Demographic monitoring of breeding grassland birds in the Northern Great Plains

Bird Conservancy of the Rockies
2017 Annual Report
January 31, 2018

A Baird's sparrow outfitted with light-level geolocator unit ready to be released. Photo by D. Casey.

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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 Bird Conservancy's International Team

Jacy Bernath-Plaisted, M.N.R.M.: Jacy joined the International team at Bird Conservancy in 2017 and coordinates the field effort for this demographic work. He also plays a key role in data management and analyses for the project. Jacy came to his position with a background in grassland bird demographic work from master's thesis at the University of Manitoba, where he examined the effects of oil and gas infrastructure on mixed-grass prairie songbirds in southern Alberta.

Dr. Maureen Correll: Mo joined the International team at Bird Conservancy in 2016 and is the principle investigator of Bird Conservancy's full-annual-cycle study of grassland bird demographics. Mo's background in *Ammodramus* sparrow demographics through her dissertation work has prepared her well to lead this project. Mo's interest in remote sensing has also driven her to explore the use of UASs as tools to collect habitat information for grassland birds on the breeding and wintering grounds.

Nicole Guido, MS candidate: Nicole joined our team in 2016 as crew leader for our demographic site in eastern Montana. Nicole returned in 2017 as crew leader and a master's student investigating the use of UASs as tools for collecting habitat information on grassland songbirds on the breeding grounds. Nicole is pursuing her degree at the University of Maine, co-advised by Mo Correll and Kate Ruskin, and expects to graduate in winter 2019.

Arvind O. Panjabi, MS: Arvind is the founder and director of the International program at Bird Conservancy. His efforts to explore the demographics of grassland songbirds across their full annual cycle have provided a conceptual vision for the full annual cycle analysis and conservation of Baird's and grasshopper sparrows. Through Arvind's leadership, Bird Conservancy also maintains a stewardship program on the wintering grounds in Mexico and Texas.

Allison Shaw, MS: Allison joined the International team in 2015 and provides database and GIS support to our demographic project. Allison holds an MS in botany and also serves as our local plant identification expert.

Erin H. Strasser, MS: Erin leads our winter demographic work in the Chihuahuan Desert in Mexico, a project initiated in 2012. Erin's expertise in the fitting, and tracking of VHF radio transmitters, and her participation in the deployment and recovery of light-level geolocator units make her an important part of the NGP project. Field technicians in the NGP follow similar telemetry protocols (including harness attachment) to those Erin implements in the Chihuahuan Desert.

Erin Youngberg: The other Erin on the International team, Erin provides financial and administrative support to the demographic work in the NGP. She also heads up our grassland bird conservation efforts with the City of Fort Collins, CO. We hope to recruit Erin in 2018 to help in our geolocator recovery effort.

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Executive Summary

Grassland songbirds are among the most rapidly declining avian assemblages in North America. Over half of these grassland populations show long-term negative trends, and species breeding in the mixed-grass prairies of the Northern Great Plains (NGP) are declining at a particularly alarming rate, in some cases experiencing total population declines >90%. In recent decades, the plight of grassland songbirds has come into focus within the conservation community. However, the best management strategies to mitigate declines have remained unclear to some extent. Bird Conservancy initiated a comprehensive demographic monitoring program for several grassland songbird species that breed in the NGP in an effort to provide more targeted and effective management solutions to slow population declines. These species include the Baird's sparrow (*Ammodramus bairdii*), grasshopper sparrow (*Ammodramus savannarum*), chestnut-collared longspur (*Calcarius ornatus*), and Sprague's pipit (*Anthus spragueii*). In 2015, Bird Conservancy established its first demographic monitoring site, located in western North Dakota in the Little Missouri National Grasslands, funded by North Dakota Game and Fish (NDGF) through a state wildlife grant. We collected data on the abundance, nesting success, and habitat of all four species, as well as adult survival on radio-tagged Baird's and grasshopper sparrows. In 2016, we expanded the project, adding a second plot in North Dakota and establishing a new site with two additional plots in eastern Montana, funded directly by two Conoco-Phillips SPIRIT grants through the National Fish and Wildlife Foundation. We also began monitoring juvenile survival of Baird's and grasshopper sparrows and deploying light-level geolocator units on adult Baird's and grasshopper sparrows at both sites, as well as a collaborator site operated by the University of Manitoba, located in southern Alberta, Canada. In 2017 we continued research activities at all sites. To date the project has monitored a total of 602 nests (Baird's sparrow= 128; grasshopper =169; chestnut-collared longspur= 271; Sprague's pipit= 34), deployed 432 radio tags on adult sparrows (Baird's sparrow= 209; grasshopper sparrow= 223), deployed 131 radio tags on juvenile sparrows (Baird's sparrow= 83; grasshopper sparrow= 48), and deployed 219 geolocator units on adult sparrows (Baird's sparrow= 132; grasshopper sparrow= 87). In 2017, we piloted the use of radio transmitters on adult Sprague's pipit at our study sites, tagging and tracking 15 individuals. Among the most exciting developments of 2017, we recovered the first geolocator units (*n* =11) in the project's history, revealing migratory timing and routes of Baird's and grasshopper sparrow from our study sites to the wintering grounds. We also introduced the use of unmanned aircraft systems (UASs, or drones) to systematically map habitat at our sites and create 3D surface and vegetation maps. Finally, in 2017 we produced the project's first modelled estimates of nesting success for all four species, and adult survival of male Baird's and grasshopper sparrows.

