Report

Where do grassland birds winter? Density, abundance and distribution of wintering grassland passerines in the Chihuahuan Desert

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Abstract.

Fifty-seven percent of North American grassland bird species are undergoing significant, long-term population declines. Thus far, conservation efforts have focused primarily on breeding habitat, but they have not been able to reverse population declines. Almost 90% of grassland-obligate bird species breeding in the western Great Plains are migratory and fully 90% of these species overwinter in the Chihuahuan Desert. The role of winter threats in continental population declines is believed to be important, but it has received relatively little attention. Biological knowledge of core wintering areas, habitat requirements, availability and trends, intra- and inter-annual movements, survival rates, and limiting factors is lacking, but is needed to advance strategic habitat conservation for these species.

We surveyed wintering bird communities annually at up to 1159 randomly-located grassland sites in 17 Grassland Priority Conservation Areas in the Chihuahuan Desert (GPCAs) in Mexico and USA between 2007 to 2013. We used 1-km line-transects with distance-sampling to estimate species' density and visual estimates to characterize vegetation structure. Using available GIS data from INEGI, with adjustments from RMBO's point-elimination data, we estimated density and population size for 12 of the most common passerine grassland bird species wintering in the Chihuahuan Desert.

Although wintering grassland bird communities throughout the Chihuahuan Desert are highly variable in species abundance and composition from winter to winter, long-term patterns suggest a greater abundance (and often density) of birds in the western desert grasslands along the Sierra Madre Occidental and in the southern Chihuahuan Desert. These areas appear to be particularly important for the conservation of migratory grassland birds from the western Great Plains. The information presented here on wintering grassland bird abundance and distribution can be used as a roadmap for grassland bird conservation in the Chihuahuan Desert, and is already being used to guide such efforts.

Grasslands in the Chihuahuan Desert are being lost at an alarming rate. In order to halt and potentially reverse continental grassland bird declines, conservationists should focus more attention on protecting and restoring grasslands in the Chihuahuan Desert. This will help protect the investments being made in similar efforts on the breeding grounds. We recommend deploying outreach biologists and range ecologists to work cooperatively with landowners in Mexico to improve range and habitat conditions for both birds and people. We also recommend continued research to characterize the desert grassland avifauna of poorly known regions in Mexico so that opportunities for species conservation are not lost before they are even discovered. We also recommend research to identify limiting factors for grassland birds so appropriate best management practices can be developed that will improve the effectiveness of outreach and management efforts in increasing abundance and survival of grassland bird species.

Key words: Chihuahuan Desert, grassland birds, Grassland Priority Conservation Areas, wintering period, density.

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Introduction

For millennia, grasslands have played a key role in the evolution and prosperity of humankind, from early hunter-gatherers, to nomadic herders, subsistence farmers, and modern industrial farms and livestock operations. It is perhaps for this very reason that grasslands are now one of the most endangered terrestrial ecosystems on Earth. Nowhere have grasslands been so decimated as in North America, where less than 4% of tall grass prairie remains (Samson and Knopf 1994). Even in the remaining tracts of native prairies, 57% of grassland-dependent bird species, including 29 species of continental or regional importance as recognized by Partners in Flight (PIF), the U.S. Fish and Wildlife Service (USFWS), Canadian Wildlife Service and SEMARNAT (Table 1), are undergoing steep, widespread and long-term population declines (Sauer et al. 2011). While the reason for the decline in tall-grass prairie species may be obvious, the drivers of declines in short- and mixed-grass prairie birds are less well understood, but still likely relate to the continuing loss and alteration of suitable habitat across their migratory range. In this regard, threats to native grasslands are accelerating in many regions due to expanding agriculture, urbanization, energy development, desertification and invasive species. However, the potential role of winter threats in these population declines, although hypothesized to be important, has never been explored.

The short- and mixed-grass prairies of the western Great Plains, from southern Alberta and Saskatchewan to eastern New Mexico and the Texas panhandle, have the most extensive and intact native grasslands remaining in North America and support the most important breeding areas for the greatest number of grassland bird species. Eighty-eight percent of grassland-obligate bird species breeding in the western Great Plains are migratory, and 90% of these overwinter in the Chihuahuan Desert grasslands (Table 1) of northern Mexico and the southwestern United States, some exclusively, making this a globally-important region for North American grassland birds. Most of these species spend more time on their wintering grounds than on their breeding grounds and several of the most steeply declining species, like Sprague's Pipit, Chestnut-collared Longspur, Baird's Sparrow and Grasshopper Sparrow, are strict grassland obligates in winter (Ruvalcaba-Ortega et al. in prep.), making them highly vulnerable to anthropogenic changes. Native grasslands in the Chihuahuan Desert are restricted in distribution, occurring primarily along the eastern piedmont of the Sierra Madre Occidental (Figure 1). Although recent GIS data (INEGI 2008) suggest grasslands occupy roughly 15% of the Chihuahuan Desert landscape (Bird Conservation Region 35) in Mexico, accuracy in discriminating among remotely-sensed grasslands vs. shrublands can be poor. Based on classification of the habitat surrounding randomly selected points along roads within the INEGI grassland layer in the Chihuahuan Desert, the actual extent of relatively shrub-free grasslands (<25% cover), such as those required by most grassland-obligate bird species, is probably closer to around 5% of the landscape (RMBO unpublished data).

Despite the importance of Chihuahuan Desert grasslands for North American grassland birds, little data has existed until present to guide conservation efforts in the region. In particular, basic information on the regional abundance and habitat use of wintering grassland birds, trends in grassland extent and condition, and spatio-temporal patterns and variation in all of the above have been lacking. This information is necessary to advance strategic conservation of priority species and habitats for these steeply declining species while opportunities still exist.

With this goal in mind, we set out to fill these critical information gaps for grassland bird conservation in the Chihuahuan Desert. Our primary objective was to estimate wintering densities of grassland bird species in Grassland Priority Conservation Areas (GPCAs; CEC and TNC 2005, Pool and Panjabi 2010) in the Chihuahuan Desert, in order to determine the importance, in terms of density and total population supported in each GPCA for each species. A secondary goal was to characterize vegetation conditions and other environmental factors that may influence grassland bird density at each site, in order to improve our understanding of bird-habitat relationships, critical habitat requirements, and availability of required conditions for each species. In this paper, we present results concerning our primary objective: multi-year average densities and population estimates of grassland bird species in the 17 Chihuahuan Desert GPCAs. This information will aid in the design and prioritization of species- and habitat-focused conservation efforts, and the development of management recommendations. Furthermore, our results help establish baseline populations and habitat conditions in the Chihuahuan Desert that will enable the evaluation and quantification of impacts from continuing grassland loss and climate change, as well as from conservation actions.

Methods

Study area.—We conducted avian and habitat surveys in up to 17 Grassland Priority Conservation Areas in northern Mexico, southern Arizona, southern New Mexico and western Texas in the winters of 2007-2012 (Levandoski et al. 2009, Panjabi et al. 2010, Macias-Duarte et al. 2011). GPCAs included in this study are Armendaris, Alto Conchos Cuatro Ciénegas, Cuchillas de la Zarca, Janos, Lagunas del Este, Llano Las Amapolas, Malpaís, Mapimí, Marfa, New Mexico Bootheel, Otero Mesa, Sonoita, Sulfur Springs, El Tokio, Valles Centrales, and Valle Colombia (Fig. 1).

