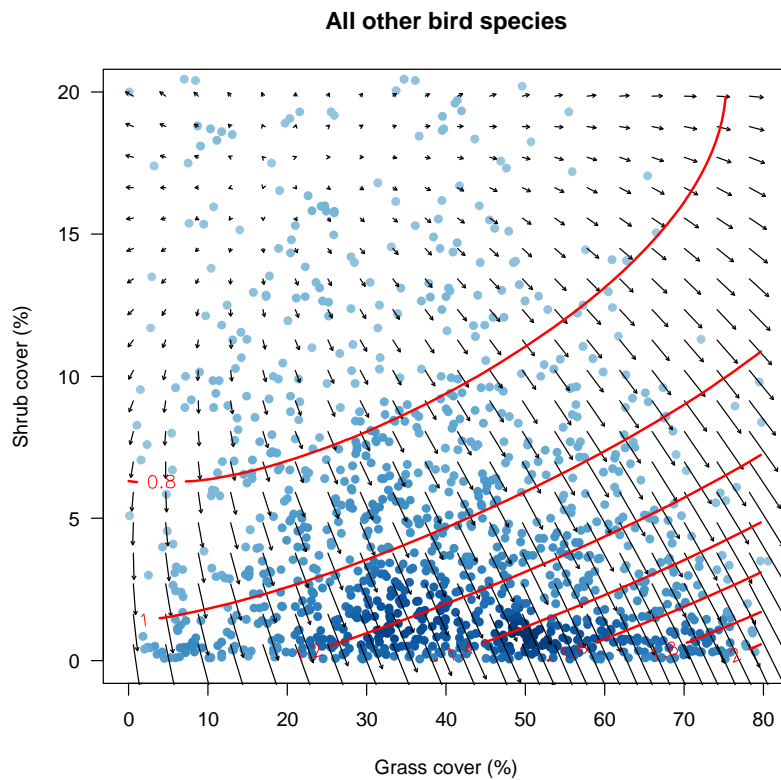
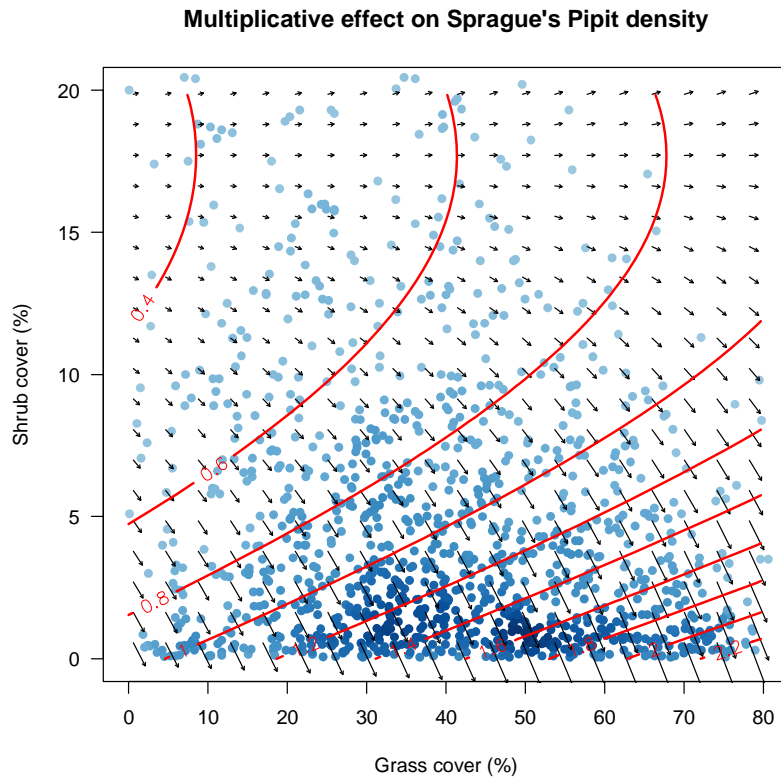




**Figure 24.** Multiplicative effect of habitat structure variables on baseline winter densities of Sprague's Pipit throughout Chihuahuan Desert grasslands.

