Winter monitoring of grassland birds in the Chihuahuan Desert

Bird Conservancy of the Rockies
2018 Annual Report

A grasshopper sparrow is released after being outfitted with a radio transmitter. Photo by Isaac Morales.

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Suggested citation:
Strasser, E. H., M.D. Correll, T. L. George, and A.O. Panjabi. 2018. Identifying limiting factors for wintering grassland birds in the Chihuahuan Desert. 2018 annual report. Bird Conservancy of the Rockies, Brighton, Colorado, USA.

Connecting People, Birds and Land

BIRD CONSERVANCY OF THE ROCKIES

Mission: Bird Conservancy of the Rockies conserves birds and their habitats through an integrated approach of science, education and land stewardship. Our work radiates from the Rockies to the Great Plains, Mexico and beyond. Our mission is advanced through sound science, achieved through empowering people, realized through stewardship and sustained through partnerships. Together, we are improving native bird populations, the land and the lives of people.

Vision: Native bird populations are sustained in healthy ecosystems

Bird Conservancy of the Rockies conserves birds and their habitats through an integrated approach of science, education, and land stewardship. Our work radiates from the Rockies to the Great Plains, Mexico and beyond. Our mission is advanced through sound science, achieved through empowering people, realized through stewardship, and sustained through partnerships. Together, we are improving native bird populations, the land, and the lives of people.

Core Values:

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.

Goals:

1. Guide conservation action where it is needed most by conducting scientifically rigorous monitoring and research on birds and their habitats within the context of their full annual cycle.
2. Inspire conservation action in people by developing relationships through community outreach and science-based, experiential education programs.
3. Contribute to bird population viability and help sustain working lands by partnering with landowners and managers to enhance wildlife habitat.
4. Promote conservation and inform land management decisions by disseminating scientific knowledge and developing tools and recommendations.

Meet the Team

Erin H. Strasser, MS has led Bird Conservancy's winter demographic work in the Chihuahuan Desert since 2012. Erin coordinates partners and funding across three sites in Mexico and one in Texas and is responsible for project development, coordination, analysis, and dissemination of results. She is also an FAA-licensed remote pilot.

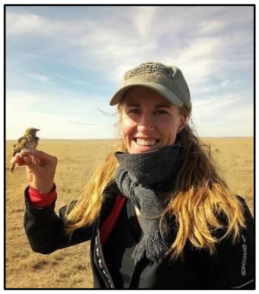
Maureen Correll, PhD joined Bird Conservancy in 2016 and is the principle investigator of Bird Conservancy's full-annual-cycle study of grassland bird demographics. Mo also started Bird Conservancy's effort to use Unmanned Aircraft Systems as tools to collect habitat information for grassland birds on the breeding and wintering grounds. She is also an FAA-licensed remote pilot.

Arvind O. Panjabi, MS joined Bird Conservancy in 2004 and is the founder of Bird Conservancy's work in Latin America. His efforts to explore the demographics of grassland songbirds across their life cycles have provided a conceptual vision for the full-annual-cycle analysis and conservation of grassland birds in North America. Arvind also leads our stewardship program on the wintering grounds in Mexico.

Irene Ruvalcaba Ortega, PhD is a professor in the School of Biological Sciences at Universidad Autónoma de Nuevo León (UANL). She has partnered with Bird Conservancy projects on wintering grassland birds since 2006 and is responsible for the grassland bird winter survival project in Valle Colombia, Coahuila. Irene advises several students conducting research for this project.

José Hugo Martínez Guerrero, PhD is a professor in the School of Veterinary Medicine and Animal Husbandry at Universidad Juárez del Estado de Durango (UJED). He has partnered with Bird Conservancy since 2007 and conducted his doctoral work on Baird's sparrows. He is responsible for the Cuchillas de la Zarca field site in Durango and advises several graduate students involved in this project.

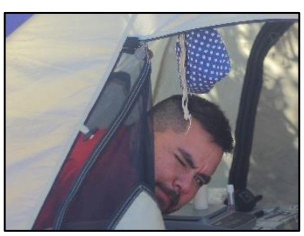
Martín Emilio Pereda Solís, PhD is a professor in the School of Veterinary Medicine and Animal Husbandry at UJED. Martin has partnered with Bird Conservancy since 2007 and provides support for the Cuchillas de la Zarca field site. He also advises several graduate students involved in the project.



Mieke Titulaer, PhD is a Research Scientist at Sul Ross State University's (SRSU) Borderland Research Institute (BRI) and oversees work at the Marfa, Texas site. She advises two graduate students collecting data at this site. Mieke's doctoral thesis investigated winter diet of Baird's and grasshopper sparrows (Titulaer et al. 2017, 2018a).

Ricardo Canales, PhD is a professor in the School of Biological Sciences at UANL. His lab is investigating genetic diversity using toll-like receptors and exploring parasite loads of our focal species. Ricardo advises several graduate students on this project.

Daniel Sierra Franco, PhD recently completed his PhD at UJED and has been involved in Bird Conservancy projects since 2008. His PhD work focused on sparrow home range characteristics and morphometric methods to determine sex of Baird's and grasshopper sparrows. Daniel coordinates field activities at Cuchillas de la Zarca and assists with field work.



Samuel Arroyo Arroyo, **MS** is a doctoral student at UJED who is studying historic genetic diversity of grasshopper sparrows. He is also interested in looking at the variation in genetic structure between wintering populations at the three field sites in Mexico.

Alexander Peña-Peniche is a doctoral student at the Instituto de Ecología (INECOL) and UANL. He is analyzing habitat use and winter home range of Baird's and grasshopper sparrows at the Valle Colombia GPCA. He is also modeling the climatic niche of Baird's sparrows throughout their annual cycle (Peña-Peniche et al. 2018).

Luz María Salazar MS is a doctoral student at UJED who is developing a bioenergetics model to estimate the link between caloric availability in the seed bank and wintering bird carrying capacity.

Andrea Montes Aldaba is a master's student at UJED who is studying how remote sensing and drones can be used to measure wintering habitat for grassland sparrows in Cuchillas de la Zarca (Montes-Aldaba et al. 2018).

Denis Perez is a master's student at SRSU. She is investigating limiting factors for winter survival of Baird's and grasshopper sparrows at the Marfa field site. She is also exploring how vegetation cover affects microclimate conditions that may impact survival.

Fabiola Baeza-Tarin is a master's student at SRSU. Fabby is evaluating bird-habitat relationships for Baird's and grasshopper sparrows in the Marfa grasslands. She is also using remote sensing to document historical shrub encroachment to identify priority areas for restoration in these grasslands.

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Executive Summary

Grassland songbirds are among the most rapidly-declining bird assemblages in North America. Over half of the species in this group show long-term negative trends, and species wintering in the Chihuahuan Desert grasslands of the southwestern United States and northern Mexico are declining more quickly than grassland birds that winter elsewhere. Since 2002, Bird Conservancy of the Rockies has spearheaded work monitoring grassland birds on their wintering grounds to explore how these birds are limited during the non-breeding season. To date, Bird Conservancy has completed a comprehensive survey of grassland birds in priority grassland areas of the Chihuahuan Desert (2007 – 2013) and in 2012 initiated a regional monitoring project to radio-track grassland birds on their wintering grounds to measure survival for these species and explore how environmental variables may affect survival. This work focuses on the Baird's sparrow (*Ammodramus bairdii*), grasshopper sparrow (*Ammodramus savannarum*), and Sprague's pipit (*Anthus spragueii*), all grassland specialist songbirds that are declining across North America. Our initial monitoring site at Rancho El Uno in Chihuahua, Mexico was established in 2012 and our work has since expanded to include an additional three field sites across the Chihuahuan Desert including the Mexican states of Durango (established 2013), Coahuila (established 2014), and the US state of Texas (established 2016). These sites are run with the aid of collaborators from Universidad Juárez del Estado de Durango (UJED), Universidad Autónoma de Nuevo León (UANL) and Sul Ross State University's Borderlands Research Institute (BRI) respectively and support several graduate student projects. At these sites, we collected data on survival rates and causes of mortality for radio-tagged Baird's and grasshopper sparrows.

We found that the primary cause of mortality was predation by loggerhead shrikes (*Lanius ludovicianus)* and diurnal raptors. We also found that winter survival rates vary across winters and sites and that survival is partially driven by shrub cover and minimum daily temperature. We also estimated the size requirements of home ranges, movement patterns, and habitat preferences for our focal species. We found that wintering sparrows displayed multiple movement patterns on the wintering grounds, including individuals that maintain a more sedentary lifestyle within fixed home ranges and others move over larger areas or shift home ranges. Across all of these groups, daily movement of Baird's and grasshopper sparrows was partially explained by minimum daily temperature. Additionally, we found that Sprague's pipits occupy home ranges almost twice as large as sparrows, and pipits also select areas with more bare ground than what is available on the landscape. We are also exploring movements and habitat use of loggerhead shrikes, a primary predator of grassland songbirds. This species selects areas with more and taller shrubs, providing a link between our observations of low sparrow survival near taller shrubs, predation of sparrows by shrikes, and shrike habitat selection. Finally, in 2017 we introduced the use of unmanned aircraft systems (UASs, or drones) to systematically map habitat at our sites and create 3D surface and vegetation maps for all of our study areas.

Highlights of 2018

Estimating survival for Baird's and grasshopper sparrows

Figure 1: A grasshopper sparrow (left) and Baird's sparrow captured and tagged in the Chihuahuan Desert. Photo by Erin Strasser

Our survival estimates indicate that adult survival for both Baird's and grasshopper sparrow (Figure 1) is highly variable among winters and sites. The primary cause of mortality in wintering birds is predation by loggerhead shrikes and raptors. We also found from analysis of our first two years of data (2012-2014) that survival can vary over the course of a winter and is lowest following bouts of cold weather and storms, especially snow which can expose birds to energetic stress and greater predation risk. Taller shrubs were implicated as drivers of low winter survival for grasshopper sparrows, possibly because shrubs can provide perches for many avian predators such as shrikes. These findings were recently published in the Journal of Field Ornithology (Macias-Duarte et al. 2017). Identifying the finer-scale thresholds of shrub tolerance in birds (e.g. 1% shrub cover vs. 5% shrub cover) is difficult due to the difficulty of measuring sparse, individual shrubs on the landscape and relating this information back to bird data. To address this need, Bird Conservancy is now integrating Unmanned Aircraft Systems (UASs, or drones) to measure shrub cover and other habitat conditions (see below). These data on winter survival will eventually be used in conjunction with demographic data being collected by Bird Conservancy on these species during the breeding season to populate an Integrated Population Model to identify where in their annual cycle grassland bird populations are most limited.

VHF tagging of Sprague's pipits

We initiated an effort to tag Sprague's pipits (*Anthus spragueii;* Figure 2) with very high frequency (VHF) radio transmitters in 2014 to identify home range size requirements, movement patterns, and microhabitat preferences of this understudied species. To date we have honed capture methods for this species and as a result tagged 9 pipits across our 4 study sites. From analysis of these data we found that average home-range size for pipits on the wintering grounds is larger than that of wintering Baird's and grasshopper sparrows (Strasser et al. in review). This highlights the difference in area requirements across species and the need for conservation and management of grassland birds considering these differing habitat requirements. We also found that Sprague's pipits selected areas with more bare soil and less "other" cover, including duff, litter, animal excrement, and rocks. This study is the first to successfully monitor individual pipits using radio tracking methods on the wintering grounds and creates baseline knowledge for the further development of additional, robust studies.

Figure 2: A Sprague's pipit on the wintering grounds. Photo by José Hugo Martínez

Application of UAS's for vegetation mapping

In 2017 we began exploring the utility of UASs to improve our data collection techniques (Figure 3). Imagery collected via UAS may be a useful tool to characterize habitat of wintering grassland birds (Cunliffe et al. 2016). In particular, we hope to use these data to identify individual shrubs on the landscape to better understand the relationships between habitat use and shrubs across our different focal species. We can then use this information to inform shrub

Figure 3: A) Launching the senseFLY eBee Plus drone (photo by Erin Strasser). B) The eBee in flight (photo by Erin Strasser). C) Erin Strasser triumphant following successful completion of data collection (photo by Mariana Martínez).

removal experiments and rangeland management strategies in the Chihuahuan Desert.

Identification of movement strategies for Baird's and grasshopper sparrows

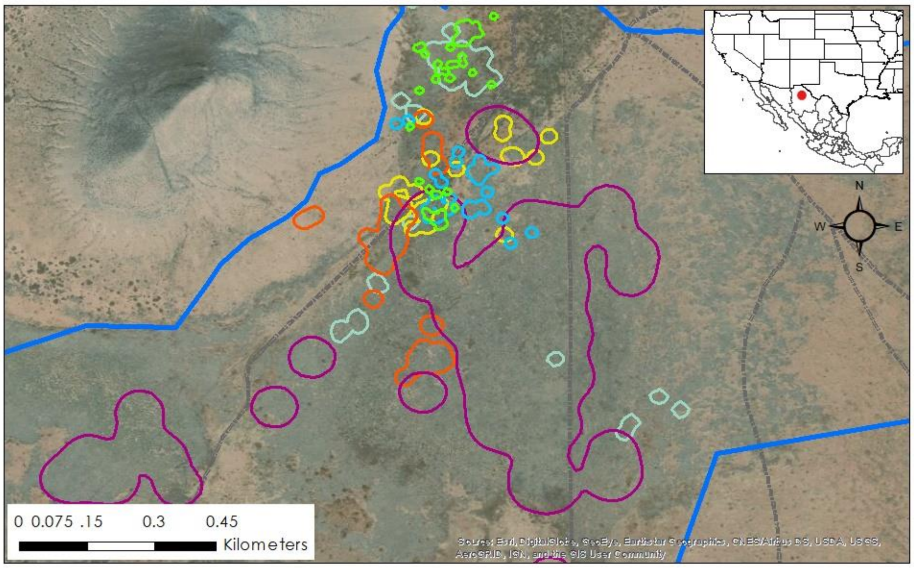

Figure 4: Examples of variation in Baird's and grasshopper sparrow home ranges during winter in the Chihuahuan Desert. Each color represents a different individual marked with a radio-transmitter.

We recently completed analyses of Baird's and grasshopper sparrow movement patterns on the wintering grounds (Figure 4). In the field, we have observed that some individuals roam across the study area while others remain in smaller home ranges throughout the winter. Using data collected since 2012 at the Janos, Chihuahua site, we explored our hypothesis that Baird's and grasshopper sparrows maintain discrete movement strategies by analyzing a suite of home-range and movement metrics derived from telemetry data to quantify and classify Baird's and grasshopper sparrows space-use patterns. Our results suggest that these species display three different space-use strategies on the wintering grounds. Some individuals remain sedentary within a smaller home range, others shift home ranges, and some are nomadic within the study area. These three classifications fall within a continuum of movement patterns spanning from small movements within a home range to large-scale wandering, however we found that daily distance moved was best explained by daily minimum temperature at the study location. As daily minimum temperature increased, birds moved longer distances. Our results suggest that movement strategies may be individualistic but also reflect behavioral or physiological responses to their environment common across all individuals.

Project background

Grassland songbirds as a group are in steep decline (Sauer et al. 2017, Table 1). Unfortunately, the factors limiting these populations across their life cycles are poorly understood. Increasing evidence suggests non-breeding survival in migratory species may have a particularly strong influence on population trends, especially in birds (Calvert et al. 2009, Macías-Duarte and Panjabi 2013, Morrison et al. 2013). Despite this, knowledge of migratory birds on their wintering grounds is sparse, and there is limited information to help inform conservation of these species on their wintering grounds.