Highlights of 2017

Nesting success analysis

Figure 1: Grasshopper sparrow nestlings on hatch day. Photo by K. Bell

Nesting success is a key vital rate that can affect the long-term viability of avian populations, and one of the primary baselines Bird Conservancy set out to monitor with the establishment of the Northern Great Plains (NGP) demographic project. The calculation of basic nesting success estimates represents not only a useful tool in potential management strategies, but also a key step towards populating an integrated population model to fuel a full-annual-cycle study of limiting factors for Baird's sparrow (*Ammodramus bairdii*) and grasshopper sparrow (*Ammodramus savannarum*). We hope that this approach will help us to identify bottlenecks in fecundity and replacement for these species. The results of our nesting success analysis revealed nesting success estimates that fall within the range of existing estimates for all species, though grasshopper sparrow exhibited low nesting success relative to existing estimates for the species. Discovering the cause of low nesting success for this species may prove to be an important piece of the puzzle in understanding population dynamics for this species in the NGP.

Adult survival analysis

Figure 2: Baird's sparrow (left) and grasshopper sparrow (right). Photos by S. Robinson.

Like nesting success, adult survival is a fundamental baseline component of demographic monitoring. Our survival estimates indicate that adult survival for both Baird's and grasshopper sparrow (Figure 2) is relatively high and invariant, suggesting that adult survival in the NGP is likely not a limiting factor for these species. However, emigration of adult males from our study sites has remained consistently high among years, suggesting that these semi-nomadic species may range widely within a given breeding season, possibly in response to environmental conditions. Additionally, we plan to use these data to populate an IMP for these species.

Geolocator unit recovery

Our team recovered 11 geolocator units deployed in 2016 and deployed 64 additional units on both Baird's and grasshopper sparrow in 2017. Light-level geolocator units record a bird's geographic position based on differences in photoperiod, as the bird traverses north to south, and back again (Bridge et al. 2013; Figure 3). These data are novel for both species in this region, and may reveal previously unknown migratory routes and stopover habitat for these birds. Our geolocator data are currently being analyzed by a colleague at the University of Oklahoma, Dr. Eli Bridges, who also manufactures some of the geolocator units we deploy. We plan to produce a manuscript detailing our findings in collaboration with him and other partners after an additional recovery effort in 2017.