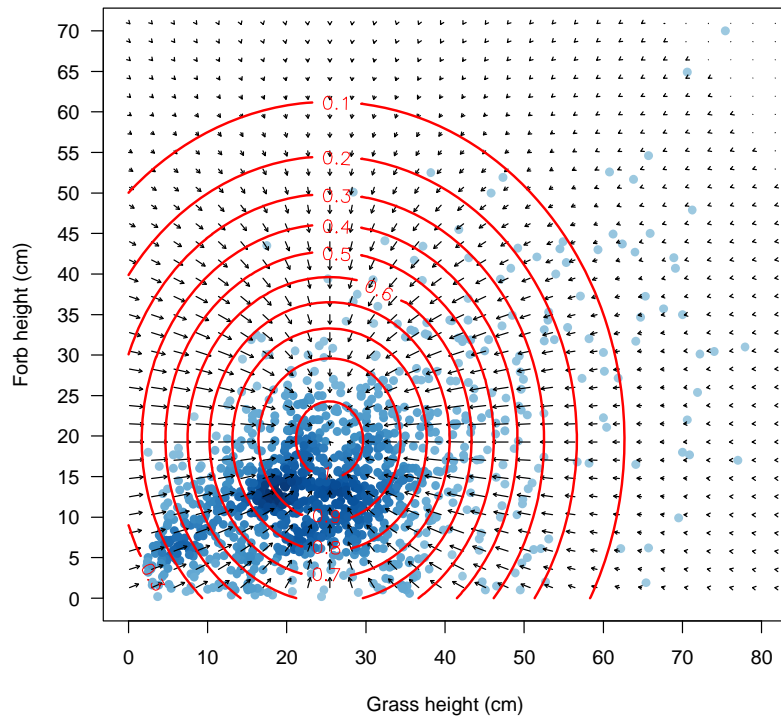


**Figure 25.** Effect of habitat management (grass cover and grass height) for Sprague's Pipit density and the other Chihuahuan Desert grassland species covered by this plan.

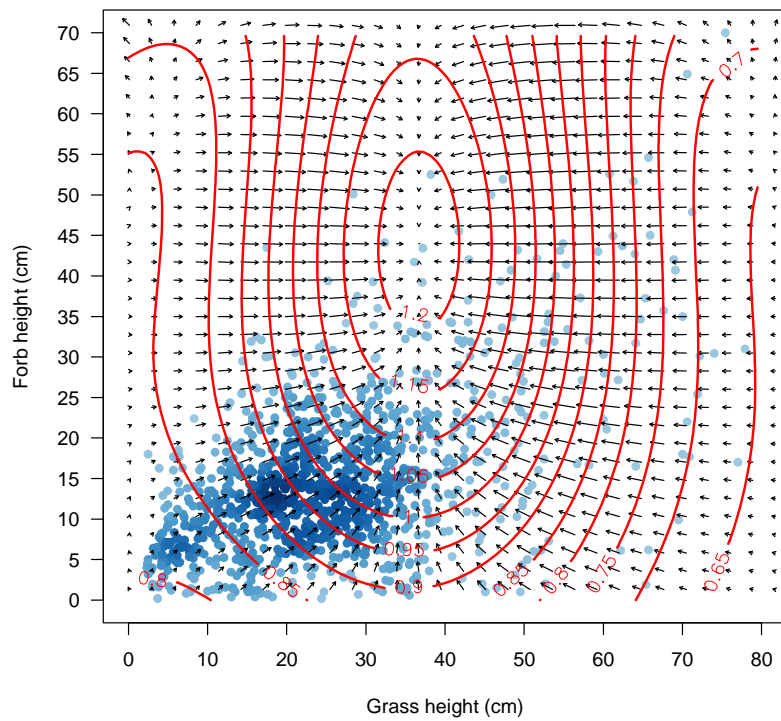


**Figure 26.** Effect of habitat management (grass cover and shrub cover) for Sprague's Pipit density and the other species covered in this plan.

### Multiplicative effect on Sprague's Pipit density



### All other bird species



**Figure 27.** Effect of habitat management (grass height and forb height) for Sprague's Pipit density and the other species covered in this plan.