Focal species.— We focused this paper on winter abundance and distribution of the passerine component of the grassland bird guild, as defined by Sauer et al. (2011). Our focus species includes Horned Lark, Sprague's Pipit, Cassin's Sparrow, Vesper Sparrow, Lark Bunting, Savannah Sparrow, Grasshopper Sparrow, Baird's Sparrow, Chestnut-collared Longspur, and Eastern and Western meadowlarks. We also include Brewer's Sparrow as a grassland facultative species, as it is one of the most abundant bird species in Chihuahuan Desert grasslands (Desmond et al. 2005, Manzano-Fischer et al. 2006, Macias-Duarte et al. 2009). All these grassland species have undergone population declines in the breeding grounds of North America (Sauer et al. 2011)

Sampling design.—We overlaid a grid of roughly 18 x 18 km^2 cell blocks across the Chihuahuan Desert and Sierra Madre Oriental Bird Conservation Regions to create a sampling frame for desert grasslands within GPCAs (Fig. 1). Eligible cells for sampling were those that intersected with GPCAs and had at least 5 km of road access to grasslands as identified 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 original GPCA boundaries. This sampling design is described in detail by Panjabi et al. (2007), with modifications by Levandoski et al. (2009). We added additional GPCAs to the sampling frame each year. In each sampling block we established randomly numbered points at 500 m intervals along roads intersecting grasslands, and established 6 paired 1-km line transects in each block, starting at the 3 lowest numbered points that met habitat requirements for native grasslands with <25% shrub cover.

Bird surveys.—We used distance sampling Buckland et al (2001) on line transects to estimate annual winter bird density in all GPCAs. We initiated surveys in early January and completed surveys by early March. Each pair of 1-kilometer 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. Each pair of technicians surveyed the 6 transects in each block starting at sunrise and continuing until completion (usually before 13:00). Sometimes, due to weather, road conditions, and variability in the time needed to complete both bird and vegetation surveys, finishing all transects within 6 hours was not possible. We did not conduct surveys during winds higher than category 4 in the Beaufort scale (20-28 kph) or during any precipitation greater than a drizzle.

From each starting point, technicians used Garmin E-trex Vista GPS units to establish the end point of the transect 1000 m away and maintain their position on the line while conducting the survey. Observers used a compass to select a point on the horizon that corresponded with the direction of the transect end point, and used this bearing to visualize the transect line in front of them. Observers recorded all birds detected during each survey and used both laser rangefinders and ocular estimates to obtain lateral distances from the transect line to each bird or bird cluster detected. We trained field technicians to obtain reasonably accurate ocular estimates of lateral distance from transects before the start of each field season. Bird clusters were defined as groups of 2 or more individuals of the same species occurring within 25 m of the first individual detected. For each detection, we recorded the cluster size. 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.

Statistical analysis.—We used distance sampling (Buckland et al. 2001) to estimate mean bird density from 2007-2013 for our focal species at each GPCA. Distance sampling methodology accounts for imperfect detection of individuals during surveys by modeling detection probability from observed detection distances. In this regard, density (D, number of individuals per unit of area) for line transects may be estimated from the equation (Buckland et al. 2001):

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

where $E(n)$ is the expected number of groups detected, $E(s)$ is the expected 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, i.e., $y = 0$. We selected the best probability density function of detection distance from 30 forms of $f(y)$ using the Akaike's Information Criterion (Burnham and Anderson 2002). We formed these 30 forms of $f(y)$ by the combination of 2 keys (half-normal and hazard-rate function), 3 series expansions (cosine, simple polynomial, and Hermite polynomial) and the first 5 orders for each series. To improve our estimation of parameters for each form of $f(y)$, we used right-truncated distance data (Buckland et al. 2001) at the 90th percentile of observed distances (i.e. 10% truncation). We stratified the estimation of density by GPCA. We calculated the standard errors for D (Buckland et al. 2001) using the delta method applied on expression (1). We performed all these calculations using package *Distance* in program *R* (R Development Core Team 2011).

Results

Survey effort.—We have generally increased our area of coverage each year since the onset of this study, from 211 transects in 75 blocks in 7 GPCAs in 2007 to 1,159 transects in 193 blocks in 15 GPCAs in 2011, 1,091 transects in 196 blocks in 16 GPCAs in 2012, and only 423 transects in 72 blocks in 5 GPCAs in 2013 (Table 2). We increased our coverage considerably in 2011 when we added 5 new GPCAs to our monitoring effort: Armendaris, Sonoita (U.S. side), New Mexico Bootheel, Otero Mesa, and Sulfur Springs. We also expanded our sampling efforts in the Janos, Valles Centrales and El Tokio GPCAs in 2011, due to boundary expansions for these GPCAs as described by Pool and Panjabi (2011). We stopped sampling in Cuatro Ciénegas in 2011 due to low bird numbers. We added GPCA Alto Conchos to our sampling effort in 2012..

Distance sampling.— Hazard-rate, half-normal, and half-normal with Hermite polynomial expansion were the most frequently selected functions by the AIC model selection procedure (Table 3). Unconditional detection probabilities and half-width transects correspond to the each species' behavior in the field. For example, the secretive Cassin's Sparrow has the lowest unconditional detection probability among all the species ($P_a = 0.29$) over a short distance from the transect (28 m) while the conspicuous Eastern Meadowlark has a relatively high unconditional detection probability ($P_a = 0.44$) over a long distance from the transect (89 m).

Brewer's Sparrow.— Although often associated with shrublands, Brewer's Sparrows are one of the most abundant birds in western Chihuahuan Desert grasslands but scarce through the eastern edge from Armendaris to El Tokio, where the species is practically absent (Table 4). The species is particularly dense in two distinct regions: 1) the northwestern extreme of the Chihuahuan Desert in Sulfur Springs (172.34 birds km^{-2}), New Mexico Bootheel (125.23 birds km^{-2}), and Janos (130.97 birds km^{-2}), and 2) the central-southern Chihuahuan Desert, reaching its highest density in Mapimi (176.12 birds km^{-2}) with high densities at the neighboring GPCAs of Cuchillas de la Zarca (159.98 birds km^{-2}) and Malpaís (128.40 birds km^{-2}). However, although density is high in Mapimí, this GPCA harbors a relatively small amount of the winter population given the low extent of suitable grasslands.

Horned Lark.— This species shows a disjunct pattern in density. Horned Larks attain their highest densities at both extremes of the Chihuahuan Desert (Table 4). The species has its highest density in El Tokio, reaching a density of 184.09 birds km^{-2}. Its density remains relatively low as latitude increases up to northern Chihuahua and New Mexico, where the species' density increases up to 98.09 birds km^{-2} in the New Mexico Bootheel. Horned Lark appears to be absent from the southern Chihuahuan Desert at Malpaís, although only a small portion of the GPCA is represented in the sample. The abundance of Horned Larks is highest in the northern Chihuahuan Desert at reaching a winter population of 879,273 birds at New Mexico Bootheel.

Sprague's Pipit.— Sprague's Pipit is widely distributed in the Chihuahuan Desert, but it occurs in low density throughout. The species tends to occur in slightly higher density in the eastern portion of the Chihuahuan Desert (El Tokio = 6.95 birds km^{-2}, Valle Colombia = 9.69 birds km^{-2}), but due to the limited extent of suitable grasslands there, these populations only contribute roughly 8% to the total Chihuahuan Desert GPCA wintering population. In contrast, the western GPCAs support slightly lower densities, but a much larger portion of the population overall (Cuchillas de la Zarca = 24%, Malpais = 20%, Valles Centrales = 16%, Janos=8%, Alto Conchos = 5%). The species appears to be particularly scarce or absent in the northern Chihuahuan Desert (i.e., New Mexico).