Grassland birds that winter in the Chihuahuan Desert are particularly imperiled. Over 90% of migratory grassland species in western North America overwinter in the rapidly-shrinking grasslands of the Chihuahuan Desert, and are declining more rapidly than their counterparts that winter elsewhere (North American Bird Conservation Initiative 2017). Conversion to agriculture is the leading cause of this grassland loss, and is likely contributing to the documented population declines of grassland birds (Figure 4, Pool et al. 2014). In addition, shrub encroachment, soil erosion, and loss of perennial grass cover from mismanaged grazing and climate change (Gremer et al. 2015) contribute further to grassland degradation in this region. This continued habitat loss and degradation make it particularly important to gather information that can help guide management practices to benefit grassland bird on the wintering grounds.

Figure 4: Loss of grasslands due to conversion to center-pivot agriculture is common in the Chihuahuan Desert, particularly in Mexico. Image from Pool et al 2014.

Table 1: Current North American population estimates (PIF Database), annual BBS trend 1966-2015 (Sauer et al. 2017), and total population declines 1966-2015 derived from BBS trends for three species of grassland songbird wintering in the Chihuahuan Desert.

Species	Population	Annual decline (%/yr)	Total decline (%)
Baird's sparrow	2,000,000	2.93	75.5
grasshopper sparrow	30,000,000	2.83	76.7
Sprague's pipit	900,000	3.50	82.5

Bird Conservancy of the Rockies has worked to conserve high-priority grassland birds of western North America in collaboration with partners from Mexico, the US, and Canada for over a decade. This work, first initiated in 2002, includes identification of important wintering areas (Pool and Panjabi 2011), bird-habitat relationships (Pool et al. 2012), and collaboration with landowners in critical areas to implement best practices, secure conservation agreements, and restore habitat for declining grassland species. Bird Conservancy's first effort to explore winter demographics of grassland birds was a pilot investigation studying vesper sparrow (*Pooecetes gramineus)* winter survival in Chihuahua during winters 2009 and 2010. Macías-Duarte and Panjabi 2013 demonstrated that habitat can influence winter survival rates. Following this pioneering work, we determined that radio telemetry was a viable option for tracking small-bodied birds in during winter in the Chihuahuan Desert grasslands. Bird Conservancy initiated a similar investigation focused on the smaller and steeper declining Baird's and grasshopper sparrows in 2012. Our goal was also to include Sprague's pipits in this study as they are of particular conservation concern, which we began tracking in 2015. To better understand the relationship between shrubs and predation of grassland birds, we also began tracking loggerhead shrikes in 2015. The goals of this ongoing work is to understand the causes of grassland bird decline and effectively inform grassland restoration and management efforts on the wintering grounds.

Bird Conservancy's monitoring efforts for grassland birds on the wintering grounds is part of a larger initiative to identify factors limiting population growth across their full annual cycle. On the wintering grounds, we are investigating Baird's and grasshopper sparrow survival at four sites in the Chihuahuan Desert (three in Mexico, one in Texas). Data collection is coordinated across these sites and we hold annual training workshops to orient new technicians, calibrate vegetation measurements across observers, and allow collaborators on the project to meet and discuss efforts moving forward. Bird Conservancy also maintains a mirrored demographic monitoring program on the breeding grounds for these species in the Northern Great Plains (Figure 5) and also leads efforts to identify stopover sites between the breeding and wintering grounds that these species use during spring and fall migration. With these data we plan to develop an Integrated Population Model (IPM, e.g. Hostetler et al. 2015) that can help us to determine which demographic rates influence population trends across their life cycles as well as what environmental factors can influence those rates. The long-term data from our four sites across the Chihuahuan Desert is a unique dataset that will directly contribute to the full-annual cycle conservation of grasslands birds in North America.

With the aid of our partners at Investigación, Manejo y Conservación de Vida Silvestre (IMC-VS), Pronatura Noreste, Rio Grande Joint Venture, and UANL, Bird Conservancy is also formalizing and expanding a Sustainable Grazing Network (SGN) in northern Mexico. The SGN includes a network of ranches that protect and improve habitat for grassland wildlife. We hope to guide the SGN's management and conservation strategies with meaningful recommendations based upon real-life data on grassland birds.

Figure 5: Recently-hatched Baird's sparrow nestlings and an adult male Baird's sparrow singing on his territory in the Northern Great Plains.

Objectives

Our long-term goal for our work in the Chihuahuan Desert is to improve knowledge of when, where, and how grassland bird populations are limited on the wintering grounds. This information can then guide on-the-ground management and investment of conservation dollars for the greatest long-term impact on population growth. To this end, this project is designed to fill existing knowledge gaps for grassland birds on their wintering grounds in the Chihuahuan Desert grasslands of the southwestern USA and northern Mexico.

The specific objectives for our project are:

1) Estimate survival rates of wintering grassland birds including Baird's sparrows, grasshopper sparrows, and Sprague's pipits using radio-telemetry (as allowed by sample size)

2) Identify causes of mortality for wintering grassland birds

3) Examine the influence of vegetation characteristics, climate, bird density, and individual characteristics (sex, condition) on winter survival

4) Investigate grassland bird movement patterns and drivers of movement on the wintering grounds for Baird's and grasshopper sparrows and Sprague's pipits

5) Share results with Bird Conservancy's network of Sustainable Grazing Network ranches and Private Lands Stewardship Biologists to better inform shrub removal and grassland restoration projects.

6) Inform an Integrated Population Model to assess how vital rates and environment during various stages of the life cycle influence population size and growth across years.

Field sites

Our field sites are located within Grassland Priority Conservation areas (GPCAs) which identify areas of contiguous grassland habitat across the Great Plains from Canada to Mexico (Pool and Panjabi 2011). We used winter surveys completed by Bird Conservancy between 2007 and 2013 across GPCAs in the Chihuahuan Desert to inform field site selection for this project(CEC 2013). Our four study areas are all located on private ranches that maintain high densities of Baird's and grasshopper sparrows (Figure 6).

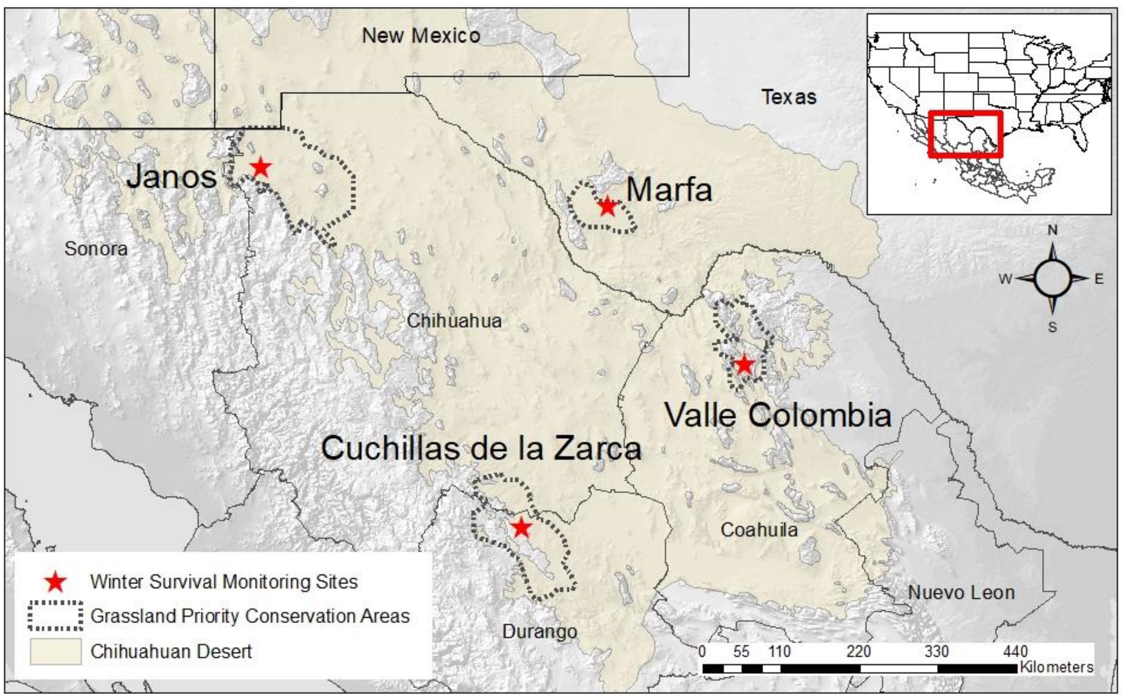

Figure 6: Bird Conservancy study sites for demographic monitoring of grassland birds on the wintering grounds.

We established study plots within each of our study areas based upon the confirmed presence of target species, prior sparrow banding and tracking locations, and individual site characteristics (shrub density < 25%, major roads, and ranch boundaries). All are periodically grazed by bison (*Bison bison*) or domestic cattle.

The Chihuahuan Desert has an arid climate and the majority of precipitation falls during the late-summer monsoons (July-October) which can be highly localized. These rains drive timing and growth of perennial grass species used for food and cover by Baird's and grasshopper sparrows in the Chihuahuan Desert. During winter, the region can receive small amounts of snow and rain. Mean annual precipitation is 235 mm (9.3 in). Elevations range from 600 -1,600 m (900-5,000 ft) resulting in generally cooler temperatures (mean annual temperature is 18^{o}C/64^{o}F) than desert environments such as the adjacent Sonoran Desert. In winter, nighttime temperatures often drop below freezing and grasslands are subject to light frosts.

Rancho El Uno: Chihuahua Mexico

Our study plots within the Janos GPCA are on a private ranch located near Janos, Chihuahua (Figure 7). Rancho El Uno, previously managed by The Nature Conservancy, was recently acquired by Fondo Mexicano para la Conservación de la Naturaleza (FMCN). Bird Conservancy has partnered with leadership at this ranch to study grassland birds on this site since 2007, including transect-based monitoring of grassland birds, job training for Mexican biologists (>100 to date) in grassland bird identification and monitoring, hosting the Grasslands Live distance learning program for the US Forest Service, and facilitating habitat management projects such as shrub removal and escape ramps for wildlife through partnership with IMC-VS. Bird Conservancy began monitoring winter survival of Baird's and grasshopper sparrows at this site in November of 2012. The study plot measures 999 ha (2,468 ac) and is made up of grasslands characterized by grasses of the genera *Aristida*, *Bouteloua*, *Eragrostis*, *Panicum, Pleuraphis* and *Bothriochloa*, with shrub species including *Ephedra trifurca* and *Prosopis glandulosa*. Elevation is ~1400 m. A reintroduced herd of American Bison (*Bison bison)* as well as domestic cattle graze within the study area in low densities. This site is within the Janos Biosphere Reserve, Mexico's only grassland-focused Biosphere reserve.

Figure 7: Study site in Janos Chihuahua. Photo by Erin Strasser.

Cuchillas de la Zarca: Durango, Mexico

Our study plots within the Cuchillas de la Zarca GPCA (Figure 8) are located on two private ranches under the same family ownership. This site was added in winter 2013-14 and partners from the UJED oversee all field logistics. This plot is 724 ha (1789 ac) and is split into two sub-plots. Depending on bird densities, monitoring does not always occur at both plots each winter as birds may be absent from one due to over-grazing or drought. Several graduate and undergraduate students are completing their theses based on data collected at this site. Projects include assessing the relationship between soil seed bank and sparrow habitat use, sex determination using morphometrics, drone imagery collection (Montes-Aldaba et al. 2018), and a recently-discovered breeding population of grasshopper sparrows. Habitat is characterized by *Aristida*, *Bouteloua*, *Mulhenbergia*, *Panicum,* and *Bothriochloa grasses*. The shrub community is dominated by species within the genera *Juniperus, Acacia,* and *Prosopsis. Elevation is ~1800 m.*

Figure 8: Study site in Cuchillas de la Zarca, Durango. Photo by Erin Strasser

Rancho Valle Colombia: Coahuila, Mexico

The Valle Colombia GPCA field site in the Mexican state of Coahuila is located on a private ranch and was added in winter 2014-15 (Figure 9). Partners from UANL handle logistics at this site. The study site is 1238 ha (3059 ac) and consists of 4 plots however in some winters birds have not been present in certain plots due to cattle grazing or drought. We therefore monitor strategically within this study area to obtain an appropriate sample size of birds. Graduate and undergraduate students also work on projects at this site including climactic niche modeling of grassland birds (Peña-Peniche et al. 2018), site specific survival and movements, and loggerhead shrike monitoring. This site is located within a valley in the Sierra Madre Oriental at ~1200 m. Grasslands are characterized by species within the genera *Bouteloua* and Aristida. Shrubs are sparse on this landscape but when present are included in the genus *Prosopsis*.

Figure 9: Study site in Valle Colombia, Coahuila. Photo by Hector Garcia

Marfa Grasslands-Marfa, Texas

Bird Conservancy began monitoring at Mimm's Ranch within the Marfa GPCA in collaboration with Sul Ross State University's Borderlands Research Institute (BRI) and funded by Texas Parks and Wildlife in 2016 (Figure 10). Mimms Ranch is located in Marfa, Texas and is owned and operated by the Dixon Water Foundation. It encompasses 4,390 ha divided in 30 rotationally-grazed pastures and one 858.3 ha pasture that is continuously grazed by 30 cattle. We monitor birds on one plot within the continuously-grazed area (289 ha/ 714 ac) and at one plot in a rotationally-grazed area (431 ha/1065 ac). Two graduate students from Sul Ross conduct research projects at this site, including the measurement seed availability and microclimate measurement using temperature loggers (Titulaer et al. 2018b) and estimation of home range requirements. The study area is dominated by grass species within the genera *Bouteloua and* Aristida, with very minimal cover by curly mesquite (*Hilaria belangeri*) and *Yucca*. Elevation is ~1400 m.

Figure 10: Study site in Marfa, Texas. Photo by Erin Strasser.

Field methods

Protocol and training

Figure 11: A group of technicians, professors, and BCR staff attend a training workshop at Rancho El Uno. Photo by José Hugo Martínez

We standardized field protocols across our study sites for measurement of bird survival, movement, and density as well as vegetation characteristics. Our protocols are based on review of existing literature and our continued experiences in the field as the project has progressed. Bird Conservancy holds a training and information-sharing workshop with partners and their field crews each winter prior to the beginning of the field season (Figure 11). At these workshops we covered data collection and management protocol, field methods including bird capture, banding, and tagging, and calibration of observer estimation and identification of vegetation cover. This workshop also provided an opportunity for graduate students to share preliminary results of their investigations related to this project. Following this workshop, teams returned to their sites and began bird capture and monitoring which continued throughout the winter.

Capture methods

We have trapped and monitored birds between early December and mid-March since the initiation of our project (2012-2018). Each year we used a flush-netting technique made up of an array of 3-5 nets placed in a straight line within the study area boundaries. We formed semi-circles up to 200 m away from the nets using groups of 5-20 people and slowly walked toward the nets to flush birds (Figure 12).

We used 2 m bamboo poles fitted with bright flagging to discourage birds from flying out of the flush-net circle during the group's approach to the net. In some cases, we also tossed brightly-colored fabric frisbees above the birds to limit them from flying over the net (Figure 13). The VHF transmitters we deploy on our focal species have a maximum battery life of 55 days. We therefore recaptured birds each January during daylight hours to replace transmitters before battery senescence. We also recaptured tagged birds in March to remove tags. During the recapture efforts, two observers first triangulated the tagged bird using radio telemetry methods (see below).