## Abundance and Capacity Estimates at Grassland Priority Conservation Areas

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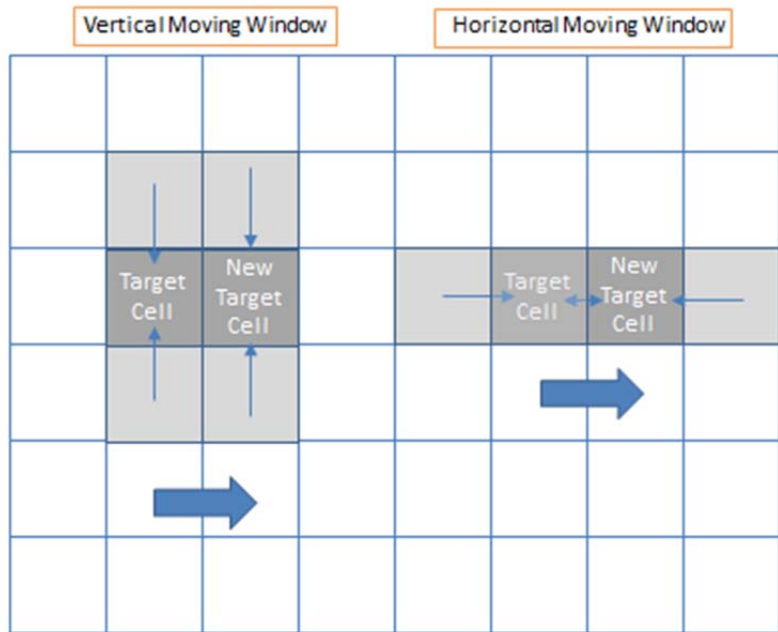
We describe potential annual grassland bird capacity at each GPCA. These GPCA accounts allow a quick assessment of the relative potential of each GPCA in the conservation of each grassland bird species. We calculated winter population capacity with two levels of complexity: using the species' mean posterior density parameters at the pixel level for GPCAs and using gross density and grassland area (Chihuahuan Desert-scale estimates).

To better understand the existing responsibilities and relative importance of the geographies of the Rio Grande Joint Venture area, incorporating habitat quantity and quality provide movement beyond density toward an estimate of capacity, i.e., the maximum number of individual birds that every GPCA is able to harbor during the winter. Furthermore, the use of highest possible density and habitat conditions will provide an estimate of potential capacity.

As described earlier in the Methods section on selection of blocks and transects, RMBO reviews each stratified random sample to assure the habitat and accessibility requirements of selection are met. Each transect is selected using GIS data inputs from INEGI and Google Earth. Field visits are arranged to validate the selection using remotely sensed digital data. A transect elimination database has been maintained that documents transects that were selected using GIS but failed to meet all transect criteria upon ground inspection. Documenting the reason for elimination as a sampling transect is also recorded. We used these transect elimination data to create an users accuracy for the INEGI land cover classification which was then used to infer grass conditions across the GPCA landscapes of Mexico (Aronoff 2005). We developed a rejection rate for each GPCA based on GPCA-associated transects randomly drawn and the number rejected based on habitat conditions, including shrub encroachments and insufficient grassland class along the transect.

The source for the US side remote sensing data was the national GAP/ReGAP data from the USGS web data server (<http://glovis.usgs.gov/>). On the Mexico side, the 2010 INEGI data were used for this portion of the analysis. We conducted an agreement analysis between the 2003 and 2010 INEGI datasets because the 2010 data was not the data coincident with the Transect Elimination Database. Therefore, the application of the elimination correction factors to the new INEGI data layer would have been inappropriate without first validating the classification with the historic data set.

To minimize the inconsistency on potential anisotropic bias (spatial variation dependent on orientation), the calculations of percentage grass was calculated using a moving window analysis (Fig. 28) of either N-S or E-W depending on the nearest cardinal direction of the majority of transects in the GPCA. If a GPCA had a greater proportion of transects oriented from 315 to 45 degrees, the moving window used a north–south orientation 3 pixels wide by 34 pixels long. GPCAs with a greater proportion of transects oriented between 45 and 135 degrees had a moving window oriented east–west for grass estimation.



**Figure 28.** Example of moving window analysis.

Habitat estimates were calculated for 50 m off each transect centerline at ten points along the transect by the field technicians. These data were summarized to characterize habitat conditions represented by each transect. Since the remote sensing data had insufficient resolution to capture shrub cover, shrub height, forb cover, forb height, and grass height, the transect averages for each GPCA were used as model inputs for these five variables. Variability in the projections of capacity was strictly from percentage grass cover as an input into the model for each GPCA based upon 30-m classified imagery. We assume a non-skewed distribution of habitat parameters in the application of the hierarchical model. However, fitting the model for all combinations of potential land cover (grass, shrub, and forb) would vastly improve the technical merits of inferring differential density at the pixel level and further extrapolation into capacity.

Each pixel in a GPCA was then independently used to calculate grass cover. Grass cover was then corrected using the point elimination results; this data was then fed into the hierarchical model along with GPCA averages for the other variables and parameterized for each GPCA. Each pixel therefore had a density estimate. Each pixel density was then summed over an entire GPCA to estimate capacity for each year. Maximum capacity was estimated by taking the highest performing year (2009–2011) for each GPCA, suggesting that if all GPCAs were operating in the best of conditions this value would represent the largest number of birds the RGJV high-priority grasslands could accommodate within the range of measured climate conditions and the existing habitat base.