Cassin's Sparrow.— The species is widespread but local throughout the Chihuahuan Desert grasslands in winter (Table 4). However, it is highly secretive and thus rarely detected on transects. The highest densities detected are in the central Chihuahuan Desert at Lagunas del Este (8.69 birds km^{-2}), Cuchillas de la Zarca (5.57 birds km^{-2}) and Marfa (5.34 birds km^{-2}), followed by Malpaís (3.87 birds km^{-2}) and Valle Colombia (6.16 birds km^{-2}). There does appear to be some withdrawal from breeding areas during the non-breeding season, although we have not identified any high-density areas in winter. Mostly, individual birds are observed in areas of shrubland within grasslands. The species' low winter detectability rate may confound insights into its distribution and abundance.

Vesper Sparrow.— Vesper Sparrows is one of the most abundant and widespread bird species wintering in the Chihuahuan Desert grasslands (Table 4). We estimate an average wintering population of 10,306,325 individuals among the Chihuahuan Desert GPCAs. The species attains its maximum density and abundance in the southwestern Chihuahuan Desert, particularly in the GPCAs Cuchillas de la Zarca (247.35 birds km^{-2}), Alto Conchos (245.60 birds km^{-2}) and Malpaís (194.84 birds km^{-2}), which collectively account for 65% of the Chihuahuan Desert GPCA wintering population. The largest wintering distribution of Vesper Sparrows occurs in Alto Conchos with 2,703,420 birds. The species also occurs in high density in Valle Colombia (188.66 birds km^{-2}) in the northeastern extreme of the Chihuahuan Desert, but grassland habitat in this region is scarce.

Lark Bunting.— The Lark Bunting has a widespread distribution in the Chihuahuan Desert with varying densities among GPCAs but with two important disjunct regions of high density in grasslands (Table 4). Within the Chihuahuan Desert grasslands, Lark Buntings reach their highest density in Mapimí, with 215.26 birds km^{-2}. However, the largest winter population occurs in the northern Chihuahuan Desert in Janos, where an estimated 604,575

Lark Buntings over-winter each year. Although widespread across the Chihuahuan Desert, Lark Bunting occurs in significantly lower densities in a few GPCAs including Cuatro Ciénegas, Otero Mesa, and Sonoita. It is possible that a significant portion of Lark Buntings are wintering in other habitat aside from grasslands, including cropland and shrublands. For example, researchers at UANL found that wintering Lark Buntings occurred in significantly higher density in croplands than in grasslands in the El Tokio GPCA (Ruvalcaba-Ortega et al., in prep). Therefore, knowledge of their distribution and abundance among grassland areas only provides partial insight into their winter ecology in the region.

Savannah Sparrow.— Savannah Sparrows are widely distributed through the Chihuahuan Desert (Fig. 2), attaining their maximum average density in Valle Colombia (235.66 birds km^{-2}). The species seem to be absent in Armendaris, Otero Mesa, Cuatro Ciénegas and El Tokio, although the species is highly nomadic. In general, Savannah Sparrow occurs in highest density throughout the western edge of the Chihuahuan Desert, from Sonoita (65.17 birds km^{-2}) and Sulfur Springs (70.34 bird km^{-2}) south through Janos (47.7 birds km-2) and Valles Centrales (33.54 birds km-2), Alto Conchos (52.32 birds km-2), Cuchillas de la Zarca (73.14 birds km-2) and Malpaís (72.27 birds km-2), with these last three GPCAs harboring 54% of the total winter population in the Chihuahuan Desert GPCAs.

Grasshopper Sparrow.— Grasshopper Sparrows are widely distributed through Chihuahuan Desert grassland, where they are among the most abundant species. Across all the Chihuahuan Desert GPCAs combined, we estimate an average winter population of roughly 2.7 million individuals. Average Grasshopper Sparrow density is highest in Cuchillas de la Zarca (74.19 birds km^{-2}), Malpaís (87.44 birds km^{-2}) and Lagunas del Este (66.91 birds km^{-2}), and together these areas support an estimated 66% of the Chihuahuan Desert GPCA wintering population. Janos and Valles Centrales support another 16%.

Baird's Sparrow.— Baird's Sparrow is one of two migratory species that winter exclusively within the grasslands of the Chihuahuan Desert and Sierra Madre Occidental. The intermountain grasslands of Cuchillas de la Zarca in Durango is unequivocally the most important winter grounds for the species, reaching a mean density of 47.27 birds km^{-2}, and supporting roughly 42% of the Chihuahuan Desert GPCA wintering population (Fig. 2). However, other grasslands in the southwestern Chihuahuan Desert are also important; Malpaís and Alto Conchos support an additional 24% of the species' wintering population within the GPCAs. Baird's Sparrows are scarce or even absent in the lower-elevation grasslands in the northern and eastern part of the Chihuahuan Desert (New Mexico, Coahuila and Nuevo Leon). Llano las Amapolas appears to be a pocket of high quality habitat for the species, with 26.57 birds km^{-2} on average. The Sonoita GPCA, while supporting the second highest density of the species (16.80 birds km^{-2}), supports only 7% of the estimated GPCA winter population due to the smaller extent of grasslands in the region.

Chestnut-collared Longspur.— The Chestnut-collared Longspur is one of the most abundant birds wintering in Chihuahuan Desert grasslands, second only in total abundance to the Vesper Sparrow. Like Baird's Sparrow, it is a species that is also largely restricted to the Chihuahuan Desert and lower valleys of the Sierra Madre Occidental. However, it has a more northerly wintering distribution (Fig. 2) compared to other species. It occurs in highest density and abundance in eastern Chihuahua, particularly in the Valles Centrales

GPCA, which supports an average density of 287 birds km-2, and an estimated wintering population of 3,426,603 birds, or roughly 36% of the total estimated GPCA wintering population. The New Mexico Bootheel supports the next highest population at 1,269,196 birds, followed by Cuchillas de la Zarca (1,031,770 birds), Lagunas del Este (1,007,991 birds) and Janos (913,180). In total, these 5 GPCAs support 80% of the GPCA wintering population of Chestnut-collared Longspur. While there are other pockets of high-density grasslands, such as in Llano las Amapolas and Otero Mesa, the extent of these areas is relatively small, as is their relative contribution to the overall wintering population. 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 Malpaís. Density of Chestnut-collared Longspurs also decreases towards the northwestern Chihuahuan Desert of Arizona and Sonora. Given the importance of the Valles Centrales for this species, the recent conversion of grasslands to farmland there exacerbates the negative trajectory of the Chestnut-collared Longspur, which is recognized as Threatened by Canada's federal government, and Near-threatened by the IUCN.

Eastern Meadowlark.— The Eastern Meadowlark (subspecies *lilianae*) is the predominant meadowlark species in the Chihuahuan Desert. Although it is widely distributed, it is most abundant in the 8 GPCAs of the western Chihuahuan Desert and Sierra Madre Occidental (i.e., Sonoita, Sulfur Springs, Janos, Valles Centrales, Alto Conchos, Cuchillas de la Zarca, and Malpaís) which together support 87% of its wintering population in the Chihuahuan Desert GPCAs. It attains a maximum regional density and population size in Cuchillas de la Zarca (26.33 birds km^{-2} and 186,762 birds). The northwestern extreme of the Chihuahuan Desert at the Sonoita Plains also provides high-quality habitat, attaining 19.34 birds km^{-2}. The species is less common in the southeastern Chihuahuan Desert at El Tokio (2.04 birds km^{-2}) and it is absent from the Armendaris GPCA in New Mexico.