Figure 12: A group of technicians, professors, volunteers, and Bird Conservancy staff form a semi-circle around a line of mist-nets to capture grassland birds. Photo by Erin Strasser

We then set up several nets 10-50 meters away from the located bird and followed identical capture methods to recapture the tagged birds and replace or remove their transmitter. We recaptured individuals of Sprague's pipits under low-light conditions (early morning or late evening) because Sprague's pipits seem to flush vertically to avoid nets when light-levels are brighter. We attempted to maintain visual contact

Figure 13: Mist-nets are set up in Janos, Chihuahua to capture wintering birds while fabric frisbees are helpful for maintaining birds from flying over the net. Photos by Greg Levandoski and Eduardo Alvarez.

with the moving pipit while the remainder of the crew quietly approached. In one case, we succeeded after several failed recapture attempts with one individual when observers held net poles and crouched low to the ground, elevating and then rotating the nets at a 45° angle towards the ground as the bird flushed and flew toward the net.

Loggerhead shrikes were trapped using a walk-in trap. This trap, designed specifically for shrikes was baited with a domestic mouse or house sparrow protected within a mesh cage (Craig 1997, Figure 14). Shrikes entered the trap which triggered a door to close. A link to a video of this process can be found here.

Figure 14: A loggerhead shrike entering and captured within a walk-in-trap. Photos by Erin Strasser and Susan Craig,

Banding data collection

We banded all captured birds with a USGS aluminum band and collected standard morphometric measurements (wing cord, tail length, culmen length, tarsus length, scored fat) and weighed birds to the nearest 0.1 g (Figure 15). We collected one tail feather (retrix 3) to genetically determine sex of sparrows following Fridolfsson and Ellegren (1999). We determined sex of shrikes following Sustaita et al. (2014).

Figure 15: Technicians band and measure a grasshopper sparrow. Photo by Eduardo Alvarez.

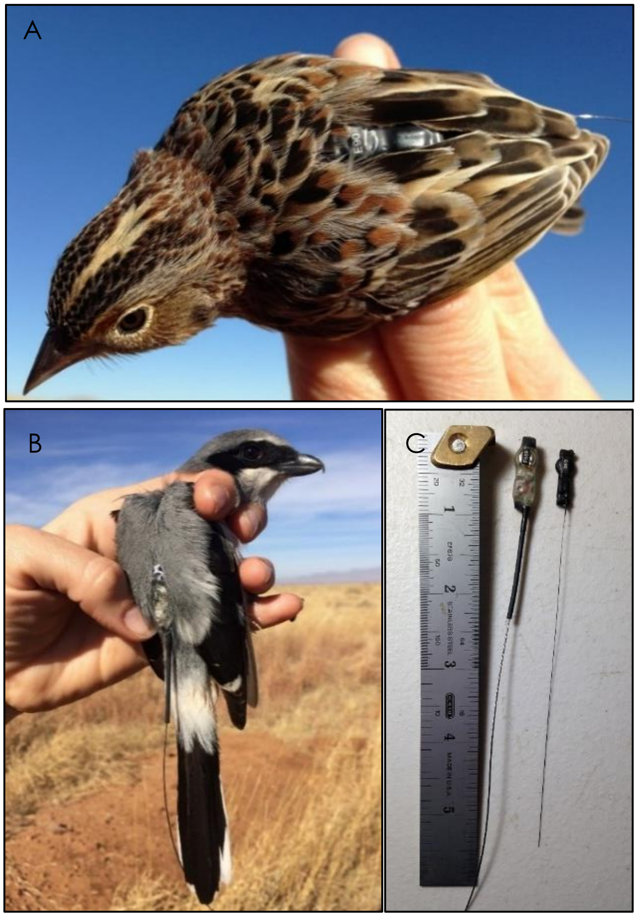

Figure 16: A) A grasshopper sparrow and B) loggerhead shrike outfitted with radio-transmitters. C)comparison of shrike (left) and sparrow/pipit (right) transmitters. Photos by Erin Strasser.

Radio telemetry: transmitter attachment and radio-tracking

We outfitted Baird's and grasshopper sparrows, Sprague's pipits, and loggerhead shrikes with radio transmitters (Figure 16) to confirm survival status, track daily movements, record habitat use, and identify causes of mortality for individual birds. At capture, sparrows and pipits were fitted with 0.5-0.6 g radio-transmitters with uncoated 13 cm antennas (PicoPip Ag379, Biotrack Ltd, Dorset, UK), each producing a unique radio frequency. We tagged shrikes with larger tags (Pip Ag376, Biotrack Ltd, Dorset, UK) that were coated with resin for added durability. We used a figure-eight leg loop harness of 1mm nylon coated elastic to attach transmitters (Rappole and Tipton 1991). Each bird was fitted with a harness unique to its body size. We secured harnesses with a square knot coated with a small drop of superglue. We minimized feather displacement to reduce thermoregulatory costs of transmitters. Total transmitter and harness weight did not exceed 4% of bird mass.

We tracked birds daily using 3- or 5-element Yagi antennas and Biotracker receivers (Biotrack Ltd, Dorset, UK). We tagged individuals between 0730-1800. We then recorded the location of individuals at different times of day within this window across the life of their transmitter to avoid time-of-day effects. We tracked birds using triangulation before approaching the birds' perceived location. Briefly, after obtaining a signal, we walked in an arc or circle around the birds' perceived location while determining the strongest signal and generating mental bearings. We repeated this technique until the bird was observed or we fixed its location (Figure 17). We then recorded the location each tracked bird using a handheld GPS unit.

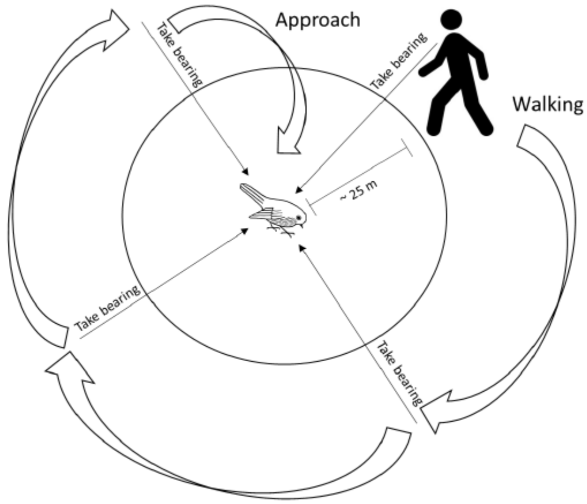

Figure 17: Diagram of the process of triangulating and locating a radio-tagged bird. From Bird Conservancy's telemetry field protocol.

Some individuals tagged with VHF transmitters would go missing because they had either left the study area or were carried away by predators. We attempted to relocate these missing individuals by walking transects through the study plots, climbing to high-elevation locations within the study plot and vicinity for added signal strength, and driving roads within 10 km of the study plots. We used handheld Yagis or truck-mounted omnidirectional or 5-element antennas (Figure 18). We attempted long distance tracking using these methods at least twice weekly until expected transmitter battery failure.

Figure 18: Handheld and truck-mounted antennas were used to track radio-tagged birds. Photos by Denis Perez and Erin Strasser

Bird transect surveys

We conducted line transects to monitor bird community composition and density at our study areas. Within the study area polygons we sampled bird communities along 500m transects spaced > 200m apart and oriented east-west within our study area. We sampled a total of 49 transects in Janos, 12 in Cuchillas de la Zarca, 44 in Valle Colombia, and 79 in Marfa. Bird Conservancy began monitoring densities at Mimm's Ranch prior to initiation of winter survival monitoring at the Marfa site(Panjabi et al. 2017). In Janos, Cuchillas de la Zarca, and Valle Colombia, a single observer conducted surveys at each site within a one-week period in late January or early February between the hours of 0700-1200. In Marfa, we conducted single-observer surveys between mid-January and mid-February. Observers recorded all bird species observed along with lateral distance from the transect, flock size, and detection type for each observation. We also recorded local weather data for each transect (wind, cloud cover, temperature).

Vegetation surveys

We sampled vegetation within our study area using a grid of points spaced every 100m across the delineated plots. We visually estimated percent cover of grass, forbs, tumbleweed, shrubs, bare ground, and 'other cover' (litter, duff, animal excrement, rocks) within a 5m radius plot centered on each grid point. We also estimated average height of grass, forbs, and shrubs within the plot to the nearest cm using a 1m pole marked every 2cm as a guide (Figure 19). This rapid-assessment method is accurate compared with more in-depth, quantitative sampling (Macías-Duarte and Panjabi 2013a). We held calibration exercises to train observers at the beginning of the field season and repeated these exercises regularly throughout the season. In 2012-13, 2013-14, 2016-17, and 2017-18 we also collected vegetation data at randomly selected subset of location points of tagged sparrows, pipits, and shrikes to quantify habitat use for individual birds. We plan to use these data to explore influence of these habitat variables on survival and movement patterns.

Figure 19: Example of grassland habitat and collecting grass height data in Janos. Photos by Erin Strasser and Denis Perez.

UAS imagery collection

In January 2017, we piloted data collection using a DJI Phantom 4 Pro quad-copter drone to survey bird habitat on the Janos plot. The products from our initial efforts were promising, and in 2017-2018 we collected imagery on all four study sites using a fixed-wing UAS (senseFLY eBee or eBee Plus, depending on site). To collect imagery on vegetation (shrub location, grass cover, etc.) we used a Parrot Sequoia multispectral camera in August 2017 to collect aerial imagery of the Janos and Marfa study plots to measure photosynthetic activity on the landscape. These images will be used to generate indices of grassland productivity (e.g. Normalized Difference Vegetation Index, or NDVI) and used in conjunction with UAS imagery datasets collected in winter of 2017-2018 to help describe winter habitat. We then used the eBee Plus outfitted with a Sensor Optimized for Drone Applications (SODA) camera in January and February 2018 (Figure 20) to produce Digital Surface Models and Digital Terrain Models (DSMs and DTMs, respectively) of each of the four study sites. We used eMotion 3 flight planning software to execute planned flights (70-80% lateral and horizontal overlap, depending on camera used) at 120m altitude and to post-process imagery and drone flight logs after mission completion. Bird Conservancy staff and partners from UJED completed imagery collection in Mexico, and partners from Texas Parks and Wildlife collected and managed data at the Marfa, Texas site following comparable protocols. Following imagery processing, we will use these data to examine relationships between grassland bird survival and habitat preferences on the wintering grounds and habitat characteristics including shrub and other vegetative cover.

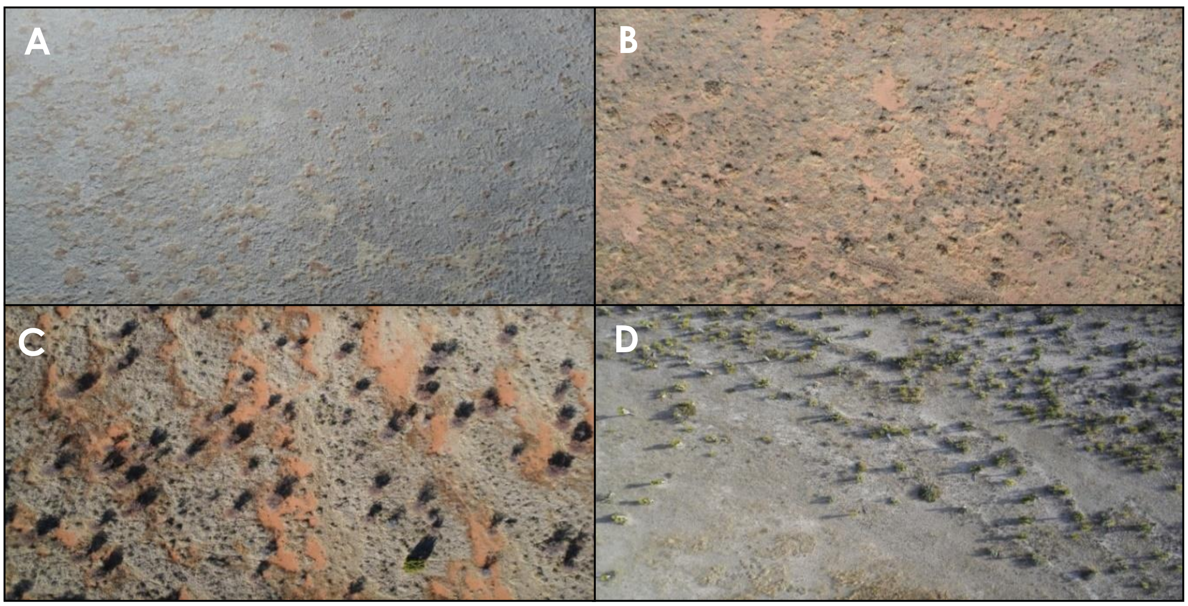

Figure 20: Examples of raw images taken by an eBee Plus drone outfitted with a SODA camera A-B) at the Janos, Chihuahua, C) Cuchillas de la Zarca and D) Valle Colombia study sites. Images were taken from ~120 m above ground. These images will be used to create digital surface models and orthomosaics for characterization of habitat features such as shrub presence and vegetation cover.

Analysis and results

Survival and causes of mortality

In Chihuahua we banded 256 Baird's and 713 grasshopper sparrows across all years but only recaptured 2 and 22 respectively. Accounting for birds banded in 2017-18 that have not had the opportunity to return in a subsequent winter, we observed an estimated 0.8% return rate for Baird's sparrows and 4.1% return rate for grasshopper sparrows. Despite banding >1500 sparrows across all sites and years, we have only observed returning individuals to our study sites across different years at our Chihuahua and Marfa (n = 1) study site.

We have radio-tagged 585 Baird's sparrows, 744 grasshopper sparrows, 9 Sprague's pipits, and 15 loggerhead shrikes (Table 2) across our survival project. We tracked individuals for up to 100 days depending on a bird's survival status and our ability to recapture and replace transmitters.

Table 2: The number of radio-tagged birds and mortalities by site between December and March of 2012-2018

Radio-tagged individuals					
	Janos	**Cuchillas de la Zarca**	**Valle Colombia**	**Marfa**	**Totals**
Species					
Baird's	191	242	64	88	585
Grasshopper	357	209	122	56	744
Loggerhead shrike	13	0	2	0	15
Sprague's pipit	1	1	7	0	9
Totals	562	452	195	144	**1353**

Mortalities					
	Janos	**Cuchillas de la Zarca**	**Valle Colombia**	**Marfa**	**Totals**
Species					
Baird's	58	86	11	13	168
Grasshopper	103	101	32	11	247
Loggerhead shrike	4	0	0	0	4
Sprague's pipit	0	0	2	0	2
Totals	165	187	45	24	**421**

We have documented 421 mortalities across all sites and years (31% of monitored birds, Table 2). The cause of death for the majority of radio-tagged birds was predation, however some individuals appeared to die from exposure to inclement weather (colder temperatures and precipitation, Figure 21). Loggerhead shrikes were responsible for most cases of depredation, followed by diurnal raptors (American kestrel (*Falco sparverius)*, northern harrier (*Circus cyaneus)*, Cooper's hawk (*Accipiter cooperii)*, and merlin (*Falco colombarius)*). We also documented a predation of a grasshopper sparrow by a Mojave rattlesnake, *Crotalus scutulatus (Figure 22)*. We tracked the snake (which had ingested the radio transmitter) for 16 days (Peña-Peniche et al. 2017). Finally, around 37% of radio-tagged birds went missing and we were unable to locate them. Many birds went missing at some point during the study season (i.e. we were not able to record a location for them on consecutive days) but were relocated within or outside of their home range.