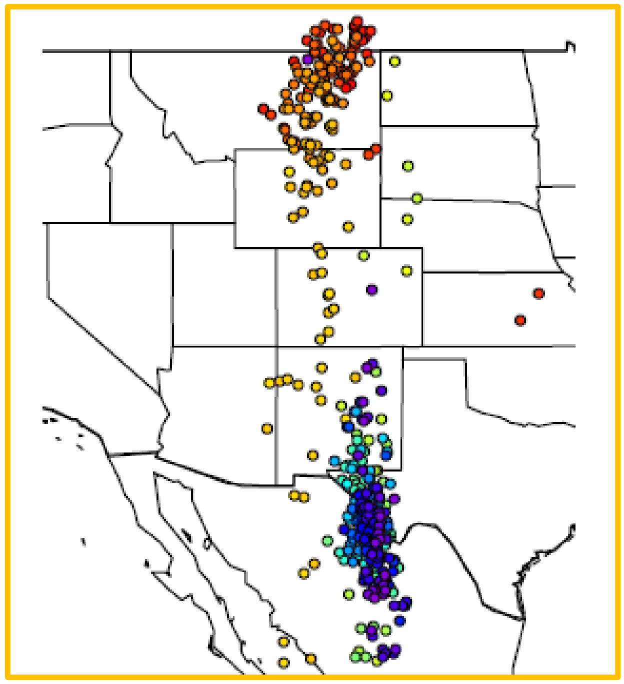

Figure 3: The migratory route of a grasshopper sparrow breeding in eastern Montana, as revealed by geolocator data. Red/orange colors represent summer and fall, and blue/purple colors indicate winter/spring.

VHF tagging of Sprague's pipit

We outfitted 15 Sprague's pipit (*Anthus spragueii;* Figure 4) with very high frequency (VHF) radio transmitters in a pilot study to determine the feasibility of using radio-tracking methods to monitor adult survival in this species at our study sites. Additionally, we plan to use the data collected to produce breeding season home-range estimates for this secretive species. In 2018 we hope to increase our effort in pipit monitoring to produce more robust data for our analyses.

Figure 4: A Sprague's pipit captured for VHF transmitter attachment Photo by K. Bell.

Application of UAS's in vegetation mapping
Another noteworthy development from our 2017 field season was the introduction of Unmanned Aircraft Systems (UASs, or more commonly known as drones) to our data collection techniques. We used quadcopter drones (Figure 5) outfitted with infrared and visible-light cameras to collect aerial imagery from 90-120m above our field sites. We then analyzed these data to create high-resolution, geo-referenced photos of our field sites as well as elevation models and vegetation reflectance data (e.g. Normalized Difference Vegetation Index, or NDVI). We plan to use fixed-wing drones (Figure 5) as well as our quadcopters to make drone data collection more efficient in 2018. If successfully validated, these techniques could signal a paradigm shift in how we collect habitat data in the future. The combination of 3D surface maps and NDVI imagery have the potential to provide a complete and systematic measure of both vegetation structure and primary productivity across our entire study sites.

Figure 5: Left: a quadcopter drone used to collect vegetation data at Bird Conservancy's NGP field sites. Right: fixed-wing drone recently purchased by Bird Conservancy held by a collaborator at Bird Conservancy's winter demography site near Marfa Texas

Project background

Grassland songbirds as a group are in steep decline. Specialist species reliant upon mixed-grass prairie habitat in the NGP have collectively experienced average population losses of >80% since 1966 (Sauer et al. 2017). Included in this group are the four focal species of Bird Conservancy's demographic monitoring project (Baird's sparrow, grasshopper sparrow, chestnut-collared longspur [*Calcarius ornatus*], and Sprague's pipit; see Table 1 for species population status). These species have all been identified as potential grassland bird focal species for the National Fish and Wildlife Foundation (NFWF) NGP conservation business plan (NFWF 2016). Numerous conservation plans and initiatives, including NFWF, North Dakota and Montana State Wildlife Action Plans, Partners in Flight (PIF), Northern Great Plains (NGPJV) and Prairie Potholes Joint Ventures (PPJV), and Region 6 of the US Fish and Wildlife Service (USFWS) identify the NGP as a critical breeding area for grassland birds of greatest conservation need. Although declines in populations of these species may be broadly attributed to the loss and degradation of grassland and rangeland habitat (*e.g.* Murphy 2003; Brennan and Kulvesky 2005; Askins et al. 2007), there is limited knowledge of how grassland conditions at a regional scale influence vital rates and what management practices should be implemented to optimize remaining habitat for these species. Over the last several years, Bird Conservancy has developed, and continues to refine, the study design and field protocols necessary to successfully carry out regional demographic monitoring for these species, with particular emphasis on Baird's and grasshopper sparrow.

Bird Conservancy's monitoring efforts in the NGP with respect to these two species are part of a larger vision to assess demographic rates across their life cycles. We are taking a full annual cycle approach to conservation of these species through development of an integrated population model (e.g. Woodworth et al. 2017). This approach will provide a holistic and powerful analysis framework that may help us to determine what demographic parameters most strongly influence population trends and what environmental factors most strongly influence those parameters. Our research efforts in the NGP began in 2015 and will continue over the next 2-3 years to allow for sufficient annual variation in climate and other environmental factors that could influence demographic rates.