## Capacity Results

The results of the analysis are habitat/climate driven. GPCA capacity estimates incorporate the habitat relationships described earlier for each species. The amount of cover for each habitat type is strongly influenced by growing conditions and herbivory. Denser and taller grass conditions require seasonal climate conditions conducive to healthy grassland conditions. Land management practices of livestock operators can heavily influence habitat conditions through the winter season.

The two approaches taken to calculate the potential capacity for the GPCAs and the other to estimate the RGJV Chihuahuan Desert area capacity are not directly comparable. It is noteworthy that the spatial relationships to species density and habitat condition of GPCAs provide much higher estimates of capacity. This is expected since the GPCAs represent the best of grassland conditions and bird density; therefore other areas of the desert will dilute the spatial distribution of grass and drive resulting capacities down from model application.

The GPCA approach to calculating “potential capacity” uses the models described earlier and habitat under the best observed climate conditions for the GPCAs and also uses only the land cover/habitats in the GPCA for extrapolation. The results of the potential capacity approach identify the best of conditions for each GPCA independently and sum those values for the BCR. These results reflect the GPCA landscapes operating at peak density simultaneously, which is unlikely at any one point in time, given spatiotemporal variation in climate-driven habitat suitability across the region. The application of the models at the GPCA level, using best of conditions, provides a reasonable insight into the potential for the Joint Venture to accommodate larger populations of winter birds. In this scenario, habitats are functioning at their best recorded level of services for the five species. Table 7 depicts the annual capacity for each species as well as the sum of peak conditions for each GPCA to estimate full potential capacity.

**Table 7.** Combined potential capacity for all GPCAs within the RGJV region excluding Alto Conchos under optimal conditions

Species	2009	2010	2011	Potential
Baird’s Sparrow	311,463	315,035	357,910	546,794
Chestnut-collared Longspur	4,619,953	5,655,841	6,096,004	9,938,526
Lark Bunting	2,206,046	3,077,266	3,600,136	5,684,760
Loggerhead Shrike	123,951	190,017	181,338	295,289
Sprague’s Pipit	150,326	98,096	132,098	212,789

Across all GPCAs, Loggerhead Shrike had an estimated capacity of nearly 124,000 birds in 2009, 190,000 in 2010, and 181,000 in 2011; however, if we sum the peak for each GPCA for any of the three years, the Joint Venture shows an ability to carry 295,000 birds. This near 50% increase over the best documented year is the result of significant heterogeneity of habitat conditions annually across the entire desert.

Understanding where birds are potentially distributed in space can be inferred from the contributions of each GPCA to the overall capacity estimates. A direct correlation to grassland area does not always hold as configuration and other parameters were part of the estimation process. The following charts indicate GPCA contributions to the total potential species capacity. This argument does not however mean a GPCA is currently out-performing other GPCAs by these amounts. These contributions only suggest the potential to carry a specified percentage of the total winter population.

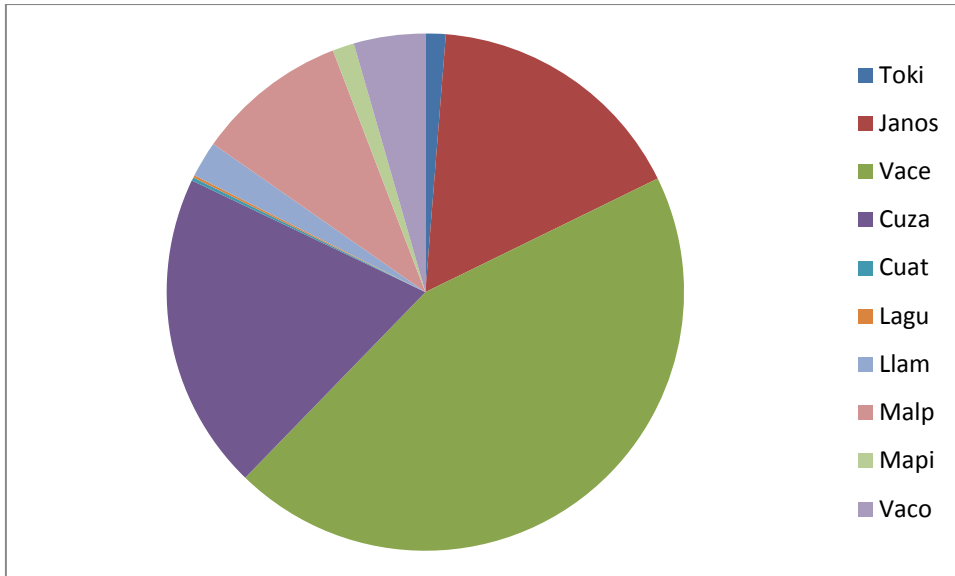
Table 8 presents a set of additional capacity estimates for the Chihuahuan Desert area outside the GPCAs and are derived from a simple application of average density across all transects in the boundary and all years (2007–2011) applied to unadjusted estimates of grassland from GIS for the entire region. This simple approach does not take into account spatial variation in the patterns or density of grasslands or the spatial distribution of the species in different regions of the Chihuahuan Desert. Average values are used because of the lack of inferential space outside the GPCA model to provide a simple capacity estimate for the Chihuahuan Desert Area. Application of gross average estimates provides a mechanism to understanding of the current conditions and how the rest of the Chihuahuan Desert is contributing to current winter habitat requirements.