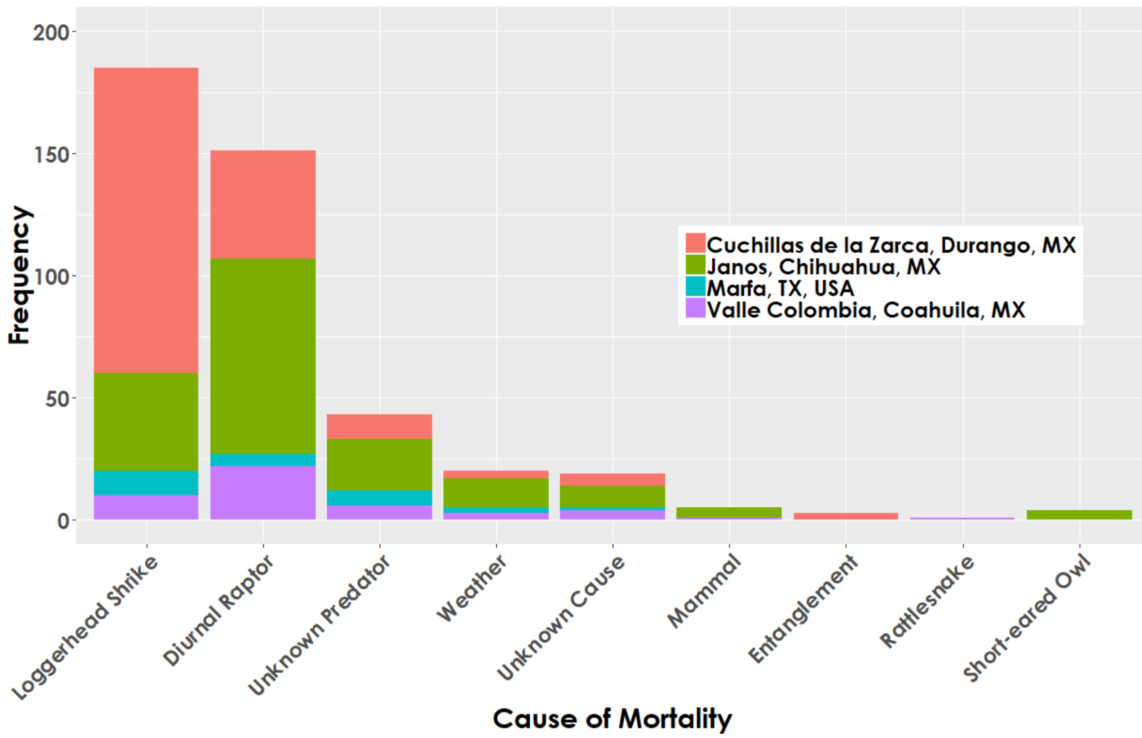

Figure 21: Cause of mortality for radio-tagged Baird's and grasshopper sparrows monitored at four field sites between December and March of 2012-2018.

Figure 22: Images of depredated Baird's and grasshopper sparrows by A) Mojave rattlesnake, B) diurnal raptor, C) short-eared owl, and D) loggerhead shrike. Photos by Erin Strasser and Alex Peña.

We generated daily survival probabilities for each species and site in Program MARK using the nest survival model (White and Burnham 1999). The flexible structure of nest survival models can incorporate data from unknown-fate birds and varied sampling periods resulting from birds moving off site or inclement weather limiting data collection during a certain day. We estimated daily adult survival for 380 Baird's sparrows and 474 grasshopper sparrows monitored between 2012-2018 at the four sites (see Table 2 for all tagging efforts). We suspect that birds may be vulnerable to depredation after transmitter deployment while adjusting to the presence of the transmitter on their body. We included a conditioning period of 7 days to reduce this potential bias when estimating survival probabilities.

Survival results from 2012-18 indicate generally low survival that varies substantially across years and sites (Figure 23). Daily survival probabilities extrapolated over a 90-day period show a 2-100% chance of Baird's and grasshopper sparrows surviving depending on the location and year. Our relatively low estimates of Baird's and grasshopper sparrow winter survival indicate that winter mortality could be a driving factor behind grassland bird declines.

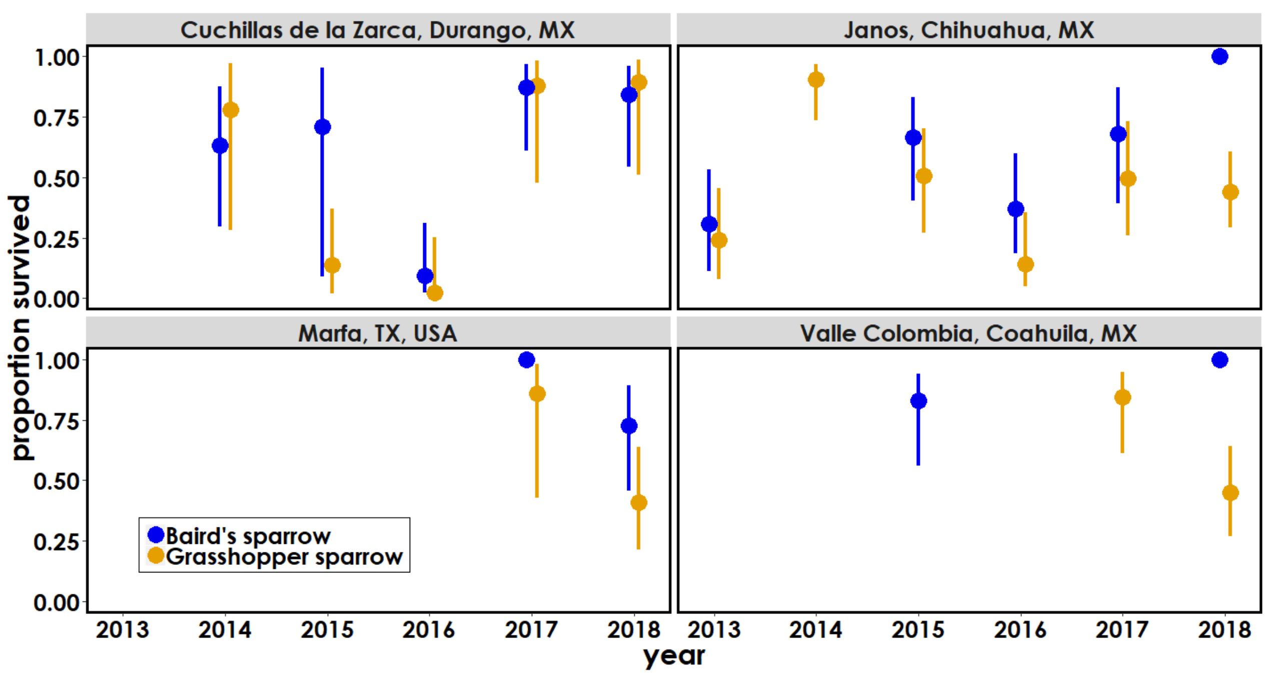

Figure 23: Proportion of Baird's and grasshopper sparrows estimated to have survived the three-month wintering period based upon nest survival analyses by site and winter season (year). Error bars represent upper and lower 95% confidence intervals.

Results from analysis of the first two seasons of survival data (Macias-Duarte et al. 2017) show that weekly survival varied over the course of the season and declined with minimum daily temperature (Figure 24). Extended cold weather and storms, especially snow, could expose birds to energetic stress and therefore greater potential predation risk through reduced vigilance against predators. We also found that there may be a negative relationship between shrub height and survival for grasshopper sparrows (Figure 24). Predation risk near shrubs could be higher because shrubs can provide perches for many avian predators such as loggerhead shrikes. Our results suggest that shrub encroachment could be a threat to grassland birds on their wintering grounds and highlight the need for shrub removal projects to further measure the relationship between survival and shrubs on the landscape.

We did not find a clear relationship with survival and grass cover or height, which was surprising given the clear tie between grass cover and grassland specialist birds on the landscape (see Macias-Duarte et al. 2017). Data derived from UAS imagery will ideally map grass cover across the landscapes of our study sites. This added habitat information could help uncover the role that grass height or cover plays in survival. Finally, we did not find evidence of sex-related differences in mortality. This is noteworthy because sex-biased mortality could lead to an imbalance in breeding-season return rates for a given sex, potentially impacting reproductive success.

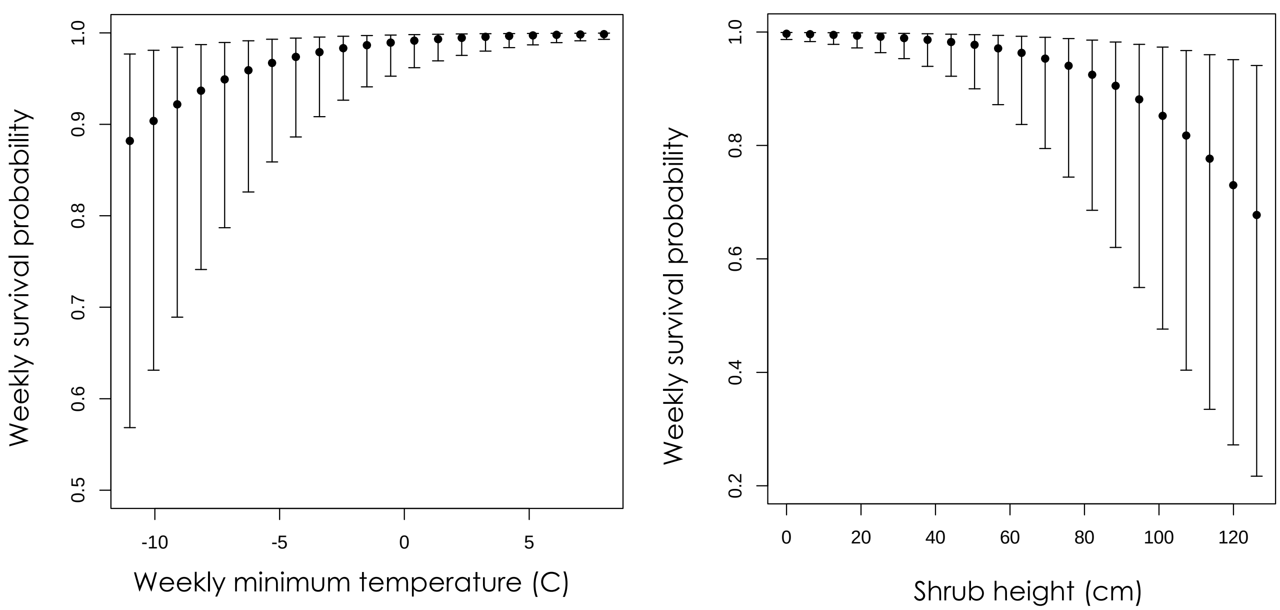

Figure 24: Association of weekly averages of minimum daily temperature and shrub height with weekly survival probability(s) of grasshopper sparrow in Chihuahuan Desert grasslands of Janos, Mexico, during the winters of 2012–2013 and 2013-2014.

Home ranges and movement patterns

Home range estimation

We used our radio-tracking data to generate home ranges and explore space-use patterns in our focal species. The movement patterns of grassland birds on their wintering grounds may be another important part to the conservation and management of these species (Jahn et al. 2017). Understanding how and why animals move (or don't move) within their surroundings can provide insight into population dynamics, habitat needs, or capacity to adapt to environmental change such as habitat fragmentation or increased drought (Cattarino et al. 2016).

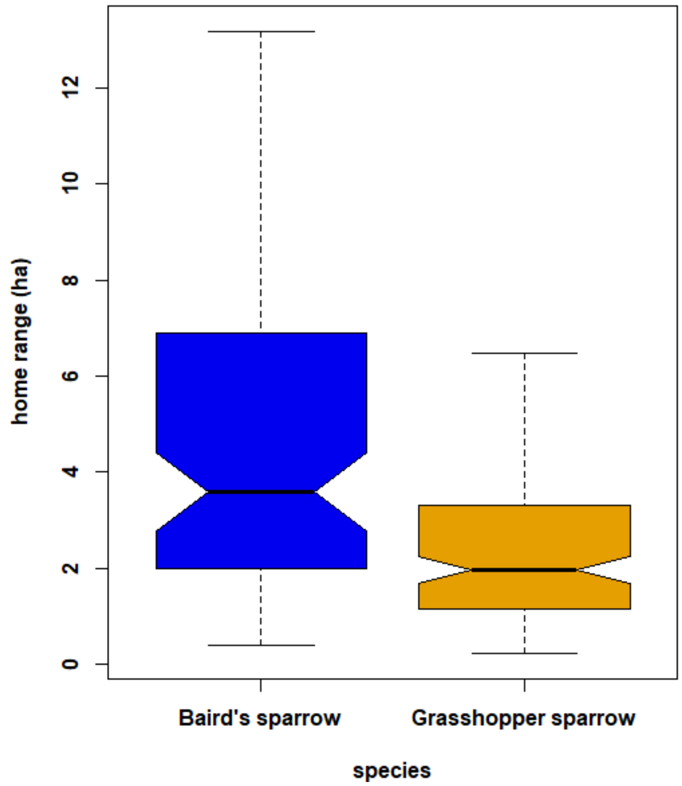

Figure 25: Mean home range sizes (in ha) and standard errors for radio-tagged Baird's and grasshopper sparrows monitored at the Janos site for winters 2012-13 through 2017-18. Outliers have been removed from this figure for presentation purposes.

We estimated home range sizes for Baird's and grasshopper sparrows as well as Sprague's pipits using the fixed kernel density estimator method (Worton 1989, Seaman and Powell 1996) with the package *adehabitatHR* (Calenge 2006) in Program R (R Core Team 2016). We estimated both home range areas (95% isopleths) and core-use areas (50% isopleths) using bivariate normal kernels and a set grid size of 300. We determined smoothing parameters with least squares cross validation (LSCV) because it can avoid overestimation of home range areas (Seaman and Powell 1996, Gitzen and Millspaugh 2003). We limited analysis to birds that had greater than 30 locations as recommended by Seaman et al. (1999), and kernel density algorithms reached convergence for all individuals included in our analyses.

We found that home range size for Baird's sparrows (n=91) was significantly larger than grasshopper sparrows (n=149) wintering at the Janos, Chihuahua site (Welch's t = 2.65, df = 238, p-value = 0.01). Home range size averaged 5.52 ha (13.64 ac) for Baird's and 3.59 ha (8.87 ac) for grasshopper sparrows (Figure 25). Home range size ranged from 0.22 ha (0.54 ac) to 48.93 ha (120.91 ac).

We compared home range size for birds with 20 or more locations between 2014 and 2017 at the three Mexico sites. Baird's sparrows had the smallest average home range size in Cuchillas de la Zarca (1.57 ha/ 3.9 ac) with larger home ranges in Janos (3.08 ha/ 7.6 ac) and Valle Colombia (3.02 ha/7.46 ac). For grasshopper sparrows, mean home range size was significantly larger in Valle Colombia (4.9 ha/ 12.1 ac) compared with Janos (2.8 ha/ 6.9 ac)and Cuchillas de la Zarca (1.87 ha/4.62 ac, Ruvalcaba-Ortega, I. et al. 2018).

Movement patterns
The observed range of home range sizes may reflect different patterns of space use for wintering Baird's and grasshopper sparrows. Space-use patterns may be driven by endogenous or environmental factors such as age, sex, weather, or habitat type. Increased movement may put a bird at increased risk of predation or may be energetically expensive but may also benefit individuals by providing access to better resources. We hypothesized that sparrows employ multiple strategies of space-use patterns during winter and that movements are influenced by weather patterns. We therefore explored patterns in movement and home-range characteristics of wintering Baird's and grasshopper sparrows at the Janos, Chihuahua site.

We performed a model-based cluster analysis using the package mclust (Scrucca et al. 2016)to explore our hypotheses concerning movement strategies in Baird's and grasshopper sparrows (Demšar et al. 2015). We first quantified the number of 95% home-range polygons, home-range area, mean, maximum, and minimum distance between 95% home-range polygons, total perimeter around polygons, and overall shape of home range (area/perimeter) for all home ranges we produced for birds at the Janos, Chihuahua site. We also used the R package adehabitatLT (Calenge et al. 2009) to measure the distance traveled between daily bird relocations in our telemetry dataset (minimum daily distance traveled). Finally, we calculated how often an individual revisited areas along their movement trajectory with the R package 'recurse' (Bracis et al. 2018). We used the natural log of all spatial metrics and scaled all metrics before analysis to conform to the assumptions of the cluster analysis used here. We used Bayesian Information Criterion (BIC, Neath and Cavanaugh 2012) to compare models with different clustering schemes.