Western Meadowlark.— The Western Meadowlark is far less abundant than the similar Eastern Meadowlark, but it is equally widespread. However, its pattern of abundance is rather peculiar in that the areas with the highest densities and largest populations extend in a narrow band southwesterly from Marfa (10.55 birds km^{-2}) through Lagunas del Este (4.67 birds km^{-2}) to Alto Conchos (5.32 birds km^{-2}) and south to Mapimí (2.51 birds km^{-2}) and Cuchillas de la Zarca (2.45 birds km^{-2}). Together these 5 GPCAs support an estimated 77% of the species' wintering population within the Chihuahuan Desert GPCAs.

Discussion and Recommendations

Due to the smaller extent of the Chihuahuan Desert and Sierra Madre Occidental grasslands relative to those in the Great Plains, grassland birds undergo significant concentration upon returning from their breeding grounds each fall. This concentration makes them more vulnerable, on a per-hectare basis, to habitat loss and alteration on the wintering grounds. From the density and abundance maps (Figure 2) it is clear that no two species share the exact same distribution pattern among the GPCAs. Therefore, conservation efforts across the region will serve the needs of each species differently. However, some similarities among species are evident. Eight of the 12 species analyzed, including Brewer's Sparrow, Vesper Sparrow, Lark Bunting, Savannah Sparrow, Grasshopper Sparrow, Baird's Sparrow, Chestnut-collared Longspur and Eastern Meadowlark, exhibit greater abundance in the western Chihuahuan Desert GPCAs, especially along the piedmont and foothills of the Sierra Madre Occidental, compared to the easternmost GPCAs. These grasslands are higher in elevation than the eastern ones and receive more rainfall with greater consistency. Grasslands in this landscape also tend to be larger and more widespread, resulting in more widespread, suitable and reliable habitat. A few species including Grasshopper Sparrow, Savannah Sparrow, Baird's Sparrow and Sprague's Pipit also appear to show an affinity toward the more southerly GPCAs in the Chihuahuan Desert over the more northerly ones. However, part of what suggests this southern affinity are the high densities estimated in the Malpaís GPCA for some species like Grasshopper Sparrow . This GPCA, which lies at the southern end of the Chihuahuan Desert, is poorly represented by our samples, which are restricted to the Durango portion of the GPCA. Unfortunately, sampling in the rest of the GPCA has not been possible to date. However, further survey effort would be required to verify whether bird densities and habitat conditions are similar throughout the GPCA. This possibility should be explored, given the apparent importance of the GPCA for some steeply declining species like Grasshopper Sparrow and Sprague's Pipit. In addition, significant grasslands exist further to the south of Malpaís (in Zacatecas, Aguascalientes, Jalisco and Guanajuato) but no data are available on their precise locations or their avifauna. Similarly, given the importance of the Sierra Madre Occidental piedmont and foothills for grassland birds, further effort should be made to quantify bird populations in the higher grasslands of the Sierra Madre Occidental. Given the potential importance of these areas for migratory grassland birds, and the high level of human-induced pressures in the region, we recommend an effort be made to identify and survey suitable grasslands in these areas to determine their status and importance for grassland conservation and incorporate them into the GPCA network as appropriate.

This survey effort has laid out a roadmap for grassland bird conservation in the Chihuahuan Desert by identifying the places that can play a significant role in species conservation efforts. Before this survey began, many of the places we now know are critical the survival of grassland birds in winter had not yet been identified. The densities and population estimates presented here provide a rigorous scientific foundation for identifying where conservation efforts should be directed and how each area contributes to the conservation of each species. Because threats to native grasslands in the Chihuahuan Desert are rapidly accelerating, we recommend that in each GPCA, teams of outreach biologists and range ecologists are deployed to engage private landowners and ejidatarios in improving range management practices and implementing habitat improvements for wildlife. Engaging the grassland stakeholders in the Chihuahuan Desert, including private landowners, ejidatarios, range managers, government representatives, farmers and others in the solutions for reversing grassland degradation and loss is critical to advancing conservation efforts for this suite of species. However, since knowledge of the specific factors limiting survival and abundance of most species is still lacking, we also recommend identifying, as early as possible, the environmental factors most important to habitat suitability and species survival, so that best management practices to mitigate those factors can be developed and incorporated into habitat management and improvement efforts to maximize their effectiveness.

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TABLE 1. Grassland-obligate bird species of the western Great Plains and Chihuahuan Desert and their migratory and conservation status.

Species	USFWS or PIF Species of Conservation Concern	Federal status (US, CA, MX)	Migratory Status	Breeds in Great Plains	Winters in Chihuahuan Desert
Lesser Prairie-Chicken	Y	candidate (US)	R	Y	
Greater Prairie-Chicken	Y		R	Y	
Sharp-tailed Grouse	Y		R	Y	
Scaled Quail			R	Y	Y
Montezuma Quail			R		Y
Swainson's Hawk	Y	Pr (MX)	M	Y	
Northern Harrier			M	Y	Y
Ferruginous Hawk	Y	threatened (CA), Pr (MX)	M	Y	Y
Golden Eagle	Y	A (MX)	M	Y	Y
Merlin			M	Y	Y
Prairie Falcon	Y	A (MX)	M	Y	Y
Aplomado Falcon		P (MX), endangered (US)	R		Y
American Kestrel			M	Y	Y
Mountain Plover	Y	endangered (CA), A (MX)	M	Y	Y
Upland Sandpiper			M	Y	
Long-billed Curlew	Y	special concern (CA)	M	Y	Y
Burrowing Owl	Y	endangered (CA), Pr (MX)	M	Y	Y
Long-eared Owl			M	Y	Y
Short-eared Owl	Y	special concern (CA), Pr (MX)	M	Y	Y
Loggerhead Shrike	Y	threatened (CA)	M	Y	Y
Horned Lark			M	Y	Y
Sprague's Pipit	Y	threatened (CA); candidate (US)	M	Y	Y
Cassin's Sparrow	Y		M	Y	Y
Brewer's Sparrow	Y		M	Y	Y
Clay-colored Sparrow			M	Y	Y
Worthen's Sparrow		P(MX)	R		Y
Vesper Sparrow			M	Y	Y
Lark Sparrow			M	Y	Y
Lark Bunting	Y	candidate (CA)	M	Y	Y
Grasshopper Sparrow	Y		M	Y	Y
Baird's Sparrow	Y	special concern (CA)	M	Y	Y
McCown's Longspur	Y	special concern (CA)	M	Y	Y
Chestnut-collared Longspur	Y	threatened (CA)	M	Y	Y
Bobolink			M	Y	
Eastern Meadowlark		threatened (CA)	M	Y	Y
Western Meadowlark			M	Y	Y

Table 2. Annual survey effort from 2007-2013 at each Chihuahuan Grassland Priority Conservation Area.