**Table 8.** Additional capacity estimates for the Alto Conchos GPCA and Chihuahuan Desert area excluding the other Mexican GPCAs using unadjusted estimates of grassland area.

<b>Species</b>	<b>Additional estimated capacity outside of GPCAs (individuals)</b>	<b>Additional estimated capacity of the Alto Conchos GPCA (individuals)</b>
Baird’s Sparrow	221,953	44,552
Chestnut-collared Longspur	5,040,456	1,011,758
Lark Bunting	4,007,924	804,501
Loggerhead Shrike	211,228	42,399
Sprague’s Pipit	94,499	18,968

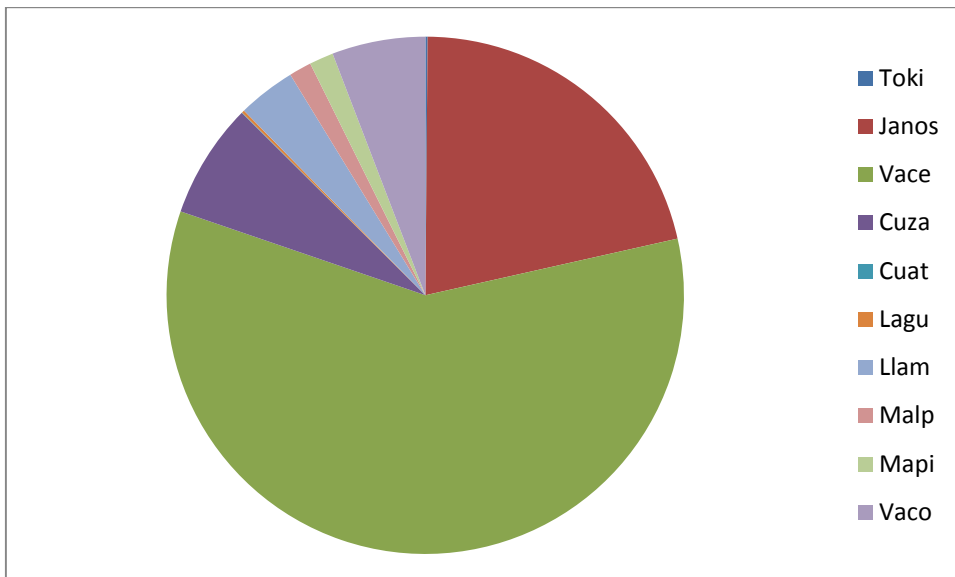
Cuchillas de le Zarca attains the highest Baird’s Sparrow density with 47 birds km<sup>-2</sup>; however, the larger grassland area of the Valles Centrales and its higher recorded grass heights indicate that even though Cuchillas de la Zarca (potential capacity = 20%) currently has a higher bird density, habitat conditions in Valles Centrales are capable of attracting large numbers of birds if the habitats stay intact (44%; Figure 29). Janos (16%) and Malpais (9%) indicate the potential to make a large contribution to winter population capacity. Though El Tokio has no records of this species, the habitat base suggests the potential to provide for the species. This type of information may be relevant in future assessments of habitat availability and species immigration due to climate change.