We found that a Gaussian finite mixture model fitted with the EM algorithm was the best-performing model, using three different groups to group individuals. The results indicated that Baird's and grasshopper sparrows display multiple patterns of space-use (Figure 26) which group into at least three unique space-use strategies on the wintering grounds (Figure 27). Some individuals remain sedentary within a smaller home range, others shift home ranges (i.e. maintain two or more discrete home ranges),and some appear to roam within a larger area (i.e. winter floaters, Brown and Long 2007) within the study area (Figure 27). These three classifications are loosely defined as they fall within a continuum of movement strategies. Birds that shift home ranges or make small movements throughout the winter are the most common (67% of individuals), those that are nomadic throughout the winter are the second most common (27% of individuals), and those that are highly sedentary within a small home range are the least common (6% of individuals). Nomadic tendencies on the wintering grounds may be more common than our data suggests as around 20-40% of birds go missing from the study area each winter.

That some Baird's and grasshopper sparrows are highly mobile during winter demonstrates an ability to exploit patchy resources, similar to what has been observed on their breeding grounds (e.g. Williams and Boyle 2018). These results support the idea that we should take into consideration the diverse space needs of a species when conserving or restoring habitat (e.g. Moffitt et al. 2009, Allen and Singh 2016, Rechetelo et al. 2016).

We were also interested in understanding how weather influences daily bird movements on the wintering grounds. Climate conditions such as temperature and rainfall could lead to changes in movement behavior because of energetic limitations as observed in reptiles (Price-Rees et al. 2014). We used linear mixed-effect models in the package lme4 (Bates et al. 2015) to explore the predictive power of environmental characteristics (daily minimum and maximum temperature, daily precipitation, Julian date) on daily minimum distance travelled for individuals. We used data from an on-site weather station at Rancho El Uno to quantify all environmental metrics. We included both season and individual as a random effect and species as a fixed effect to account for variation based on these characteristics. We scaled all environmental characteristics and no variables were correlated.

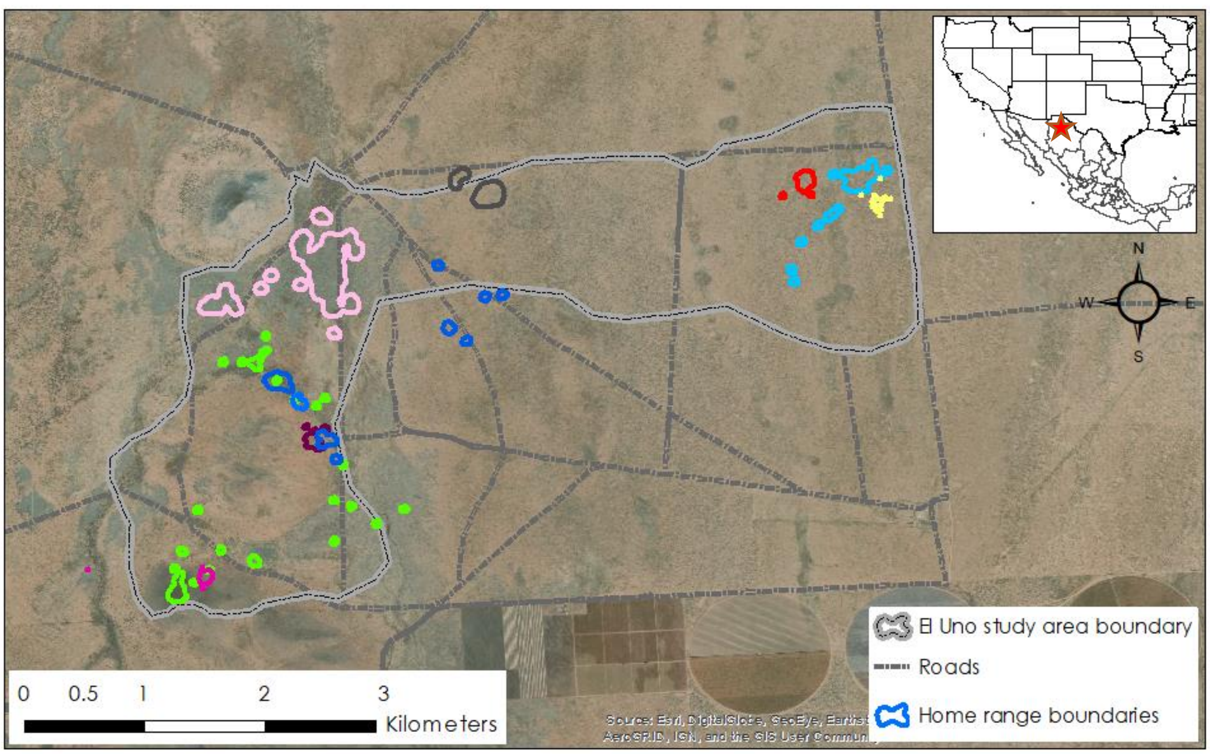

Figure 26: Examples demonstrating the variety of space-use strategies employed by grasshopper sparrows wintering at the Janos, Chihuahua site. Each color represents a different individual's 95% home range.

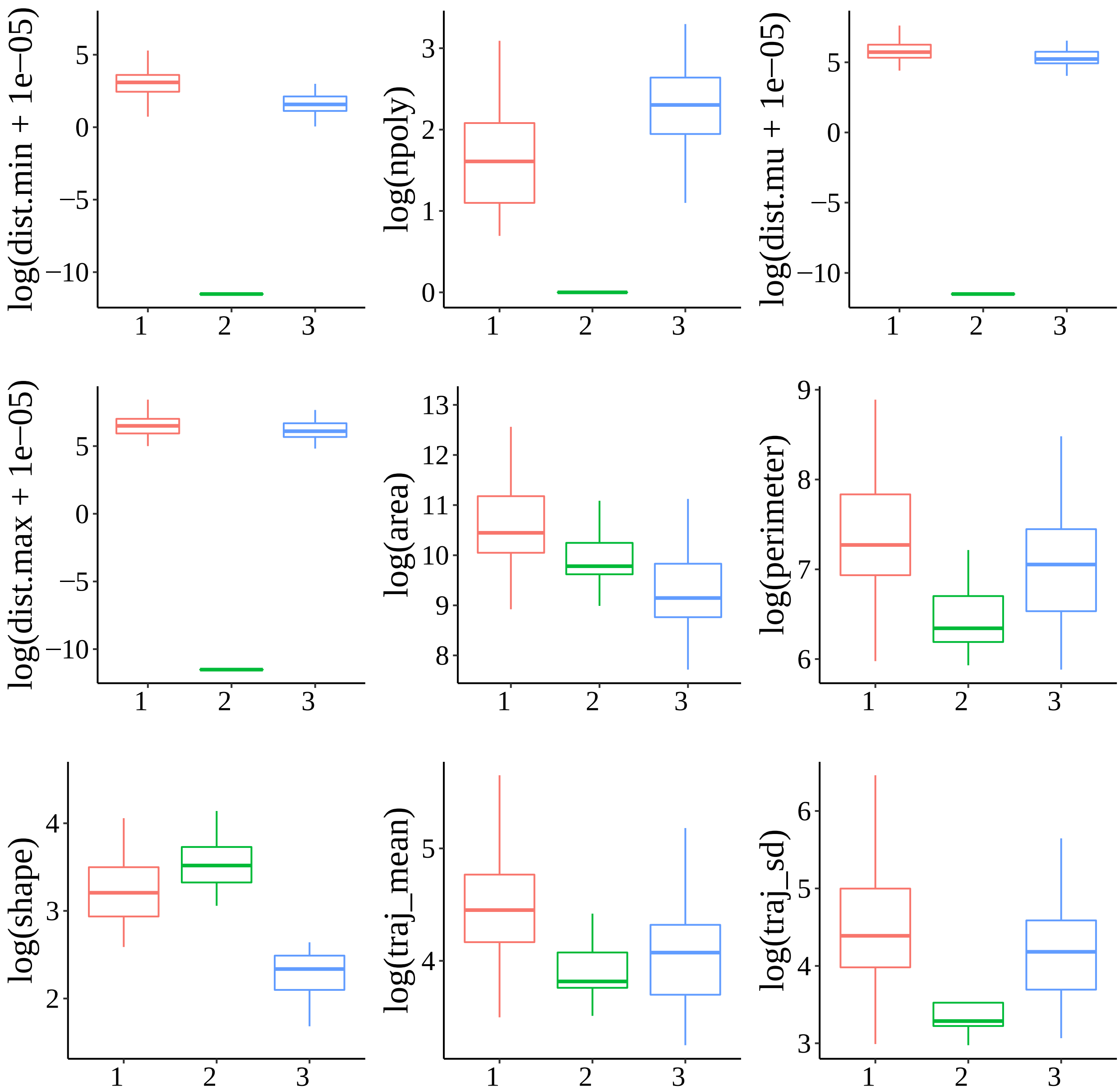

Figure 27. Results of a model-based clustering using an EM algorithm to group movement strategies in wintering Baird's and grasshopper sparrows in the Chihuahuan Desert grasslands near Janos, Chihuahua. On the x-axis, numbers 1-3 represent the different movement strategies. 1. birds that shift territories at some point during the winter; 2. individuals that remain sedentary throughout the winter; 3. birds that roam throughout the winter.

Minimum daily temperature best explained daily movements (see Appendix II for AIC table). When daily minimum temperatures were higher, daily bird movement increased (estimate 0.031 CI 0.01-0.05, Figure 28). Julian date also appeared in the top model (estimate = -.053, CI -0.080, -0.028). Interestingly, lower minimum daily temperature is associated with lower survival in Baird's and grasshopper sparrows possibly because of thermal stress and increased predation risk. This relationship with minimum daily temperature has also been found in other species/taxa groups, including in Pacific black ducks (*Anas supercilious,* McEvoy et al. 2015) whose increased movements following precipitation and increased minimum daily temperature reflect reduced physiological constraints or increased foraging opportunities. If temperatures are below a certain threshold, our focal species may limit foraging within a smaller, more localized area to conserve energy (Villén-Pérez et al. 2013). As minimum temperature goes up, small-bodied species such as Baird's and grasshopper sparrows may be able to energetically afford longer distance movements or predation risk may be lower when temperatures are warmer. Temperature loggers placed at the Marfa site indicate that minimum daily temperature is lower in shorter grass compared with bare ground or medium-tall grass (Titulaer et al. 2018). Further research is needed to explore the links between temperature, movement, predation, and vegetation to understand these relationships and determine how habitat conditions can be managed in a way that minimizes predation risk and thermal stress.

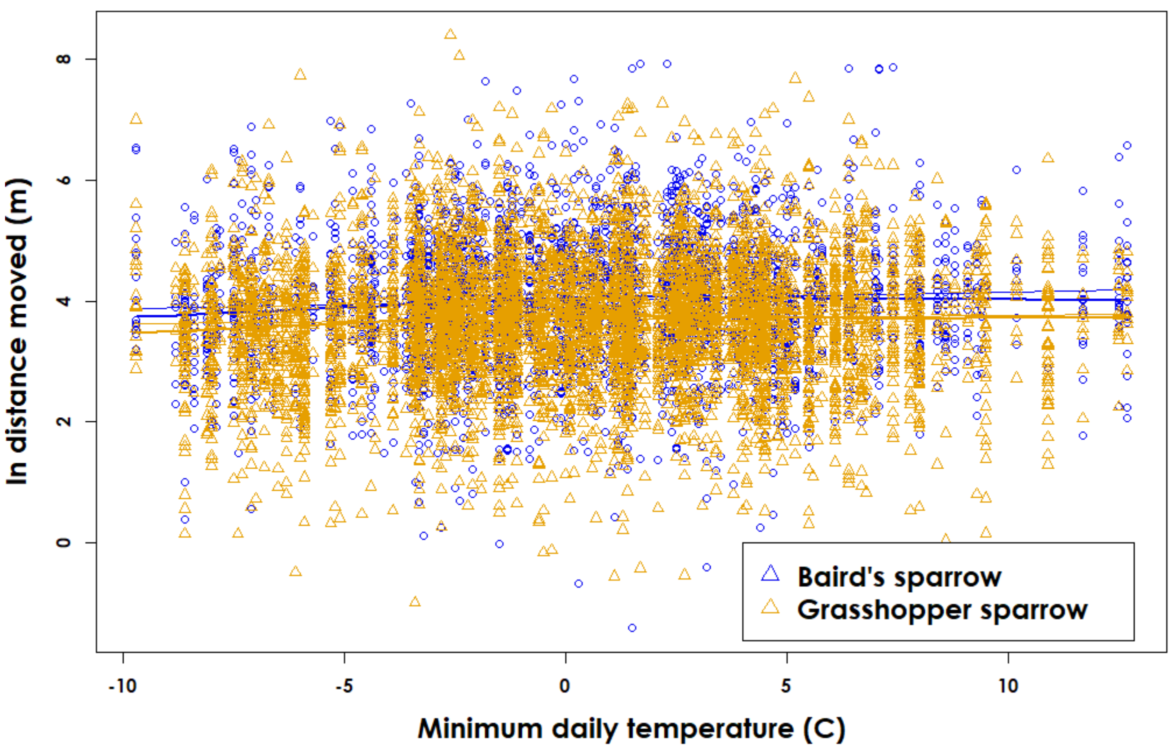

Figure 28: Relationship between minimum daily temperature and log transformed daily distance moved by Baird's and grasshopper sparrows at the Janos, Chihuahua site between winters 2013-14 and 2016-17

We captured nine and radio-tagged eight Sprague's Pipits (2 females and 6 males) within the Janos, Cuchillas de la Zarca, and Valle Colombia sites over the course of 3 winters. All captures were incidental during sparrow trapping. We monitored pipits between 3 and 67 days (μ= 25 days). Two pipits in Valle Colombia were depredated during monitoring by a loggerhead shrike and an American kestrel. We lost signal for 2 individuals after less than 2 weeks of monitoring and could not relocate them. We estimated winter home range size for 4 individual pipits (2 males and 2 females) using the methods described above.