	2007		2008		2009		2010		2011		2012		2013	
Grassland Priority Conservation Area	Blocks	Transects	Blocks	Transects	Blocks	Transects	Blocks	Transects	Blocks	Transects	Blocks	Transects	Blocks	Transects
Armendaris									6	36	6	33		
Alto Conchos											19	113	19	111
Cuatro Ciénegas	3	18	3	18	3	18	3	18						
Cuchillas de la Zarca	16	24	16	96	16	96	17	102	17	102	16	96		
Janos	13	73	13	78	13	78	14	84	22	132	23	135		
Lagunas del Este					13	76	13	76	12	72	11	61		
Llano Las Amapolas									1	6	1	6		
Malpaís							6	36	6	36	6	36	6	34
Mapimí	12	23	12	71	13	76	14	78	13	75	13	56		
Marfa					14	78	13	77	13	78				
New Mexico Bootheel									25	146	25	143		
Otero Mesa									6	36	6	15		
Sonoita			2	12	5	36	5	36	13	78	12	78		
Sulfur Springs									11	78	11	64		
El Tokio	9	9	7	60	8	62	8	60	11	62	11	57	11	62
Valles Centrales	21	58	21	126	21	126	22	132	31	186	30	165	30	180
Valle Colombia	1	6	6	36	6	36	6	36	6	36	6	33	6	36
All GPCAs	75	211	80	497	112	682	121	735	193	1159	196	1091	72	423

TABLE 3. Characteristics of the best detection function for 12 grassland bird species selected from 30 models by the means of the Akaike's Information Criterion (AIC). The symbol P_a denotes unconditional detection probability associated to the detection function.

Species	Key	Serial adjustment	Order	$\hat{P}_a \pm \mathrm{SE}(\hat{P}_a)$	Transect's half-width (m)
Baird's Sparrow	Half-normal	Hermite polynomial	8	0.4025 ± 0.0297	12
Brewer's Sparrow	Hazard-rate			0.6430 ± 0.0119	38
Cassin's Sparrow	Half-normal	Hermite polynomial	8	0.2925 ± 0.0254	28
Chestnut-collared Longspur	Hazard-rate			0.5344 ± 0.0147	70
Eastern Meadowlark	Hazard-rate			0.4398 ± 0.0155	89
Grasshopper Sparrow	Half-normal	Hermite polynomial	8	0.3575 ± 0.0116	15
Horned Lark	Half-normal			0.6611 ± 0.0085	68
Lark Bunting	Half-normal			0.5868 ± 0.0154	76
Savannah Sparrow	Half-normal	Hermite polynomial	10	0.5100 ± 0.0154	37
Sprague's Pipit	Half-normal			0.5099 ± 0.0169	39
Vesper Sparrow	Half-normal	Polynomial	8	0.5461 ± 0.0103	37
Western Meadowlark	Hazard-rate			0.4875 ± 0.0317	120

TABLE 4. Estimated mean bird density and winter population size for 12 grassland bird species at each Grassland Priority Conservation Area from 2007-2013 .

Species	GPCA	Density, *D* (birds/km^2)	SE(*D*)	95%LCL (*D*)	95%UCL (*D*)	Area (km^2)	Population (birds)
Baird's Sparrow	ALCO	7.07	3.29	2.96	16.93	11,008	77,866
	ARME	0.00	0.00	0.00	0.00	564	0
	CUAT	0.00	0.00	0.00	0.00	224	0
	CUZA	47.27	5.20	38.11	58.63	7,095	335,393
	JANO	6.73	1.56	4.29	10.56	5,667	38,140
	LAGU	4.20	1.57	2.06	8.56	4,132	17,348
	LLAM	26.57	16.04	8.39	84.12	1,506	40,029
	MALP	9.58	3.32	4.92	18.65	11,298	108,239
	MAPI	1.10	0.55	0.43	2.79	548	604
	MARF	1.37	0.79	0.48	3.95	2,632	3,613
	NMBO	1.43	0.72	0.57	3.63	8,964	12,859
	OTME	1.48	1.48	0.28	7.78	1,724	2,547
	SONO	16.80	3.74	10.89	25.90	3,082	51,767
	SUSP	1.61	1.13	0.46	5.65	2,826	4,540
	TOKI	0.00	0.00	0.00	0.00	755	0
	VACE	7.81	1.26	5.71	10.70	11,921	93,158
	VACO	3.84	1.35	1.96	7.51	930	3,566
Brewer's Sparrow	ALCO	49.86	10.96	32.49	76.51	11,008	548,856
	ARME	12.23	7.03	4.22	35.48	564	6,897
	CUAT	5.10	4.32	1.18	22.11	224	1,144
	CUZA	159.98	14.43	134.06	190.91	7,095	1,135,070
	JANO	130.97	16.31	102.66	167.10	5,667	742,228
	LAGU	70.32	18.47	42.30	116.91	4,132	290,586
	LLAM	21.36	21.37	3.82	119.58	1,506	32,180
	MALP	128.40	28.30	83.49	197.47	11,298	1,450,607

Species	GPCA	Density, D (birds/km^2)	SE(D)	95%LCL (D)	95%UCL (D)	Area (km^2)	Population (birds)
	MAPI	176.12	19.44	141.86	218.65	548	96,542
	MARF	15.54	7.44	6.35	38.03	2,632	40,899
	NMBO	125.23	22.94	87.59	179.05	8,964	1,122,642
	OTME	19.39	9.01	8.03	46.83	1,724	33,419
	SONO	30.70	7.00	19.71	47.82	3,082	94,622
	SUSP	172.34	36.26	114.19	260.11	2,826	487,069
	TOKI	1.46	1.30	0.33	6.58	755	1,106
	VACE	87.06	9.71	69.99	108.28	11,921	1,037,799
	VACO	10.82	4.55	4.89	23.96	930	10,062
Cassin's Sparrow	ALCO	1.65	0.78	0.68	3.99	11,008	18,183
	ARME	0.00	0.00	0.00	0.00	564	0
	CUAT	0.00	0.00	0.00	0.00	224	0
	CUZA	5.57	1.05	3.86	8.03	7,095	39,495
	JANO	3.50	0.79	2.27	5.42	5,667	19,858
	LAGU	8.69	2.57	4.91	15.36	4,132	35,906
	LLAM	0.00	0.00	0.00	0.00	1,506	0
	MALP	3.87	1.54	1.82	8.25	11,298	43,746
	MAPI	0.64	0.46	0.18	2.25	548	352
	MARF	5.34	1.81	2.79	10.22	2,632	14,062
	NMBO	2.72	1.05	1.31	5.66	8,964	24,397
	OTME	0.00	0.00	0.00	0.00	1,724	0
	SONO	3.61	1.41	1.72	7.60	3,082	11,134
	SUSP	3.28	1.40	1.47	7.35	2,826	9,277
	TOKI	0.66	0.33	0.26	1.67	755	496
	VACE	2.06	0.41	1.40	3.04	11,921	24,584
	VACO	6.16	2.40	2.93	12.93	930	5,725
Chestnut-collared	ALCO	41.96	15.65	20.60	85.45	11,008	461,837