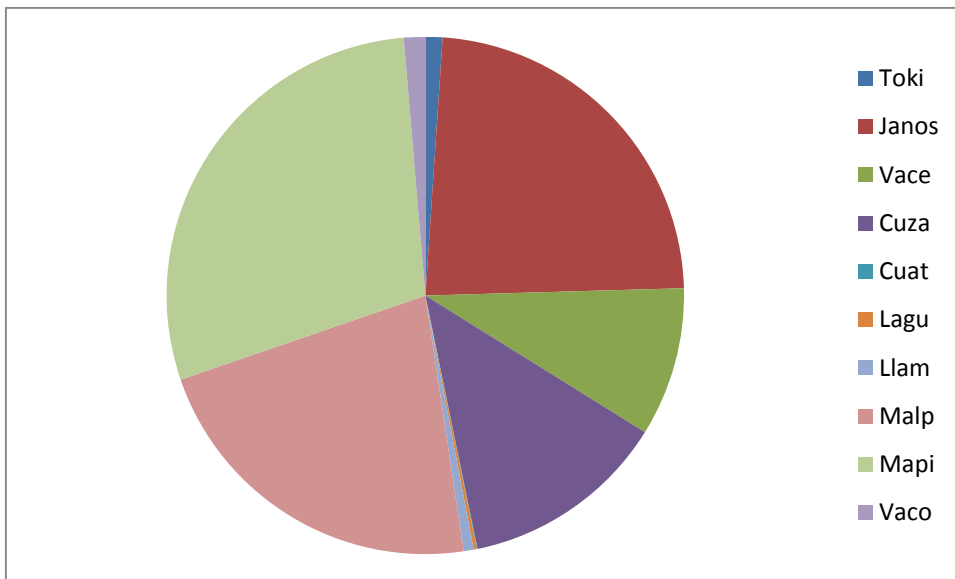
**Figure 29.** Proportion of the winter population capacity for Baird’s Sparrow per GPCA.

Valles Centrales alone accounts for 59% of potential Chestnut-collared Longspur capacity. These large area grasslands under documented threat are of utmost conservation importance in the Chihuahuan Desert (Figure 30). The northern and central grasslands of Janos (21%), Cuchillas de la Zarca (7%), and Valle Colombia (6%) account for the majority of the remaining potential for Chestnut-collared Longspur.



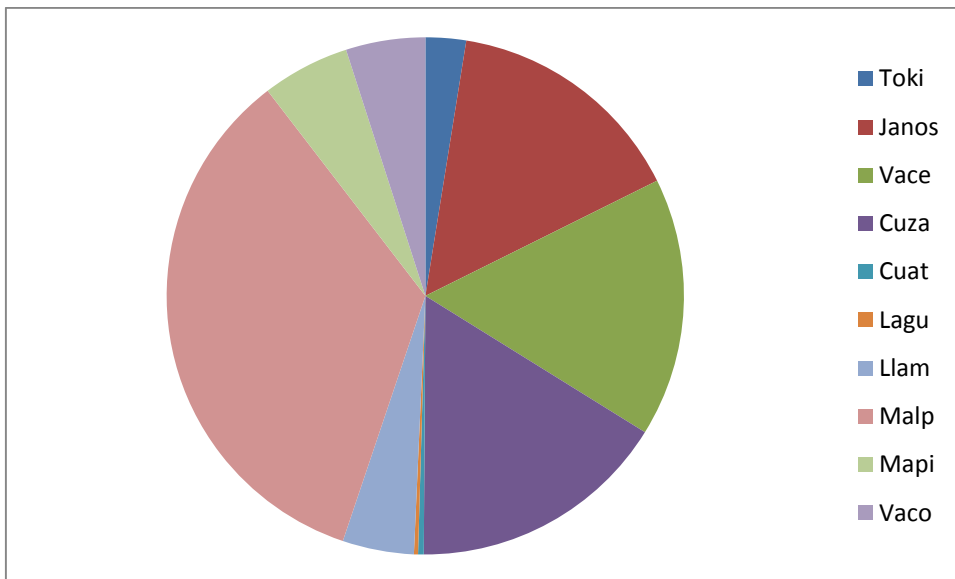
**Figure 30.** Proportion of the winter population capacity for Chestnut-collared Longspur per GPCA.

Potential capacity for Lark Bunting is fairly well distributed between five major GPCAs; Mapimi (29%) is the largest contributor with Janos (23%), Malpais (22%), Cuchillas de la Zarca (13%), and Valles Centrales (9%) contributing to the region’s potential capacity to attract Lark Bunting (Figure 31).