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 four species of grassland songbird breeding in the NGP.

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
Chestnut-collared longspur	3,000,000	4.35	88.7
Sprague's pipit	900,000	3.50	82.5

Objectives

Declines in grassland songbirds breeding in the NGP may be driven by several different factors within their life histories. Low nesting success and productivity, survival rates in juveniles and adults, and differences in these rates across different seasons can all contribute to the growth or decline of a population. Declines may also be driven by complex seasonal interactions among various phases of the annual cycle. Given the importance of the NGP as a breeding area for grassland songbirds, knowledge of demographic rates in grassland songbird populations in this area and how they are influenced by various environmental parameters is needed to guide conservation and management in the region. However, data on vital rates are lacking or incomplete for many migratory grassland songbirds, as are data on factors influencing vital rates, site fidelity, and local movement patterns. With this project, we seek to quantify nesting success, adult and juvenile survival, and how home range patterns influence survival in multiple breeding populations in the NGP. We will also assess the influence of vegetation, climate, and other parameters on these vital rates to inform grassland management in the NGP.

The objectives for our demographic work in the NGP are to:

1) Estimate baseline rates of reproduction (nesting success and productivity) in Baird's and grasshopper sparrows and other focal species as allowed by sample size

2) Estimate baseline rates of survival in adult and juvenile Baird's and grasshopper sparrows, and adult Sprague' pipits as allowed

3) Examine the influence of vegetation characteristics, climate, and other environmental factors on demographic rates

4) Develop recommendations to share with Bird Conservancy's stewardship program and other organizations to inform management strategies for grassland songbirds breeding in the NGP.

5) Inform an integrated population model to assess how vital rates during various stages of the life cycle influence population size and growth across years.

Field sites

Little Missouri National Grasslands – Western North Dakota

Our demographic monitoring site in North Dakota (Figure 6) was established in 2015 under a 3-year grant from NDGF, with additional support from USFWS Region 6, the NGPJV in the Little Missouri National Grasslands and North Dakota Natural Resources Trust. These lands are managed by the United States Forest Service (USFS) and grazed to varying extents by cattle ranchers in the Little Missouri Grazing Association holding leases administered by the USFS. Our field plots at this site are dominated by exotic grasses such as Kentucky bluegrass (*Poa pratensis*) and crested wheatgrass (*Agropyron cristatum*). Native vegetation typical of the mixed-grass prairie also occurs throughout the plots, particularly on hilltops. Our North Dakota field site experienced severe drought during both the 2016 and 2017 field seasons.

Eastern Montana

Northeastern Montana is one of the last strongholds in the U.S. for Baird's sparrow and Sprague's pipit, and is a high-density area for grassland songbirds (Sauer et al. 2017). Added in 2016 using funding from the NFWF Conoco Phillips SPIRIT award (renewed through 2018), this site (Figure 7) expanded the geographic scope of the project and helps our study capture potential regional variation in demographic rates. Contrary to our North Dakota plots, the vegetation on our Montana plots is predominantly native. These plots are managed by the Bureau of Land Management (BLM) and leased by grazers or owned privately by ranchers. Our Montana site also experienced severe drought in 2017.

Figure 6: Bird Conservancy study site in western North Dakota. Photo by K. Bell.

Figure 7: Bird Conservancy study site in eastern Montana. Photo by N. Guido.

Field methods

Overview

We implement standardized field protocols across our study sites to quantify adult and juvenile survival, nesting success, species abundance, vegetation characteristics, and migratory connectivity for grassland songbirds. Our protocols are based on review of existing literature, recommendations from other grassland ecologists, and our continued experiences in the field as the project has progressed.

Figure 8: Bird Conservancy crew lead Sasha Robin with 5-element antenna and extension pole, used to track tagged birds. Photo N. Guido.