Species	GPCA	Density, *D* (birds/km^2)	SE(*D*)	95%LCL (*D*)	95%UCL (*D*)	Area (km^2)	Population (birds)
Longspur	ARME	73.39	31.22	32.55	165.50	564	41,379
	CUAT	0.00	0.00	0.00	0.00	224	0
	CUZA	145.42	32.06	94.79	223.09	7,095	1,031,770
	JANO	161.14	20.44	125.74	206.51	5,667	913,180
	LAGU	243.93	89.91	120.82	492.49	4,132	1,007,991
	LLAM	275.16	123.74	113.28	668.33	1,506	414,471
	MALP	0.00	0.00	0.00	0.00	11,298	0
	MAPI	48.43	13.75	28.01	83.71	548	26,546
	MARF	130.98	39.73	73.00	235.00	2,632	344,684
	NMBO	141.58	26.98	97.63	205.32	8,964	1,269,196
	OTME	138.17	45.57	72.82	262.18	1,724	238,171
	SONO	92.35	20.62	59.80	142.61	3,082	284,630
	SUSP	6.48	2.87	2.80	14.98	2,826	18,309
	TOKI	0.11	0.11	0.02	0.55	755	80
	VACE	287.44	28.78	236.29	349.67	11,921	3,426,603
	VACO	40.30	23.09	14.10	115.19	930	37,465
Eastern Meadowlark	ALCO	9.96	2.48	6.15	16.14	11,008	109,660
	ARME	0.53	0.30	0.19	1.54	564	301
	CUAT	2.84	1.19	1.27	6.35	224	636
	CUZA	26.33	3.40	20.45	33.89	7,095	186,792
	JANO	13.61	2.21	9.92	18.68	5,667	77,147
	LAGU	6.27	1.18	4.34	9.05	4,132	25,891
	LLAM	0.53	0.53	0.10	2.99	1,506	805
	MALP	5.43	1.59	3.07	9.58	11,298	61,309
	MAPI	11.73	2.74	7.46	18.46	548	6,430
	MARF	5.25	1.41	3.12	8.83	2,632	13,812
	NMBO	2.90	0.71	1.81	4.65	8,964	26,000

Species	GPCA	Density, D (birds/km^2)	SE(D)	95%LCL (D)	95%UCL (D)	Area (km^2)	Population (birds)
	OTME	3.39	1.76	1.28	8.99	1,724	5,842
	SONO	21.66	4.49	14.46	32.45	3,082	66,765
	SUSP	12.80	5.82	5.43	30.17	2,826	36,173
	TOKI	2.04	0.57	1.19	3.48	755	1,538
	VACE	7.29	0.73	5.99	8.87	11,921	86,881
	VACO	9.67	2.11	6.31	14.80	930	8,985
Grasshopper Sparrow	ALCO	6.26	1.78	3.61	10.86	11,008	68,942
	ARME	0.00	0.00	0.00	0.00	564	0
	CUAT	0.00	0.00	0.00	0.00	224	0
	CUZA	74.19	7.04	61.59	89.36	7,095	526,362
	JANO	26.73	4.13	19.78	36.14	5,667	151,503
	LAGU	66.91	12.09	47.02	95.20	4,132	276,474
	LLAM	11.76	8.62	3.03	45.65	1,506	17,721
	MALP	87.44	12.93	65.38	116.93	11,298	987,833
	MAPI	44.85	5.89	34.68	58.00	548	24,583
	MARF	27.96	6.77	17.47	44.74	2,632	73,581
	NMBO	8.57	1.88	5.59	13.14	8,964	76,850
	OTME	6.54	2.85	2.85	15.01	1,724	11,276
	SONO	35.61	4.57	27.69	45.80	3,082	109,761
	SUSP	34.14	8.33	21.21	54.94	2,826	96,481
	TOKI	6.22	2.23	3.15	12.31	755	4,699
	VACE	22.94	2.38	18.72	28.11	11,921	273,431
	VACO	34.81	8.10	22.14	54.72	930	32,361
Horned Lark	ALCO	17.81	7.17	8.30	38.22	11,008	195,990
	ARME	43.30	13.35	23.74	78.98	564	24,411
	CUAT	49.12	16.97	25.14	95.95	224	11,021
	CUZA	9.98	2.85	5.76	17.30	7,095	70,802

Species	GPCA	Density, *D* (birds/km^2)	SE(*D*)	95%LCL (*D*)	95%UCL (*D*)	Area (km^2)	Population (birds)
	JANO	83.86	16.61	57.05	123.27	5,667	475,233
	LAGU	22.97	6.88	12.90	40.91	4,132	94,937
	LLAM	115.19	54.82	45.24	293.31	1,506	173,519
	MALP	2.16	1.35	0.69	6.74	11,298	24,450
	MAPI	21.05	4.94	13.35	33.17	548	11,537
	MARF	24.19	4.31	17.07	34.28	2,632	63,662
	NMBO	98.09	16.71	70.31	136.83	8,964	879,273
	OTME	48.66	12.08	29.88	79.24	1,724	83,881
	SONO	52.24	7.82	38.97	70.04	3,082	161,016
	SUSP	13.82	2.47	9.73	19.61	2,826	39,047
	TOKI	184.09	17.84	152.22	222.64	755	139,012
	VACE	68.57	6.27	57.33	82.02	11,921	817,462
	VACO	12.12	4.45	6.01	24.42	930	11,266
Lark Bunting	ALCO	34.35	11.95	17.65	66.86	11,008	378,108
	ARME	80.90	38.26	33.03	198.13	564	45,610
	CUAT	9.93	9.94	1.89	52.26	224	2,229
	CUZA	24.41	5.21	16.12	36.95	7,095	173,172
	JANO	106.68	23.55	69.51	163.75	5,667	604,575
	LAGU	53.30	14.49	31.51	90.15	4,132	220,238
	LLAM	97.39	70.61	25.39	373.54	1,506	146,698
	MALP	22.75	6.51	13.07	39.60	11,298	257,018
	MAPI	215.26	37.11	153.77	301.35	548	117,998
	MARF	15.19	5.80	7.34	31.43	2,632	39,980
	NMBO	56.79	16.38	32.55	99.07	8,964	509,088
	OTME	1.56	1.28	0.37	6.55	1,724	2,693
	SONO	8.78	4.59	3.34	23.10	3,082	27,075
	SUSP	92.99	29.89	50.01	172.88	2,826	262,796

Species	GPCA	Density, D (birds/km^2)	SE(D)	95%LCL (D)	95%UCL (D)	Area (km^2)	Population (birds)
	TOKI	40.06	37.38	8.45	189.92	755	30,251
	VACE	24.99	5.92	15.80	39.52	11,921	297,874
	VACO	30.67	13.38	13.47	69.83	930	28,508
Savannah Sparrow	ALCO	52.32	8.58	37.96	72.12	11,008	575,940
	ARME	0.70	0.70	0.13	3.70	564	397
	CUAT	0.35	0.35	0.07	1.84	224	79
	CUZA	73.14	10.00	55.98	95.56	7,095	518,954
	JANO	47.70	8.65	33.50	67.90	5,667	270,296
	LAGU	7.83	2.62	4.13	14.86	4,132	32,361
	LLAM	7.40	5.40	1.92	28.56	1,506	11,143
	MALP	72.27	32.67	30.81	169.51	11,298	816,489
	MAPI	13.46	2.60	9.25	19.61	548	7,381
	MARF	18.13	6.02	9.58	34.29	2,632	47,704
	NMBO	28.75	11.88	13.16	62.81	8,964	257,720
	OTME	2.12	1.57	0.57	7.92	1,724	3,647
	SONO	65.17	11.52	46.14	92.06	3,082	200,875
	SUSP	70.34	29.66	31.60	156.58	2,826	198,792
	TOKI	8.25	2.47	4.63	14.69	755	6,230
	VACE	33.54	4.38	25.98	43.29	11,921	399,785
	VACO	235.66	53.45	151.57	366.41	930	219,082
Sprague's Pipit	ALCO	0.85	0.40	0.35	2.06	11,008	9,391
	ARME	0.00	0.00	0.00	0.00	564	0
	CUAT	1.77	0.87	0.70	4.48	224	397
	CUZA	6.36	1.00	4.68	8.64	7,095	45,139
	JANO	2.58	0.53	1.73	3.84	5,667	14,608
	LAGU	2.53	0.71	1.47	4.35	4,132	10,462
	LLAM	4.01	4.01	0.71	22.45	1,506	6,035