**Figure 31.** Proportion of the winter population capacity for Lark Bunting per GPCA.

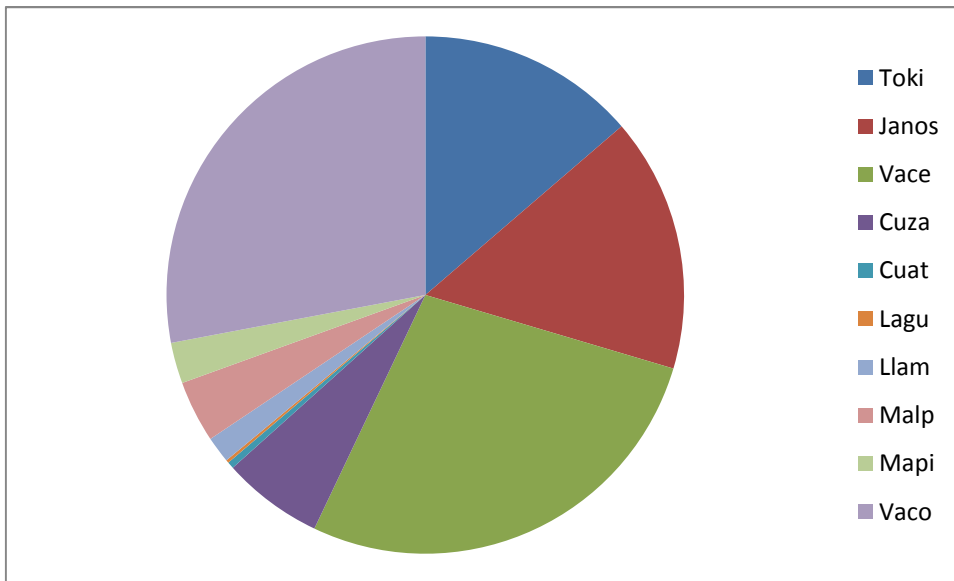
Malpais accounts for 34% of the potential capacity for Loggerhead Shrike with Cuchillas de la Zarca, Valles Centrales, and Janos providing nearly equal contributions (16%, 16%, and 15%, respectively; Figure 32). These four GPCAs account for nearly 80% of potential. The GPCAs of Llano las Amapolas, Valle Colombia, and Mapimi each account for nearly 5% of Loggerhead Shrike capacity.



**Figure 32.** Proportion of the winter population capacity for Loggerhead Shrike per GPCA.

Sprague's Pipit capacity is near evenly dominated by Valle Colombia with 28% and Valles Centrales with 27% of potential (Figure 33). Janos and El Tokio also add significantly to the total potential with 16% and 14% respectively, and smaller contributions are made by several other GPCAs. Sprague's Pipit again demonstrates the importance of well-

distributed conservation strategies with 85% of potential capacity distributed across four widely separated GPCAs.



**Figure 33.** Proportion of the winter population capacity for Sprague's Pipit per GPCA.

The distribution of contribution to species capacity reinforces the importance of the portfolio of GPCAs to the breadth of species diversity wintering in the Chihuahuan Desert and Rio Grande Joint Venture. When considering differences between Desert gross estimates and GPCA pixel-based estimates, the models were parameterized differently and applied differently. The Desert model took advantage of a larger range of data collection, years 2007–2011, for estimating model parameters for baseline density by year and GPCA. This approach was used to ensure the best possible range and maximum number of observations for the larger area density estimates. The GPCAs were fitted to a smaller range of available years, 2009–2011, for which we had consistent vegetation data to account for habitat effects at the transect level. Models used a Poisson distribution for within and between GPCA spatial variability and GPCA became a proxy for spatial distribution at a coarse scale. For some species, the presence of grassland conditions in the absence of observed birds has deflated the wider estimate down from the GPCA estimates, and where species tend to be surveyed on all GPCAs the addition of more available desert grasslands inflate the estimates of capacity above annual GPCA summaries. For example, Baird's Sparrow is well below GPCA estimates when using the larger desert area estimate 266,505 versus 311,463–357,910 for the range of GPCA summaries.

## Recommendations and concluding remarks

Winter grassland bird communities throughout the Chihuahuan Desert are highly variable in abundance and composition from winter to winter. Bird densities may change by orders of magnitude at the GPCA level and bird species may reach their maxima at different

GPCAs in different years. These results suggest that migratory grassland birds have low site fidelity in the wintering grounds and their movement may be largely governed by annual changes in the distribution of resources required for winter survival. Both habitat and food resources may be largely governed by summer precipitation. In this regard, this project is providing valuable information that will enable us to further explore, among some topics, the influence of climate on the abundance and distribution of grassland birds in the winter and the consequences of climate change in the persistence of grassland birds in North America. However, large annual variability in species distribution throughout the Chihuahuan Desert poses a challenge to the conservation of grassland birds since no subset of GPCAs may suffice to protect all species. This result however clarifies the need to provide habitat distributed across the Rio Grande Joint Venture area and to plan conservation targets that account for variability in both time and space.