Radio telemetry: tracking and transmitter attachment

Between mid-May and early-August (2015-2017), adult male Baird's and grasshopper sparrows were captured using targeted mist-netting techniques (Figure 9, left) and outfitted with radio transmitters (Figure 9, right) for tracking purposes. At capture, all birds were fitted with a Lotek PicoPip radio transmitter using an elastic leg-loop harness (Rappole and Tipton 1991). Captured birds were also fitted with USGS aluminum bands and one or more color bands, and measured for standard morphometrics. In 2016, technicians also collected one primary feather (P1) and several body feathers from each bird for isotopic analyses to aid in assessing migratory connectivity (along with partners at University of Colorado-Denver and USGS). In 2017 we discontinued the capture of adult females on the nest because we found that it sometimes resulted in nest abandonment despite attempts to refine methods by only capturing females during nestling stage. Instead, we continued to focus on survival of adult males and juveniles. Two nestlings per nest were randomly selected and fitted with smaller (0.4g) radio transmitters when nestlings were 7-9 days of age, depending on development. We only tagged nestlings that weighed a minimum of 12g and displayed sufficient feather development (most pin and primary feathers beginning to unsheathe) to qualify. Birds were recaptured at the end of the season when possible to remove tags prior to migration. All tagged Individuals were tracked daily (Figure 8) to monitor survival and identify causes of mortality. Coordinates were taken at each recorded bird location and will be used to estimate home ranges and movement patterns. In 2017 we introduced a brief vegetation survey at every tracking location, so that survival and habitat use can be linked to vegetation characteristics in analysis.

Figure 9: A mist net used to capture grassland songbirds for banding and transmitter attachment (left; photo by J. Bernath-Plaisted); Bird Conservancy crew lead Kelsey Bell holding a Baird's sparrow outfitted with a radio transmitter (right; photo by J. Bernath-Plaisted).

Nest searching and monitoring

We monitored nests of Baird's sparrow, grasshopper sparrow, chestnut-collared longspur, and Sprague's pipit (Figure 10) during the 2015-2017 breeding seasons. We located nests using a hybrid approach including rope-dragging and systematic walking (Winter et al. 2003; Figure 11), behavioral observation (Martin

1993), and opportunistically discovery while traversing plots. Once located, we visited nests daily in 2015 and every 2-3 days in 2016-2017, occasionally with longer intervals between checks due to weather or logistics. We visited nests more frequently (1-2 days) when near fledging age. At each visit we recorded nests contents and photographed and we examined nests for evidence of predators or brood parasitism by brown-headed cowbirds (*Molothrus ater*). We aged nests using egg floatation (Liebezeit et al. 2007) and nestling aging techniques based on physiological benchmarks (Jongsomjit et al. 2007). In 2017, to enhance our ability to discern nest fates accurately, we introduced 15- to 30-minute observation periods on potentially fledged nests. During observations, technicians watched for indicators of fledging, such as feeding of fledglings by parents (Figure 10). We considered nests that fledged ≥1 young "successful". We also collected vegetation data at each nest within three days post-fledge or failure, as well as at a corresponding random point within the plot for analysis of nest-site selection in these species.

Figure 10: From top to bottom: Baird's sparrow eggs, grasshopper sparrow nestlings, chestnut-collared longspur nest hatching, and Sprague's pipit nestlings. Photos by J. Bernath-Plaisted

Point Count Surveys

We followed point count protocol from Bird Conservancy's Integrated Monitoring of Bird Conservation Regions (IMBCR; Pavlacky et al. 2017) to estimate bird abundance within the study areas using 6-minute passive point count surveys that employ distance sampling (Buckland et al. 2001) and time-removal methods (Royle and Dorazio 2008). We selected point count locations by placing a 250m grid over our study site, and visited each location twice during the breeding season (June, 2015-2017) leaving at least 10 days in between visits. We conducted 6-minute point counts at each selected location following IMBCR methods. These data allow us estimate local abundance each year on the study plots. We can use these estimates along with regional IMBCR estimates to measure change in these populations.

Vegetation surveys

In addition to vegetation surveys conducted at nest sites and bird locations (and associated random points) we also surveyed points on a 100-meter grid across each study plot to assess vegetation community composition and structure across the landscape. At each point we employed a modified BBIRD Grasslands Protocol (Martin et al. 1997) using a

Daubenmire frame (25 x 50 cm) and Robel pole to assess cover, structure, and composition. We collected data at each landscape grid point twice (early and late season, 2016-2017) to capture changes in vegetation structure, cover, and composition to assess the influence of seasonal changes and climate on vegetation. We will use these data to explore habitat selection by breeding songbirds as well as the influence of these habitat variables on survival and nesting success.

Figure 11: From left to right: technicians rope dragging for nests (photo by K. Bell); recently fledged Baird's sparrow (photo by K. Bell); adult male chestnut-collared longspur carrying food (photo by J. Horvat).