Of these 4 individuals, one individual was monitored at the Chihuahua site and 3 at the Coahuila site. Winter home range (95% isopleths) size ranged between 6.25 ha (15.44 ac) and 22.78 ha (56.29 ac) with an average size of 11.90 ha (29.41 ac). Core areas used by pipits (50% isopleths) ranged between 1.34 and 4.58 ha ($\bar{x}$= 2.43 ha/6 ac). These area estimates are larger than territories of wintering Baird's and grasshopper sparrows. One individual in Coahuila shifted its home range 1.3 km into a new area of activity after 19 days of monitoring following disturbance through cattle grazing. This individual remained

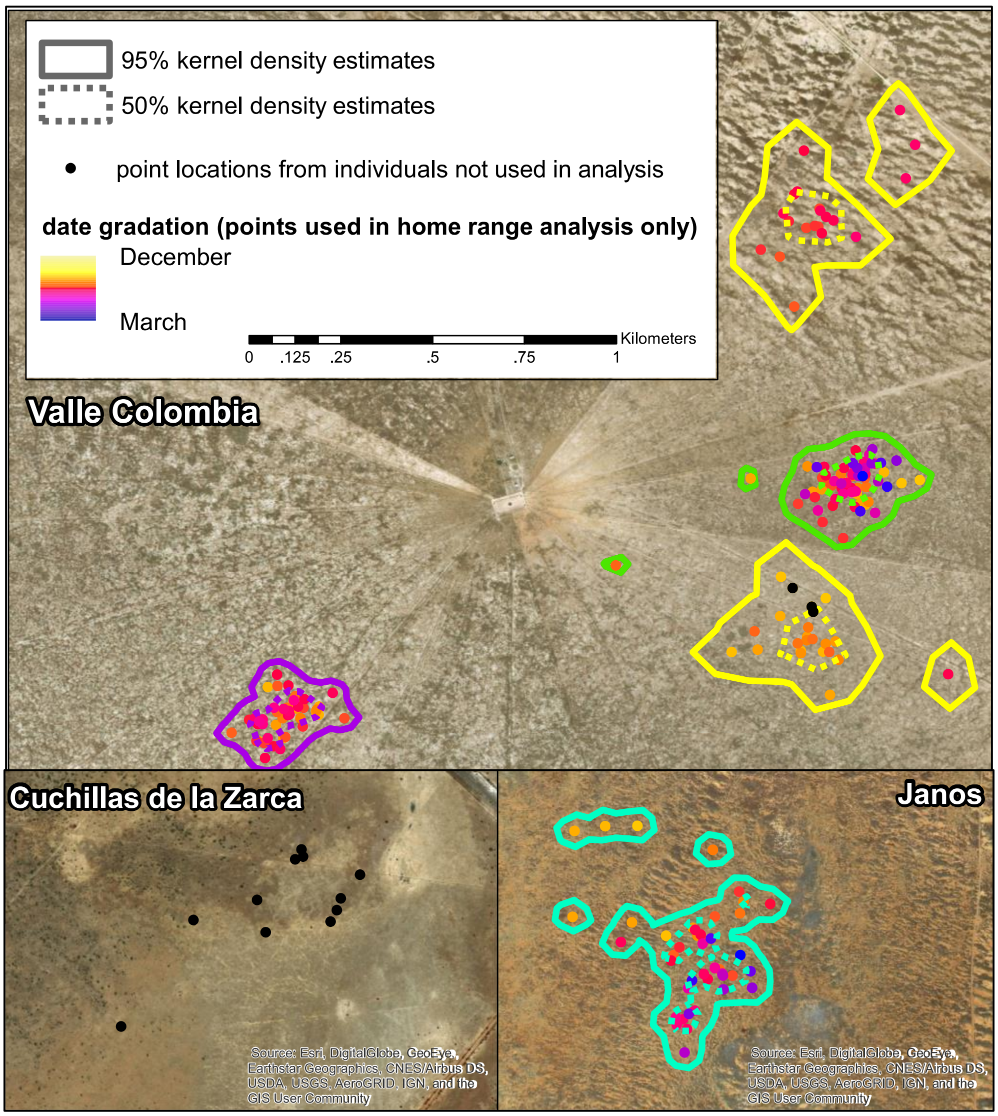

Figure 29: Radio-tagged Sprague's pipit locations, home ranges (95% isopleths), and core areas (50% isopleths) generated with kernel density estimators within the Janos, Valle Colombia, and Cuchillas de la Zarca field sites during winters 2014-15, 2015-16, and 2016-17. Color gradations of location points for pipits used in home range analysis represent date: points get darker with later dates. Polygon color represents individual bird home ranges (95% kernel density estimates).

at its new locale for 20 additional days before its transmitter failed, only revisiting its previously occupied range once (Figure 29). Further, two of the tagged birds left the study areas after 3 and 12 days of monitoring indicating that wintering pipits may shift their territories over the course of the winter. This type of behavioral plasticity in response to a changing environment (e.g. overgrazing, drought) may benefit pipit survival (Wong and Candolin 2015) although our dataset is not yet robust enough to support such an analysis.

Habitat selection on the wintering grounds

We found that radio-tagged Baird's and grasshopper sparrows used areas with taller and denser grass than what was available within the study plots (Table 3). These species were also found in areas that had less shrub cover and shorter shrubs than what was available within the study plots. Conversely, radio-tagged loggerhead shrikes at the Janos study site were found in areas with taller shrubs, greater shrub cover, and less grass cover than what was available in the study area (Figure 30). Mean values of vegetation cover and height for selected vs. available habitat for radio-tagged Baird's and grasshopper sparrows, Sprague's pipits, and loggerhead shrikes are presented in Table 3.

We used mixed-effect logistic regression models to explore fine-scale (third order, Johnson 1980) habitat selection in tagged Sprague's pipits. We used the "glmer" function in the lme4 package (Bates et al. 2015) within Program R (R Core Team 2016) for all analyses. We combined vegetation data from all points where tagged pipits were observed (n=111) with vegetation data from our randomly selected points (n = 6242) within study plots. We then assigned a random individual ID (n = 6) to each random point, stratified by study plot. This individual designation was included as a random effect in all regression models.

We compared all continuous variables for correlation before analysis and found bare ground cover and grass cover had a correlation >0.6. Univariate regressions including each variable and the random variable for individual showed the models including bare ground cover yielded a larger effect size and a lower Akaike Information Criterion (AIC, Burnham and Anderson 2004) than identical models including grass cover. We therefore included bare ground in our global model and excluded grass cover in all further analyses.

Figure 30: Loggerhead shrike and Baird's sparrow habitat in the Chihuahuan Desert grasslands. Photos by Isaac Morales and José Hugo Martínez

Table 3. A) Mean values for available and selected Sprague's pipit habitat at the Janos and Valle Colombia sites. B) Mean values for available and selected Baird's and grasshopper sparrow habitat at the Janos, Valle Colombia, Cuchillas de la Zarca, and Marfa sites. C) Mean values for available and selected loggerhead shrike habitat at the Janos site. Images from the Sibley (2016).

Vegetation parameters	mean available (min, max)	Sprague's pipit mean selected (min, max)	Baird's & grasshopper sparrow mean available (min, max)	Baird's sparrow mean selected (min, max)	Grasshopper sparrow mean selected (min, max)	Loggerhead shrike mean available (min, max)	Loggerhead shrike mean selected (min, max)
bare ground cover (%)	55.77 (0, 100)	75.09 (37, 94)	53.82 (0, 100)	39.90 (0, 98)	48.64 (0, 99)	65.51 (1, 100)	70.48 (10, 96)
forb height (cm)	8.14 (0, 102)	5.28 (0, 62)	10.79(0, 115)	11.68 (0, 222)	12.99 (0, 321)	4.95 (0, 110)	2.84 (0, 52)
forb cover (%)	1.02 (0, 21)	1 (0, 5)	1.02 (0, 52)	1.30 (0, 45)	0.98 (0, 56)	0.41 (0, 52)	1.18 (0, 12)
grass height (cm)	16.61 (0, 76)	14.27 (6, 28)	17.6 (0, 95)	22.86 (0, 93)	21.87 (0, 188)	17.38 (0, 67)	13.94 (0, 30)
grass cover (%)	34.35 (0, 96.5)	21.82 (0, 61.5)	37.23 (0, 99.5)	48.90 (0, 99)	42.14 (0, 99.5)	22.1 (0, 98)	10.98 (0.5, 70)
other cover (%)	8.11 (0, 84)	1.81 (0, 13)	6.17 (0, 100)	8.80 (0, 69)	7.00 (0, 83)	9.69 (0, 77)	8.75 (0.5, 31)
shrub cover (%)	0.86 (0, 40)	0.32 (0, 6.5)	1.16 (0, 77)	0.38 (0, 50)	0.66 (0, 40)	0.57 (0, 13)	2.86 (0, 36)
shrub height (cm)	21.97 (0, 300)	12.43 (0, 78)	26.47 (0, 500)	13.73 (0, 470)	23.31 (0, 887)	18.22 (0, 163)	83.90 (0, 263)
tumbleweed cover (%)	0.01 (0, 18.5)	0 (0, 0.3)	0.61 (0, 77)	0.68 (0, 32)	0.61 (0, 32)	1.59 (0, 77)	6.12 (0, 26)

Our additive global model included metrics for bare ground cover, average grass height, forb cover, average forb height, shrub cover, average shrub height, and "other" cover, and random effect of individual. All metrics were scaled to allow post-hoc comparison of parameter estimates within models. We then compared our global model to a null model including only the random effects using AIC and used the Wald approximation function to estimate 95% confidence intervals post hoc for each parameter. To further validate our results (due to skewed sample size of "selected" vs. "available" points) we repeatedly subsetted (n = 50) our "available" vegetation measurements to match the number of "selected" points and reran our global model on this smaller dataset. We report parameter estimates from our global model run with the full dataset.

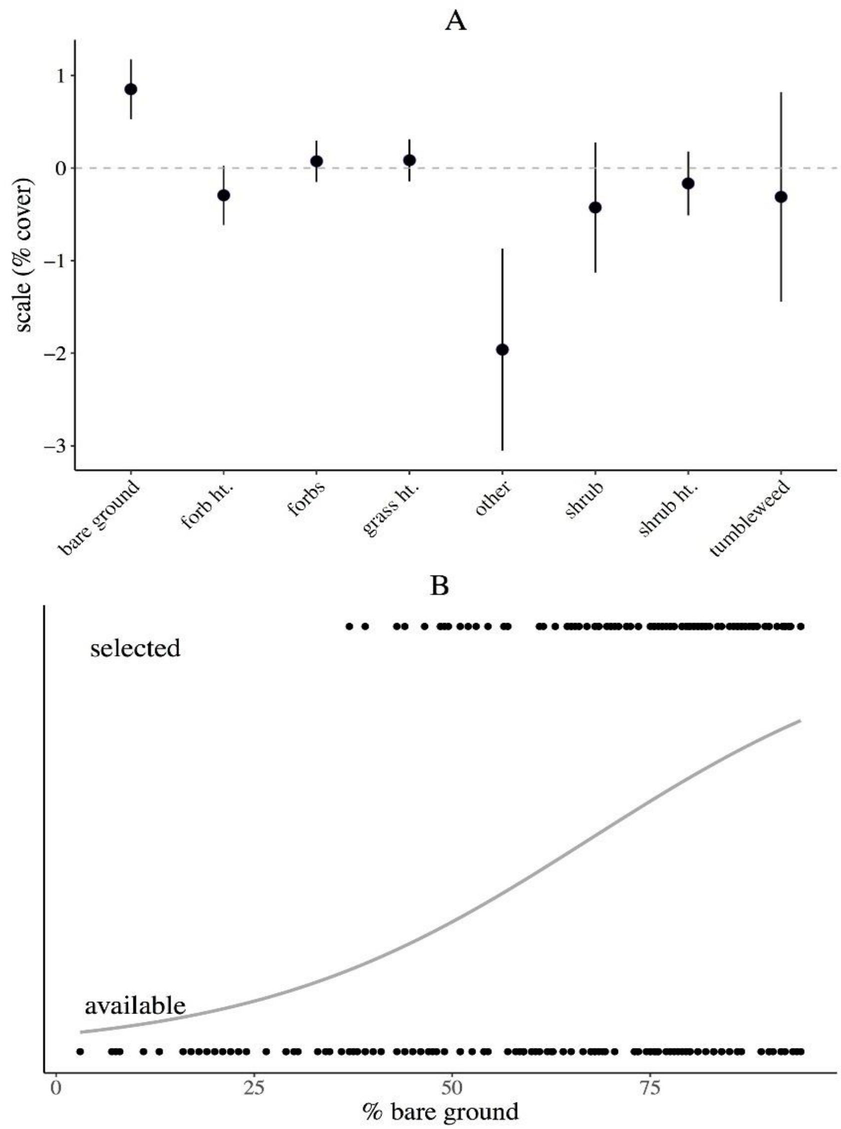

Figure 31: Results of mixed model logistic regression of Sprague's pipit habitat selection in the Chihuahuan Desert in Mexico, including A) scaled parameter estimates from global model, and B) subsetted data points and regression line for bare ground cover.

We found that our global model for third-order pipit habitat selection performed better than the equivalent null model using our full (ΔAIC = 99.08) and sub-setted datasets. Bare ground and "other" cover were the most influential predictors of habitat selection (Figure 31); 95% confidence intervals did not overlap zero for these parameters in global or subsetted data. Pipits selected for more bare ground (β = 0.85, CI 0.53, 1.18) and less "other" cover (β = -1.96, CI -3.05, -0.87) than what was available on the landscape.

Past studies indicate that pipits winter in grasslands characterized by more grass cover at the larger scale (Macías-Duarte et al. 2009, Pool et al. 2012). We did not find that tagged pipits selected for dense grass at a finer scale within healthy grasslands. Together these results suggest that pipits winter in grasslands characterized by extensive grass cover but select for patches of bare ground or sparser vegetation within these grasslands. These fine-scale habitat preferences are very different from those of Baird's sparrows, which prefer denser and taller grass (Macías-Duarte et al. 2009, Pool et al. 2012). Despite the differences in fine-scale habitat selection, these 2 species are often found in wintering near one another (Pool et al. 2012). Even though these species likely rely on different microhabitat conditions for their survival, both may find suitable habitat in a structurally diverse grassland, with areas of bare ground interspersed among patches of dense grass.

These results highlight that conservation on the wintering grounds may not be effective for a diverse suite of grassland birds under a one-size-fits-all approach. Management strategies that embrace requirements for multiple grassland bird species should create structurally diverse and heterogeneous grassland (e.g. open patches of bare ground within dense patches of vegetation, (Schmidt et al. 2017)) instead of focusing solely on creating taller, denser grass--an aim of many grazing paradigms (Fuhlendorf and Engle 2001). We need to collect longer-term data on Sprague's pipits to confirm these conclusions.

Bird Densities

We developed a Bayesian, zero-inflated N-mixture model (Royle 2004, Sillett et al. 2012) to estimate bird densities at each field site (Figure 32). We used distance sampling methods (Buckland et al. 2001) to estimate the probability of detecting individual birds by fitting models using the half-normal and hazard detection functions. We chose the most parsimonious model, based on the deviance information criterion (DIC; Spiegelhalter et al. 2002), on which to make inference.

Figure 32: A flock of chestnut-collared longspurs on their wintering grounds. Photo by José Hugo Martínez.

We estimated densities for 16 species and present estimates for 9 species including 2 key predators of Baird's and grasshopper sparrows (loggerhead shrikes and northern harriers) at each site (Appendix I). At the Janos site, bird densities for many species were higher in winter 2013-14 (Figure 33). These elevated densities coincided with high survival rates for grasshopper sparrows (Figure 23). It is possible that high abundance of prey items (e.g. sparrows) reduces the chance that any one prey item will be eaten (Waraniak et al. 2017). Cryptic, ground-dwelling species such as *Ammodramus* sparrows may particularly benefit when more conspicuous prey species (e.g. Savannah and Brewer's sparrows) are present in high numbers. On the contrary, higher densities can have negative impacts on survival because of competition for resources (Ryan et al. 2016). Within our study species, survival could partially depend on an interaction between the quality (i.e. cover and food availability) or size of a given grassland patch and bird densities. We intend to explore these relationships further to better understand limiting factors for grassland birds.