Species	GPCA	Density, D (birds/km^2)	SE(D)	95%LCL (D)	95%UCL (D)	Area (km^2)	Population (birds)
	MALP	3.33	1.70	1.29	8.63	11,298	37,658
	MAPI	0.83	0.29	0.43	1.61	548	455
	MARF	2.90	0.71	1.80	4.67	2,632	7,626
	NMBO	0.32	0.19	0.11	0.93	8,964	2,908
	OTME	0.45	0.45	0.08	2.35	1,724	768
	SONO	2.53	0.79	1.39	4.60	3,082	7,805
	SUSP	0.00	0.00	0.00	0.00	2,826	0
	TOKI	6.95	1.04	5.18	9.32	755	5,249
	VACE	2.52	0.35	1.92	3.30	11,921	30,013
	VACO	9.69	2.01	6.47	14.51	930	9,005
Vesper Sparrow	ALCO	245.60	31.97	190.24	317.06	11,008	2,703,420
	ARME	0.00	0.00	0.00	0.00	564	0
	CUAT	0.33	0.33	0.06	1.76	224	75
	CUZA	247.35	18.01	214.42	285.33	7,095	1,754,953
	JANO	120.78	9.14	104.13	140.09	5,667	684,467
	LAGU	94.64	13.85	71.06	126.04	4,132	391,083
	LLAM	9.08	4.07	3.74	22.02	1,506	13,673
	MALP	194.84	37.08	134.20	282.88	11,298	2,201,221
	MAPI	102.49	11.13	82.84	126.80	548	56,181
	MARF	23.14	5.39	14.72	36.38	2,632	60,886
	NMBO	28.74	4.75	20.81	39.71	8,964	257,677
	OTME	1.68	1.00	0.56	5.02	1,724	2,900
	SONO	118.76	14.77	93.06	151.57	3,082	366,052
	SUSP	134.63	14.40	109.03	166.24	2,826	380,481
	TOKI	8.71	2.85	4.65	16.30	755	6,574
	VACE	104.96	7.21	91.74	120.09	11,921	1,251,292
	VACO	188.66	31.37	136.26	261.23	930	175,390

Species	GPCA	Density, *D* (birds/km^2)	SE(*D*)	95%LCL (*D*)	95%UCL (*D*)	Area (km^2)	Population (birds)
Western Meadowlark	ALCO	5.32	2.66	2.10	13.49	11,008	58,565
	ARME	0.24	0.17	0.07	0.84	564	134
	CUAT	0.12	0.12	0.02	0.62	224	27
	CUZA	2.45	0.67	1.45	4.14	7,095	17,400
	JANO	1.67	0.36	1.10	2.54	5,667	9,470
	LAGU	4.67	1.59	2.44	8.97	4,132	19,317
	LLAM	0.36	0.36	0.06	2.00	1,506	538
	MALP	0.30	0.25	0.07	1.24	11,298	3,355
	MAPI	2.51	0.90	1.27	4.97	548	1,374
	MARF	10.55	1.81	7.55	14.74	2,632	27,759
	NMBO	0.92	0.19	0.61	1.39	8,964	8,290
	OTME	0.24	0.17	0.07	0.84	1,724	411
	SONO	0.14	0.07	0.06	0.36	3,082	439
	SUSP	0.45	0.23	0.17	1.18	2,826	1,281
	TOKI	2.38	0.84	1.21	4.66	755	1,796
	VACE	0.83	0.34	0.39	1.78	11,921	9,872
	VACO	1.74	0.55	0.95	3.19	930	1,616