UAS imagery collection

Beginning in 2017, we used several DJI Phantom 4 Pro quad-copter drones to systematically survey the vegetation and surface features of each of our four plots. We photographed our plots using the DJI gimbal camera (altitude of 90m) for red green blue imagery and the Parrot Sequoia camera (altitude of 120m) for infrared and near-infrared imagery, mapping the entire surface area using Pix4d mapper software for mission planning.

Geolocator deployment and recovery

In partnership with the National Audubon Society, University of Oklahoma, and the University of Manitoba we deployed geolocators on Baird's and grasshopper sparrow adults across their breeding ranges in the NGP (Figure 12) in an attempt to map migratory pathways and connectivity between breeding populations in the NGP and the birds' wintering grounds (e.g., Bridge et al. 2013). Geolocators were produced by Migrate Tech or Eli Bridge, and are attached using harness configurations similar to our VHF transmitters but constructed from StretchMagic plastic cord and crimp beads to allow for harness sizing and fitting on individual birds.

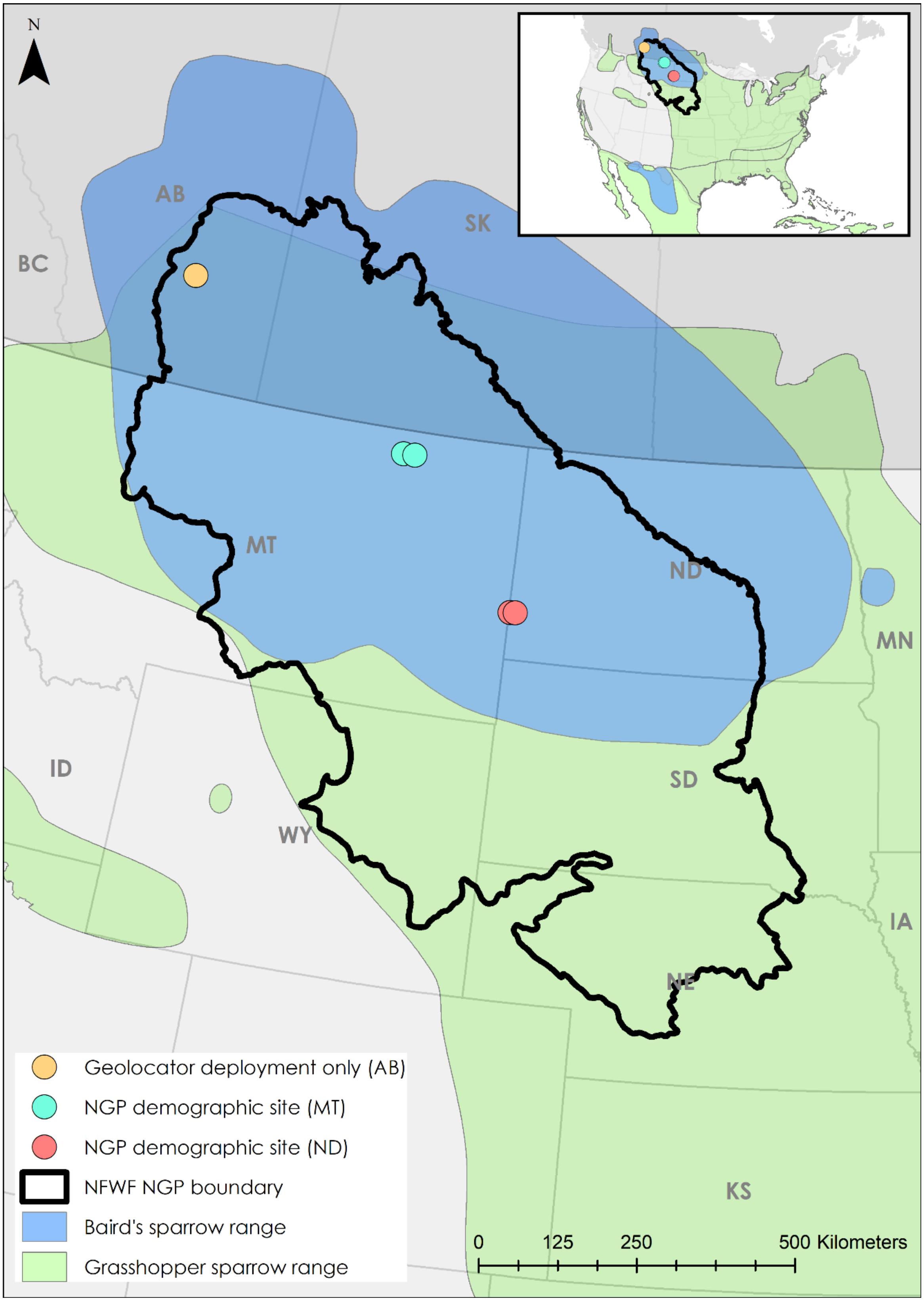

Figure 12: Map showing the locations of Bird Conservancy's geolocator deployment sites in the NGP relative to the breeding ranges of Baird's and grasshopper sparrow.