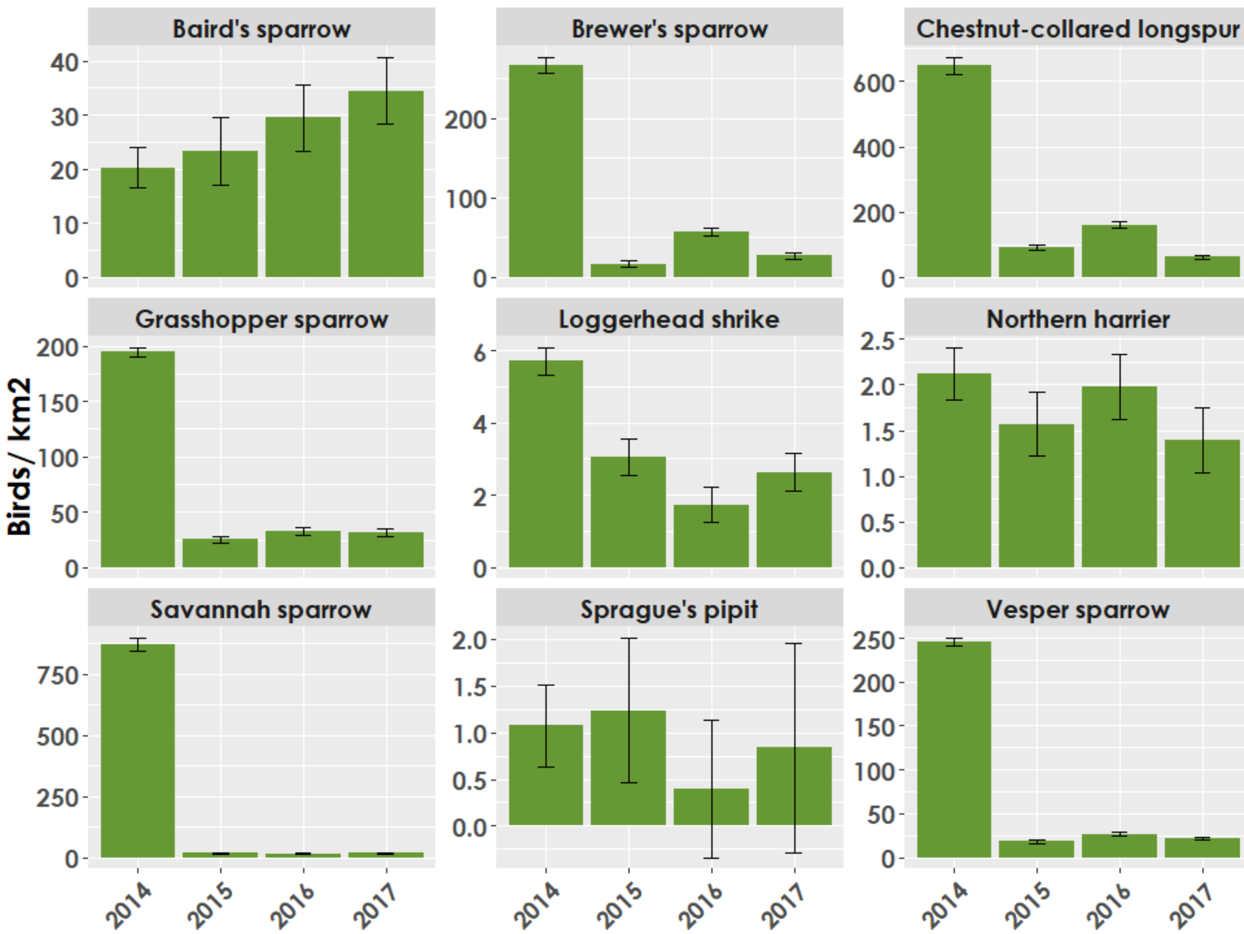

Figure 33: Density estimates (bird/km2) and standard deviations for 9 bird species at the Janos field site from winter 2014 to 2017.

Analysis of UAS-derived imagery

To address the relationship between shrubs and grassland birds, we are processing and analyzing UAS-derived imagery collected in 2017 and 2018 at the four study sites. Specifically, with this imagery we are producing rasters including digital surface models (DSMs) and vegetation indices (e.g. Normalized Difference Vegetation Index, or NDVI). Analyses are conducted in Pix4Dmapper software (Pix4D SA, Switzerland).

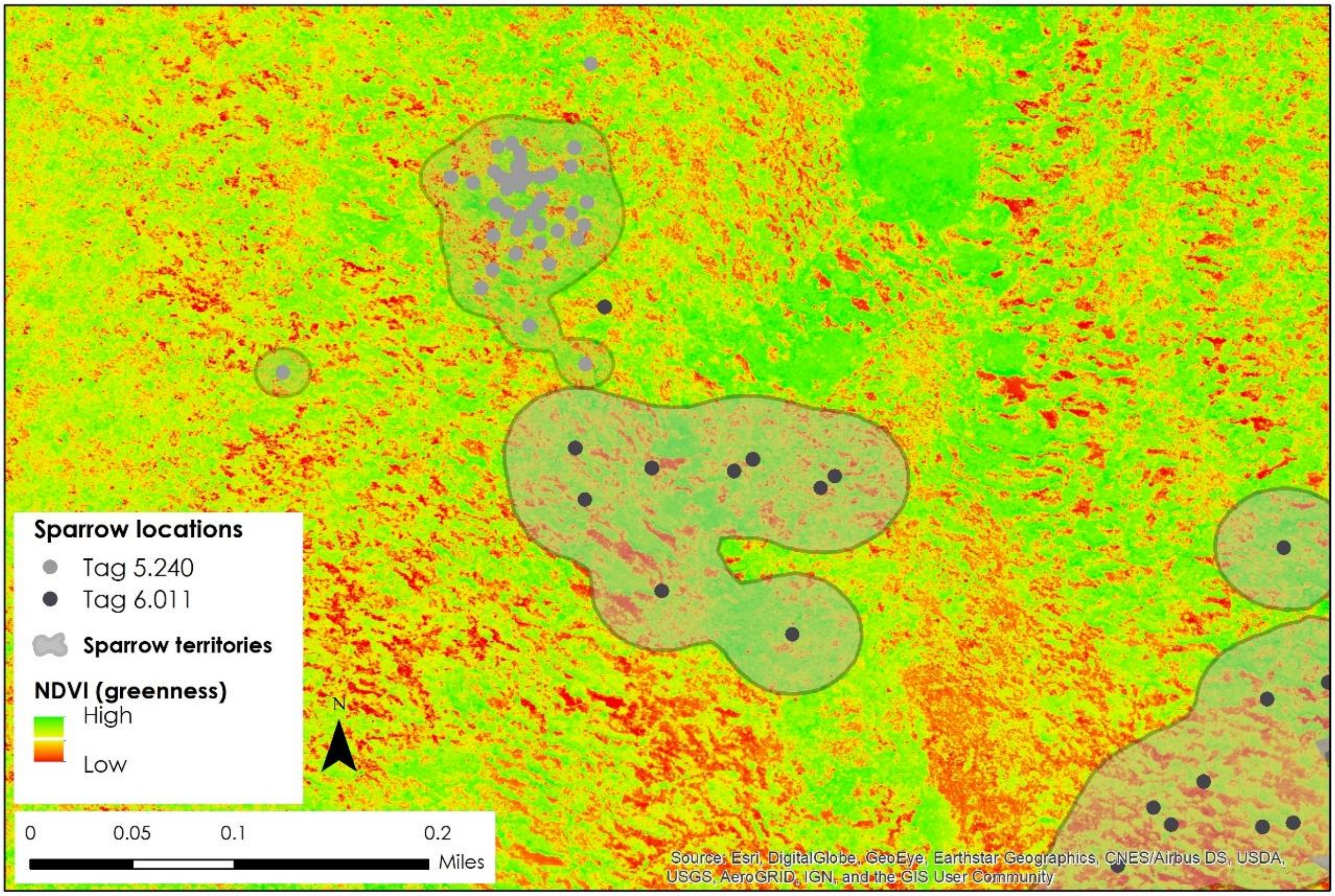

Figure 34: Image of raster for Normalized Difference Vegetation Index (NDVI) indicating greenness of vegetation at the Janos, Chihuahua site. This raster was generated from UAS-derived infrared imagery collected in late Aug 2017. Warmer colors indicate lower vegetation productivity, while greener areas indicate the presence of green vegetation. Winter territories of sparrows are included to demonstrate

Initial outputs from processed imagery are promising: NDVI rasters provide high resolution insight into our study plots, indicating which areas are more productive Figure 34). We anticipate using NDVI raters in combination with DSMs to help quantify vegetation cover within sparrow home ranges and to identify shrubs. We know that plant biomass following summer monsoons (quantified with NDVI) has a positive relationship with local abundance of some grassland bird species (Macías-Duarte et al. 2018). We intend to explore the relationship between pre-winter NDVI and winter survival of grassland birds.

Local participation, outreach and environmental education

We have actively collaborated with private landowners and various local organizations in Mexico since 2007. In this time we jointly increased the capacity of Mexican partner organizations by training more than 100 biologists and students in the identification and monitoring of grassland bird populations. We contract local biologists as technicians that are recent graduates from their undergraduate studies; several of them have chosen to pursue graduate educations following their experience. Additionally, funds from the U.S. Consulate General in Ciudad Juárez supported three winter internships where Mexican university students gain valuable experience. We also encourage wintering season technicians to apply for and fill similar Bird Conservancy technician positions on the breeding grounds.

We also work with a local environmental educator to bring primary and secondary school groups to the Janos site to help capture sparrows and learn about migratory birds, bird tracking technology, and the value of Chihuahuan Desert grasslands (Figure 35). In fall 2016 with partners from the U.S. Forest Service International Program and others, Bird Conservancy assisted with a distance learning program called PastizalesEnVIVO that highlighted the conservation and importance of grasslands and their wildlife. This program was broadcast on live television in northern Mexico as well as through an interactive webcast

Figure 35: At Rancho El Uno, Bird Conservancy and partners from IMC-Vida Silvestre work with groups of secondary-age students to show them how we monitor birds with drones and radio-telemetry. Photos by Erin Strasser.

Future directions

Quantifying shrub density on the landscape

Our next step is to use the data layers derived from UAS imagery to identify individual shrubs on the landscape at our field sites. We can then relate these habitat data to the bird movement data we collect using radio telemetry use to gain insight into bird-habitat relationships such as bird thresholds of tolerance to shrub cover and height at various spatial scales. This information can then increase the precision of recommendations for grassland management to benefit grassland birds on their wintering grounds, promoting greater returns to their breeding grounds in the Northern Great Plains.

Measuring the influence of shrub removal on wintering grassland birds

We aim to experimentally test the impact of shrub removal on survival and bird density at the Janos site using the results of our survival analyses (Figure 36). A similar project will take place in the Marfa and Marathon grasslands in Texas. Because predation pressure may be lower in more homogenous landscapes (i.e. grasslands with fewer shrubs, (Atuo and O'Connell 2017) and perch height directly influences prey visibility in open habitats (Andersson et al. 2009) we expect to observe higher survival for birds at sites where most tall shrubs are removed.

Figure 36: Mesquite shrubs in a grassland at the Janos, Chihuahua site. Photo by Erin Strasser.

Development of Integrated Population Models for wintering grassland birds

We plan to combine the data collected on the wintering grounds with similar demographic data from the breeding grounds (Bernath-Plaisted et al. 2017)and population data from the breeding (Pavlacky et al. 2017) and wintering (Macias-Duarte et al. 2011) grounds into an Integrated Population Model for Baird's and grasshopper sparrows. These models will help identify limiting factors within the annual cycle for these species (Figure 37) and will help guide conservation effort and funding where it is most needed. We currently have the data necessary to populate this model but are seeking additional funding to support staff time to put towards model development, analysis, and interpretation.

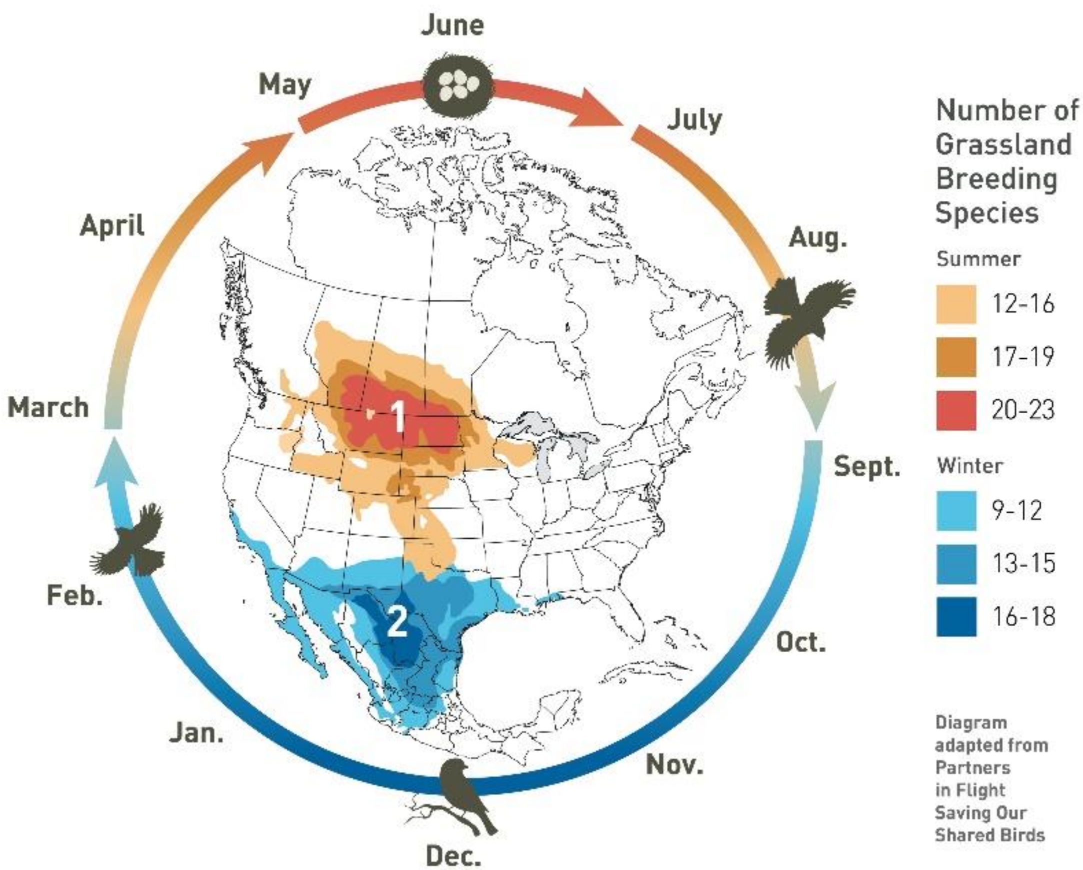

Figure 37: A visualization of the full annual cycle monitoring approach, depicting the connection between grassland habitat on the breeding grounds in the Northern Great Plains (1), and wintering grounds in the southwestern United States and Mexico (2).

Dissemination of results to partners in Mexico

We will use the results from this project to inform habitat management and conservation strategies by Bird Conservancy, IMC-Vida Silvestre, and other partners working in the Chihuahuan Desert (Figure 38). For example, data from our vesper sparrow work indicates a negative relationship between survival and shrub height, as well as a positive relationship with grass cover (Macías-Duarte and Panjabi 2013) results which have been incorporated into Spanish-language outreach materials. Our results from grasshopper sparrow work show a similar negative relationship between shrub height and winter survival (Macias-Duarte et al. 2017) and results from our work with Sprague's Pipits highlights the importance of habitat heterogeneity *(Strasser et al.* in review). We have and will continue to incorporate these findings into grassland management prescriptions for SGN ranches. We will also share these results at conferences and meetings and will include them in future Spanish-language outreach materials. We anticipate that drone derived variables will improve our understanding of habitat and survival relationships, allowing for more specific management guidance. We will continue to publish results and management suggestions stemming from this work in peer reviewed journals to maximize exposure of our efforts and conclusions reached from this work. Ultimately we hope to improve habitat for a range of grassland species while supporting profitable ranching operations in the Chihuahuan Desert.