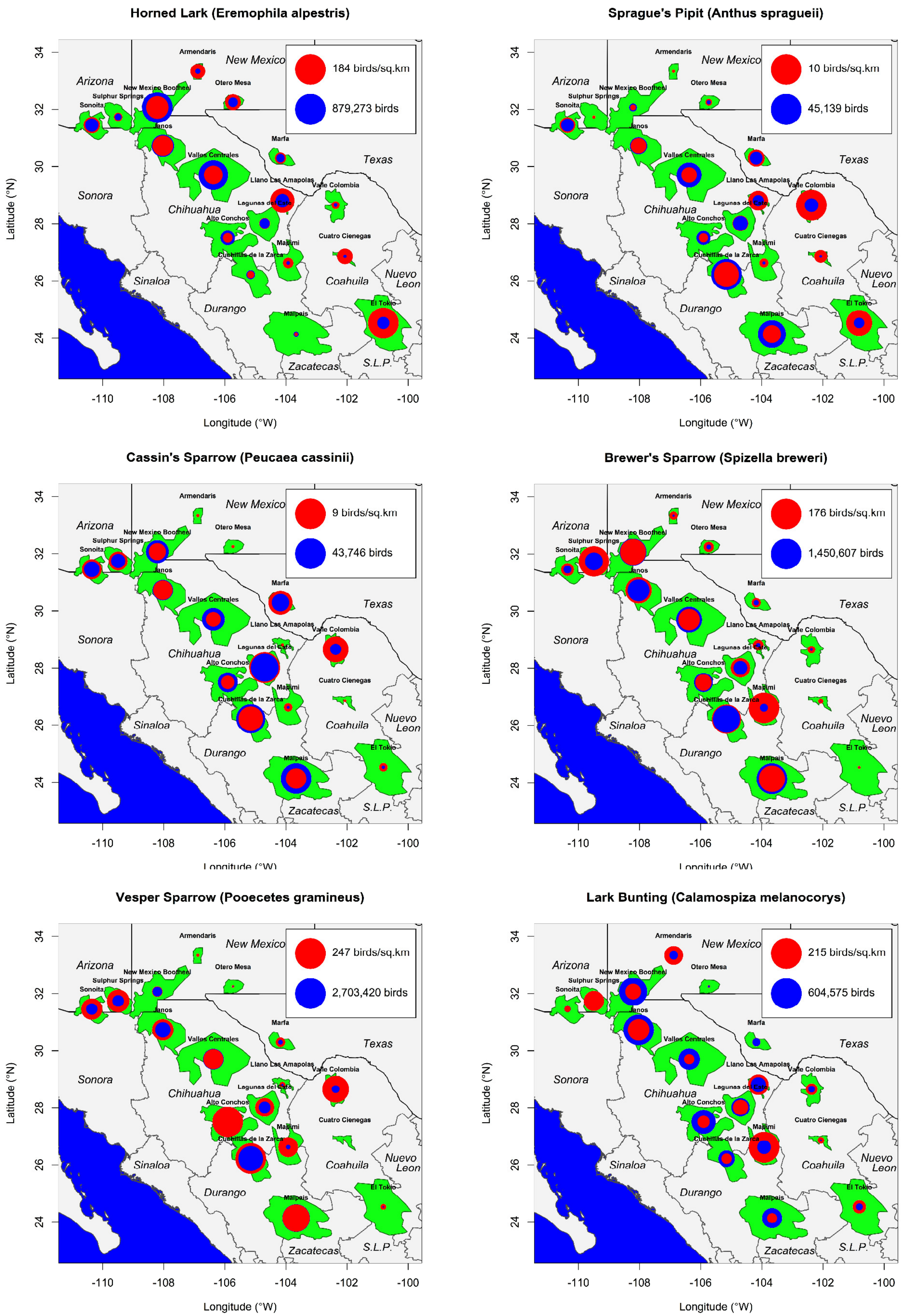
Figure Legends

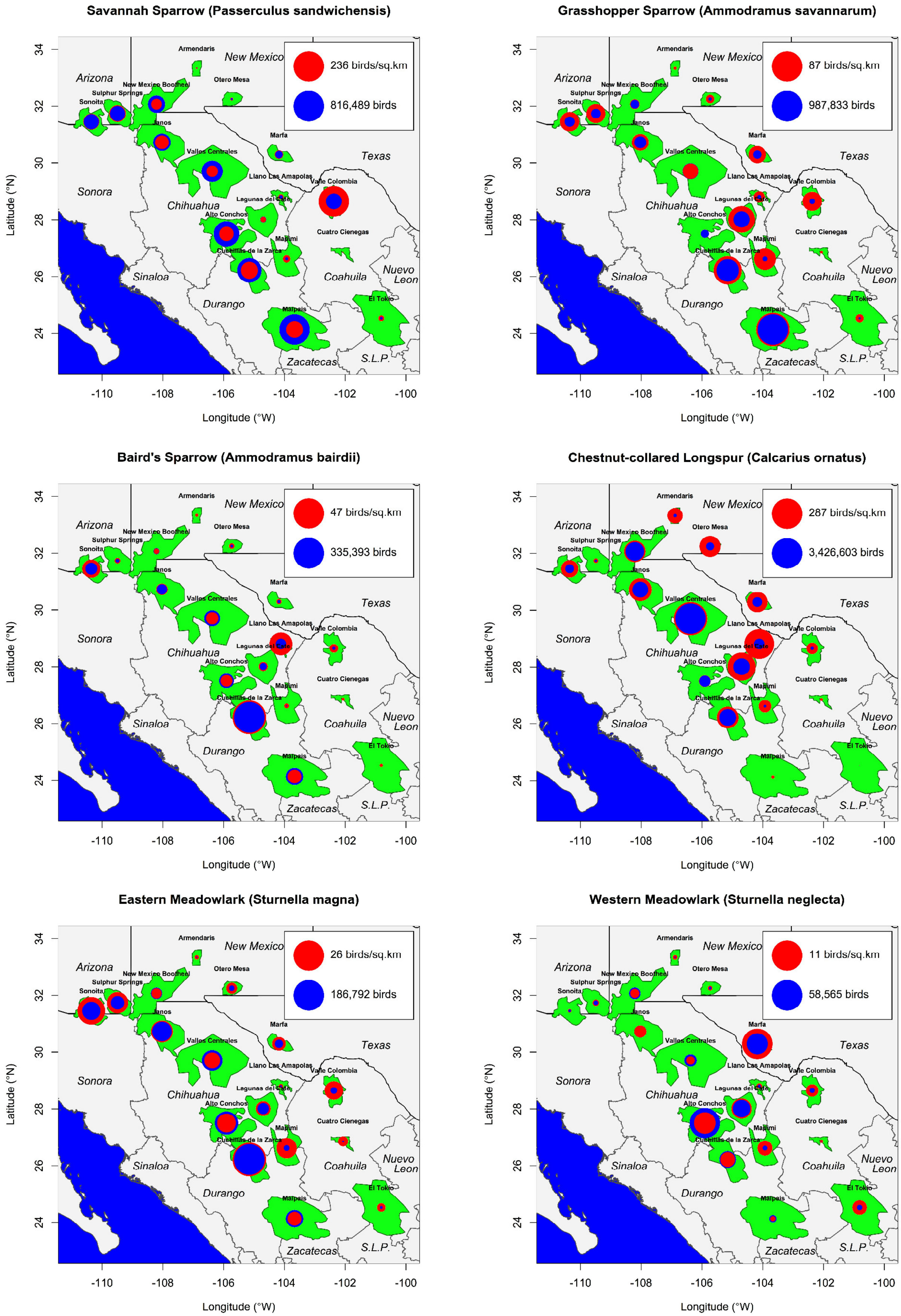
Figure 1. Wintering grassland bird survey blocks in Grassland Priority Conservation Areas (CEC and TNC 2005, Pool and Panjabi 2010) in the Chihuahuan Desert, 2007-2013. Green shading shows the extent of desert grasslands according to INEGI (2003).

Figure 2. Winter distribution of 12 passerine grassland bird species (*sensu* Sauer et al. 2011) in Grassland Priority Conservation Areas (GPCA) of the Chihuahuan Desert of Mexico and southwestern United States. Size of the red and blue circles denote the relative bird density and relative number of birds between GPCAs, respectively. Only Cuchillas de La Zarca, Janos, Mapimí, El Tokio, Valles Centrales and Valle Colombia were surveyed each year during 2007-2013.

FIGURES

Figure 1.


Horned Lark (Eremophila alpestris)
184 birds/sq.km
879,273 birds
Sprague's Pipit (Anthus spragueii)
10 birds/sq.km
45,139 birds
Cassin's Sparrow (Peucaea cassinii)
9 birds/sq.km
43,746 birds
Brewer's Sparrow (Spizella breweri)
176 birds/sq.km
1,450,607 birds
Vesper Sparrow (Pooecetes gramineus)
247 birds/sq.km
2,703,420 birds
Lark Bunting (Calamospiza melanocorys)
215 birds/sq.km
604,575 birds
Latitude (°N)
Longitude (°W)
New Mexico
Arizona
Texas
Sonora
Chihuahua
Sinaloa
Durango
Coahuila
Nuevo Leon
Zacatecas
S.L.P.
Armendaris
Otero Mesa
New Mexico Bootheel
Sulphur Springs
Sonoita
Janos
Marfa
Valles Centrales
Llano Las Amapolas
Valle Colombia
Lagunas del Este
Alto Conchos
Cuatro Cienegas
Mapimi
Cuchillas de la Zarca
El Tokio
Malpais
Figure 2.


Savannah Sparrow (Passerculus sandwichensis)
236 birds/sq.km
816,489 birds
Grasshopper Sparrow (Ammodramus savannarum)
87 birds/sq.km
987,833 birds
Baird's Sparrow (Ammodramus bairdii)
47 birds/sq.km
335,393 birds
Chestnut-collared Longspur (Calcarius ornatus)
287 birds/sq.km
3,426,603 birds
Eastern Meadowlark (Sturnella magna)
26 birds/sq.km
186,792 birds
Western Meadowlark (Sturnella neglecta)
11 birds/sq.km
58,565 birds
Latitude (°N)
Longitude (°W)
Arizona
New Mexico
Texas
Sonora
Chihuahua
Sinaloa
Durango
Coahuila
Nuevo Leon
Zacatecas
S.L.P.
Armendaris
Otero Mesa
New Mexico Bootheel
Sulphur Springs
Sonoita
Janos
Marfa
Valles Centrales
Llano Las Amapolas
Valle Colombia
Lagunas del Este
Alto Conchos
Cuatro Cienegas
Mapimi
Cuchillas de la Zarca
El Tokio
Malpais