Bird conservation planning for these five species is likely to have both positive and negative impacts on other species. Trade-offs are a reality of habitat management. Additional information about the response of other species to the conservation actions articulated for the five species addressed in this plan should be extended. From additional analysis of survey data, we found that in spite of the large annual variability in grassland bird abundance, some patterns are evident. Most of the species abundance (>50%) resides in less than five species for all GPCAs, a recurrent pattern that has been identified in other studies (Macias-Duarte et al. 2012). Dominant species at GPCAs include Chestnut-collared Longspur, Lark Bunting, Vesper Sparrow, Horned Lark, Brewer's Sparrow, and Savannah Sparrow. All these species have significant declining trends on their breeding grounds according to the North American Breeding Bird Survey. Analysis of biodiversity measures, mainly species richness and Shannon's diversity index, show that in order to optimize biodiversity conservation, Cuchillas de la Zarca, Janos, and Malpais should be effectively protected. These three GPCAs have the highest species richness and since they belong to different clusters of GPCAs (Macias-Duarte et al. 2012), protection of different grassland bird guilds can be achieved. Furthermore, protection of El Tokio, although ranking low in biodiversity among GPCAs, must also be sought since this GPCA harbors wintering populations of endangered wildlife (SEMARNAT 2010) dependent on the ecological conditions generated by the also-endangered Mexican prairie dog (*Cynomys mexicanus*) colonies.

Information in this bird plan provides valuable direction to land managers and ranchers willing to improve range conditions for grassland bird conservation. This research has demonstrated that there is a strong relationship between vegetation structure and bird species abundance in Chihuahuan Desert grasslands (Panjabi et al. 2010). These relationships have allowed us to develop species-habitat models to predict bird abundance. Incorporating new data (from 2011 and 2012) and refining our modeling approaches will enable us to set guidelines for habitat management to achieve target population levels.

## Future research needs

Topics for potential research include (not in any particular order):

- Measure and monitor habitat loss across GPCAs. Understand the rates, cost in birds and actions needed to offset the losses through other management actions.
- Monitor grassland bird responses to management actions in desert landscapes.
- Generate a more precise land cover data set for the combined grassland-shrubland. Models suggest that a few percent change in mixture of grass and shrub cover can have significant outcomes in terms of species use. GIS data needs to be developed that contains precision sufficient to infer habitat capacity and attractiveness for grassland birds, at least in terms of shrub and grass cover. A project covering the entire Chihuahuan Desert is a large undertaking but a pilot study could ascertain the efficacy of the various methods and costs of developing these data.
- There needs to be a better set of data for protected lands with defined fields based on the type of easement, level of protection (wetland only, upland, use limits,...) and enforceability. There are currently at least 3 databases being maintained on protected lands. Guidance documents such as this will greatly benefit if the conservation community were to develop a set of standards and scales for protected lands and join together in pooling private and public GIS on protected lands. We suggest working in cooperation with the USGS, ESA and CEC to develop a pilot project for the RGJV and then encourage the three leaders to implement on a continental or global scale.
- Project the range of conditions and impacts on expected species distribution and densities due to potential climate change on wintering grassland birds.
- Determine where and what types of anthropogenic changes are occurring and predict the impacts of anthropogenic change on wintering grassland birds.
- Develop a decision support tool to target grassland bird conservation implementation that incorporates biological targets and projected climatic and anthropogenic impacts.
- Determine food uses, preferences, and role in distribution, density, and health of grassland birds in winter.
- Expand wintering grassland bird inventories in under-sampled areas, including in the Alto Conchos GPCA in Chihuahua, as well as grasslands outside current GPCAs in the states of Zacatecas, Aguascalientes, Jalisco, Sonora and Texas. Additional surveys in the Gulf Coast region, from Texas to Tabasco, would also provide greater insight into grassland bird wintering distributions.

- Conduct focused species-based monitoring for those that are under-sampled using habitat approaches or that have specific conservation need of additional information at the species level (e.g., Mountain Plover).
- Determine migratory connectivity with breeding grounds for wintering species in the Chihuahuan Desert grasslands (e.g., satellite telemetry research on raptors, geolocators, genetic and isotope analyses, etc.).
- Link together disparate parts of life cycles to identify the key limiting periods and factors for grassland birds.
- Measure grassland bird (e.g., Chestnut-collared Longspur, Sprague's Pipit) survival on wintering grounds and identify limiting factors.
- Verify the precision of vegetation parameter visual estimates through sampling/analysis of ground cover photos. These data are central to modeling species-habitat relationships and the validity of the field methods should be tested.
- Look outside the grasslands. Do grassland birds use agricultural fields, how often, how many, does it influence their survival, health, behavior... ?

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