Figure 38: Bird Conservancy's mission is to conserve birds and their habitats through an integrated approach of science, education and land stewardship. Our research on limiting factors for grassland birds in the Chihuahuan Desert takes this approach. Results will inform grassland management with the goals of improving habitat for birds and ranching. Photos by Sujata Gupta.

Acknowledgements

Logistics - We would like to extend thanks to The Nature Conservancy for their logistical and in-kind support at Rancho El Uno, and the landowners in Cuchillas de la Zarca and Valle Colombia (O. Bermudez Finnan). Thank you also to the hard-working technicians and volunteers, particularly J. Ordaz, M. Martinez, and S. B. Tejón for their dedication and sense of humor despite long hours in the field. Thank you to Susan Craig for advice on trapping loggerhead shrikes.

Funding- Our study was funded by USFWS Neotropical Migratory Bird Treaty Act (agreement # F14AP00617, F16AP00613, F14AP00397, F16AP00608), U.S. Forest Service International Program, The National Park Service (H1200-09-0005), Environment Canada, WWF Fundación Carlos Slim, the National Council for Science and Technology of Mexico (CONACYT; project CB-2013-01-222920), PRODEP/SEP, Pronatura Noreste A.C., Texas Parks and Wildlife, and the US State Department.

Permits- All research was conducted under U.S. Fish and Wildlife Service banding permit 22415 and with permission from the Dirección General de Vida Silvestre of Secretaría de Medio Ambiente y Recursos Naturales (DGVS/SEMARNAT) permits 13360/14, 12736/15, and 10768/16, and received permission from the Comisión Nacional de Areas Naturales Protegidas (CONANP)

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Appendices

Appendix I.

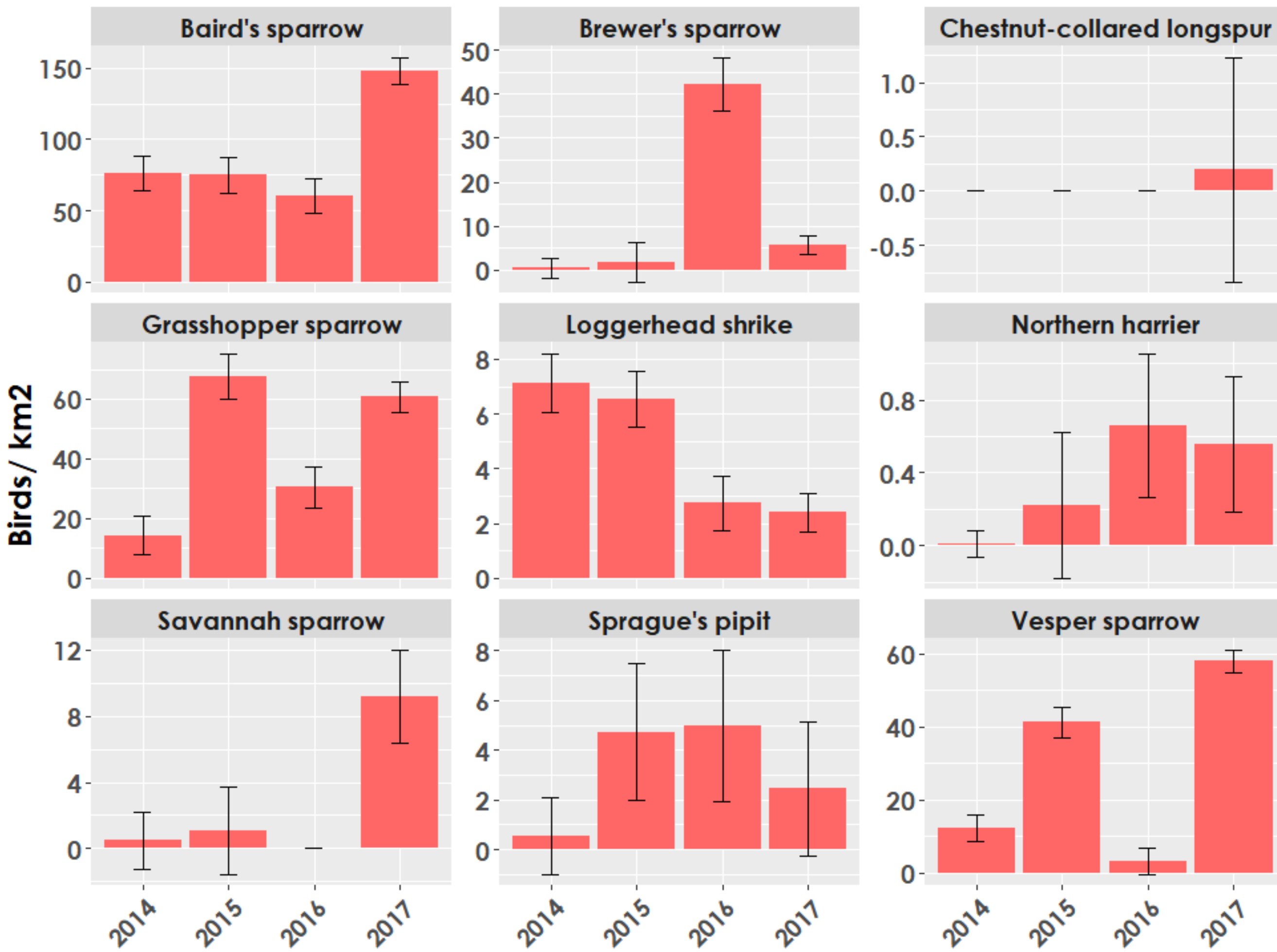

Figure 1: Density estimates (bird/km2) and standard deviations for 9 bird species at the Cuchillas de la Zarca, field site from winter 2014 to 2017.

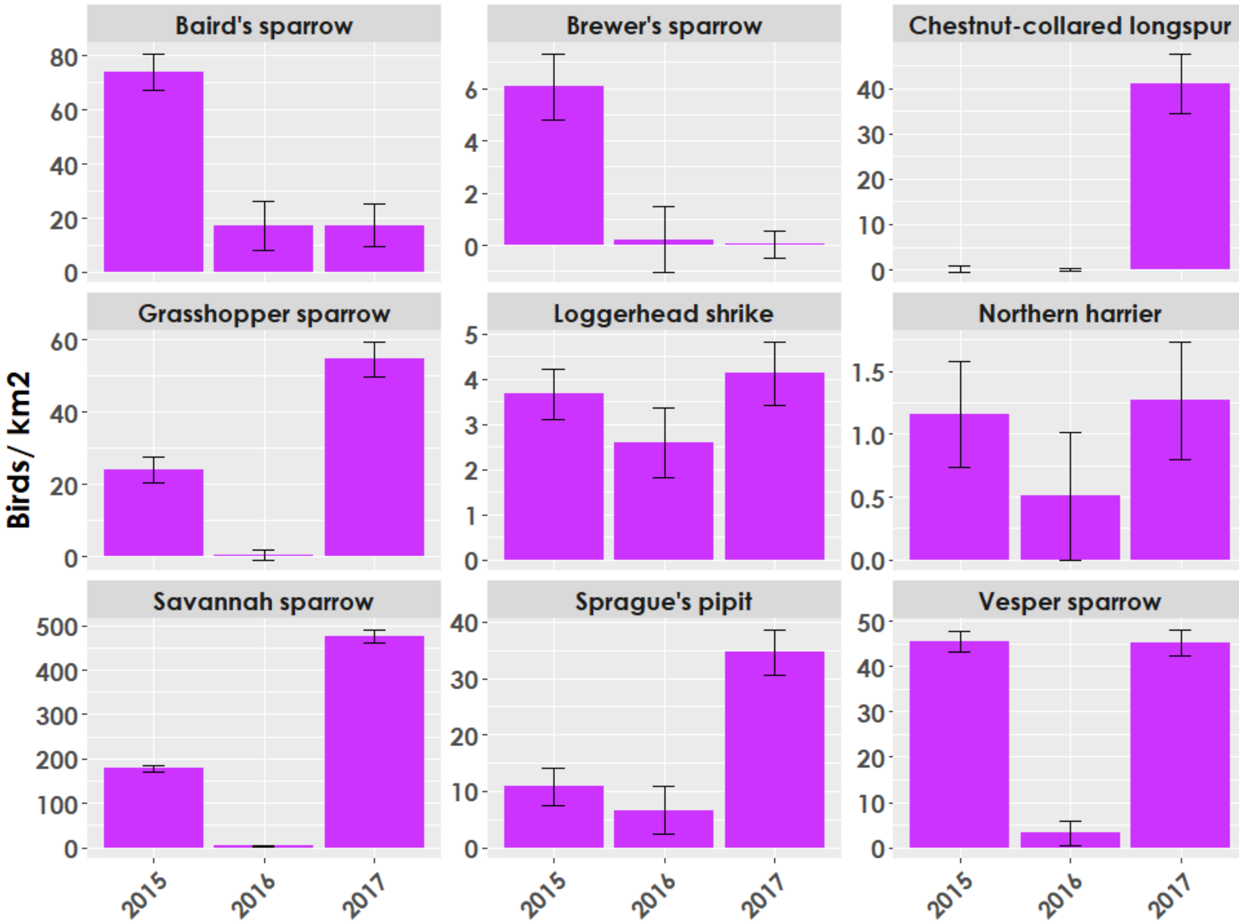

Figure 2: Density estimates (bird/km2) and standard deviations for 9 bird species at the Valle Colombia field site from winter 2015 to 2017.

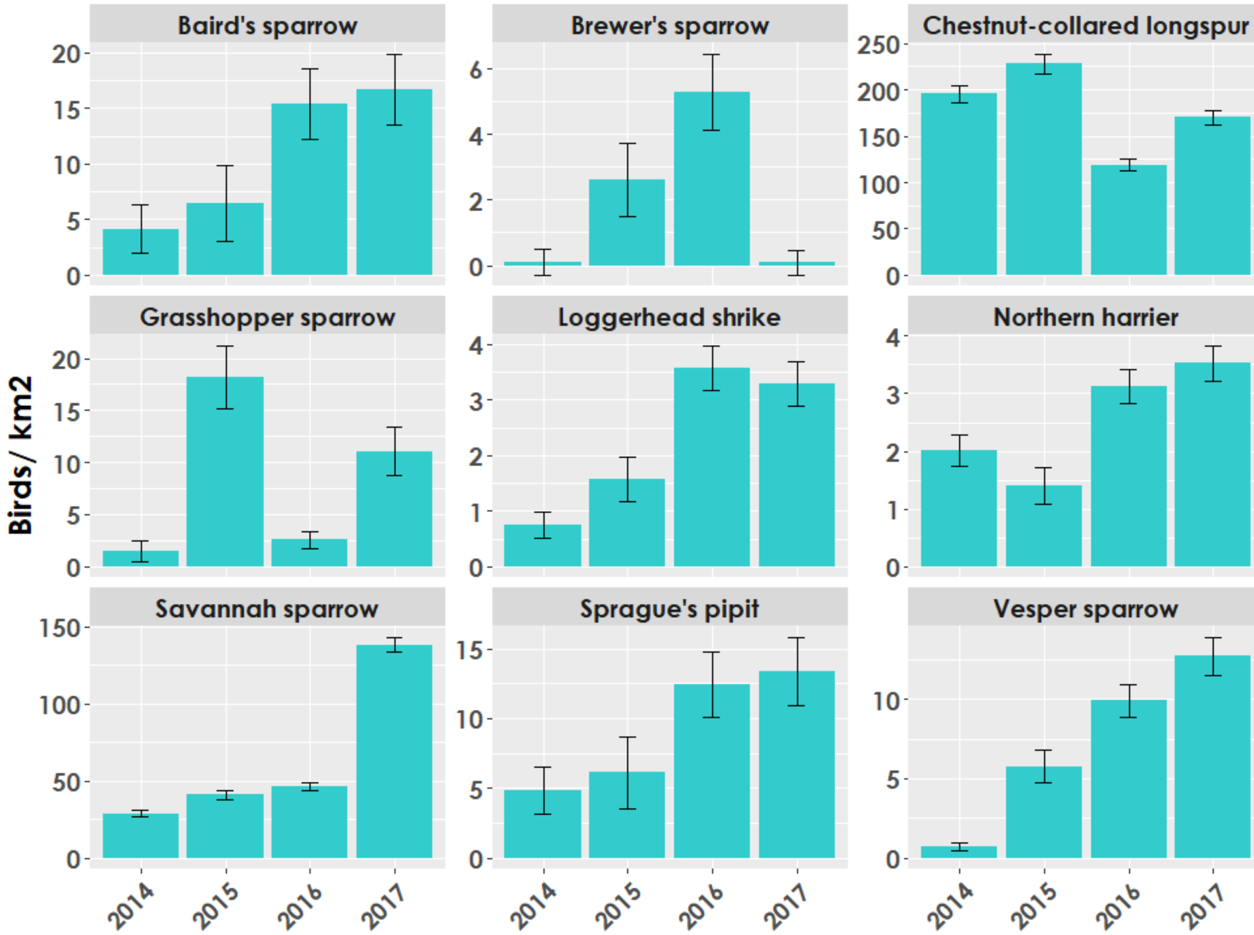

Figure 3: Density estimates (bird/km2) and standard deviations for 9 bird species at the Marfa field site from winter 2014 to 2017. Although we did not gather survival data prior to winter 2016-17, we have been conducting winter transects at this site since 2014.

Appendix II.

Table 1: Delta AICc and AICc model weights of linear mixed models to explain daily movement patterns in Baird's and grasshopper sparrows wintering at the Janos, Chihuahua site winters 2012-13 through 2016-17.

model	AICc	ΔAICc	weight
trajectory~species+julian+min temp	24773.30	0.00	0.95
trajectory~species+precipitation+julian+min temp	24781.06	7.76	0.02
trajectory~species+julian+max temp+min temp	24781.28	7.98	0.02
trajectory~julian+min temp	24781.61	8.30	0.01
trajectory~species+julian	24786.29	12.98	0.00
trajectory~precipitation+julian+min temp	24789.40	16.10	0.00
trajectory~species+precipitation+julian+max temp+min temp	24789.55	16.24	0.00
trajectory~julian+max temp+min temp	24789.71	16.41	0.00
trajectory~species	24791.24	17.94	0.00
trajectory~species+precipitation+julian	24791.85	18.54	0.00
trajectory~species+min temp	24792.44	19.14	0.00
trajectory~julian	24794.63	21.33	0.00
trajectory~species+julian+max temp	24795.11	21.80	0.00
trajectory~species+max temp+min temp	24795.94	22.63	0.00
trajectory~species+precipitation	24796.58	23.28	0.00
trajectory~precipitation+julian+max temp+min temp	24797.96	24.66	0.00
trajectory~species+precipitation+min temp	24799.06	25.75	0.00
null	24799.14	25.84	0.00
trajectory~species+max temp	24799.26	25.96	0.00
trajectory~species+precipitation+julian+max temp	24800.00	26.70	0.00
trajectory~min temp	24800.16	26.85	0.00
trajectory~precipitation+julian	24800.24	26.94	0.00
trajectory~julian+max temp	24803.39	30.09	0.00
trajectory~max temp+min temp	24804.05	30.75	0.00
trajectory~species+precipitation+max temp+min temp	24804.30	31.00	0.00
trajectory~precipitation	24804.55	31.24	0.00
trajectory~species+precipitation+-max temp	24805.29	31.98	0.00
trajectory~precipitation+min temp	24806.84	33.53	0.00
trajectory~max temp	24807.35	34.04	0.00
trajectory~precipitation+julian+max temp	24808.27	34.97	0.00
trajectory~precipitation+max temp+min temp	24812.40	39.10	0.00
trajectory~precipitation+max temp	24813.35	40.05	0.00