Analysis and results

Adult survival

We analyzed adult survival (Figure 13) for 165 adult male Baird's sparrows and 149 adult male grasshopper sparrows monitored during 2015-2017 in North Dakota and 2016-2017 in Montana (see Table 2 for all tagging efforts). We estimated survival using logistic exposure (Shaffer 2004) and evaluated models using an information theoretic approach (Anderson and Burnham 2002). All analyses were conducted in Program R (R Core Team 2017) using the lme4 package (Bates et al. 2014) combined with a modified logit-link function provided by Shaffer (2004). Our models tested for univariate effects of year, site (North Dakota or Montana; only used in the all sites models), time of season (days from May 1st, standard, quadratic and cubic terms), temperature (daily and weekly averages), and precipitation (daily and weekly accumulation), as well as global models including multiple variables. However, none of these

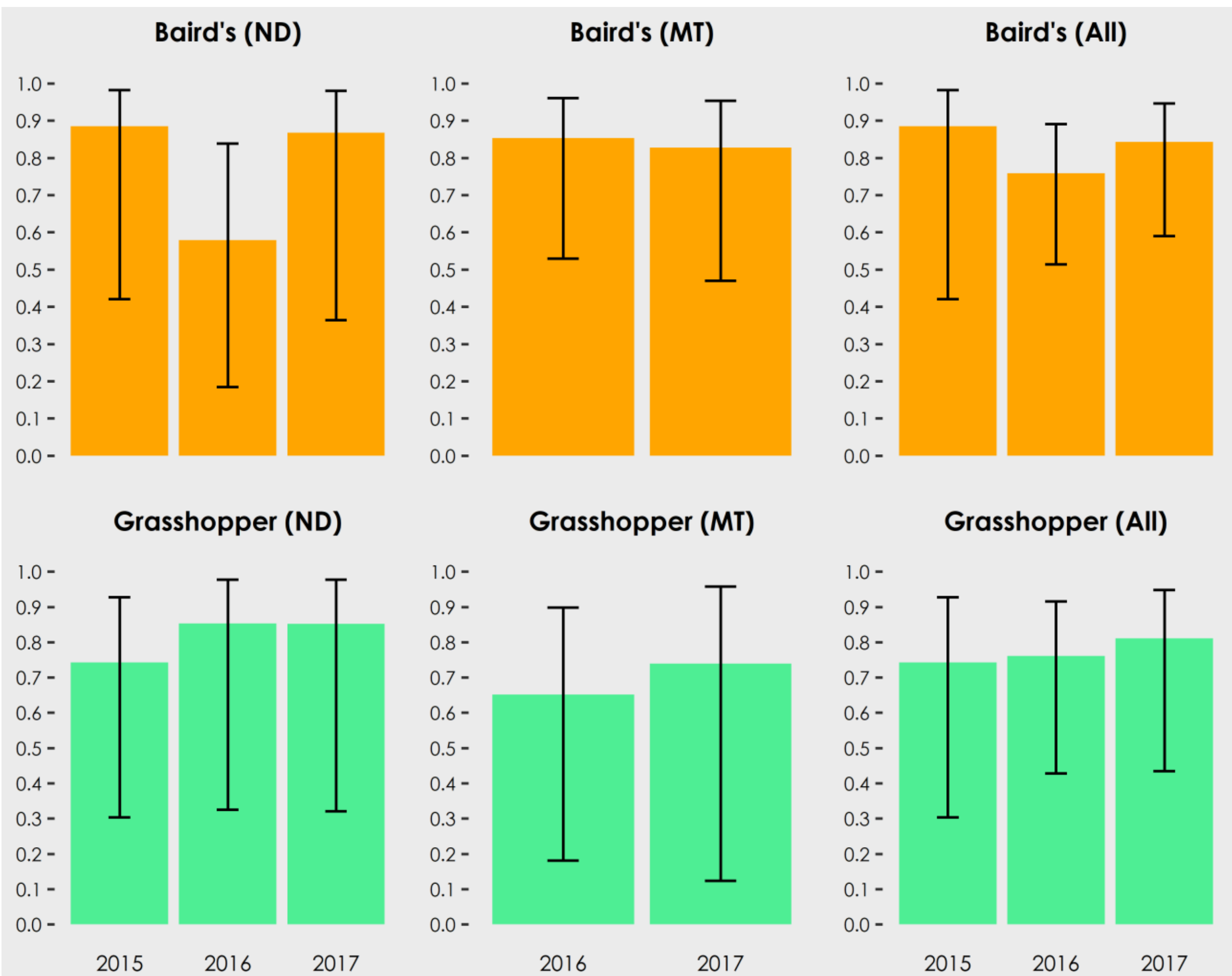

Figure 13: Adult male Baird's and grasshopper sparrow survival estimates over a period of 90 days on the breeding grounds in North Dakota (ND) and Montana (MT), 2015-2017. Probability of survival is shown on the Y-axis and year on the X-axis.

variables were explanatory, and all models were equivalent or inferior to null models (ΔAIC<3; Appendices I-III).

These results are not surprising given that survival estimates were relatively constant among sites and years. Overall, adult survival was high and showed little variation. Adult survival for grassland songbirds on the breeding grounds varies among species, but typically ranges from 50-75% for similar species, such as savannah sparrow (*Passerculus sandwichensis*) and dickcissel (*Spiza americana*; Fletcher et al. 2006; Perlut et al. 2008). The estimates we present here help rule out adult breeding-season survival as an important contributor to population declines for Baird's and grasshopper sparrow relative to other parameters like nesting success, juvenile survival, and adult survival on the wintering grounds. For both species, confirmed deaths made up a relatively low percentage of known fates (Baird's sparrow= 15%; grasshopper sparrow= 28%), but interestingly individuals that appear to have emigrated during monitoring made up a very large percentage of total birds tagged (Baird's sparrow= 59%; grasshopper sparrow= 81%). This suggests that a large proportion of these species' populations are semi-nomadic throughout the season, and may be responding to shifting climate and grassland conditions during the breeding period, or interspecific changes in social hierarchy and dominance. Existing literature on the movements of grasshopper sparrows on the breeding grounds indicates that individuals habitually change territories throughout the season and sometimes range up to 9km from original locations (Williams and Boyle 2017).

Table 2: Numbers of nests monitored and number of birds tagged with radio transmitters for four species of grassland songbird by Bird Conservancy of the Rockies.

Year	Species	Nests (*n*)	Adults (*n*)	Juveniles (*n*)
2015	Baird's sparrow	21	35	
	Grasshopper sparrow	39	50	
	Chestnut-collared longspur	10		
	Sprague's pipit	1		
2016	Baird's sparrow	46	86	32
	Grasshopper sparrow	78	94	31
	Chestnut-collared longspur	114		
	Sprague's pipit	16		
2017	Baird's sparrow	61	88	51
	Grasshopper sparrow	52	79	17
	Chestnut-collared longspur	147		
	Sprague's pipit	17	15	
All years	Baird's sparrow	128	209	83
	Grasshopper sparrow	169	223	48
	Chestnut-collared longspur	271		
	Sprague's pipit	34	15	

Nesting success
We monitored the nesting success (Figure 14) for nests of four grassland songbird species breeding in the mixed-grass prairies of North Dakota and Montana (Baird's sparrow= 105; grasshopper sparrow= 142; chestnut-collared longspur= 268; and Sprague's pipit= 31; see Table 2). Mean nesting success (CI range) rates across years and sites for these species were 34% (16-50), 16% (7-28), 36% (28-43), and 33% (14-53), respectively. We analyzed nesting success using the same logistic exposure methods described for adult survival. Nests with unknown fates were included in the analysis, but truncated to the interval of last known activity, as suggested by Manolis et al. (2000). We compared univariate models against one another using AIC to explore the individual effects on nesting success; we also ran global models including multiple variables. Variables tested in models included year, site (North Dakota or Montana), and time of season (days from May 1st, standard, quadratic and cubic terms). For Baird's sparrow, and grasshopper sparrow, these variables were not explanatory (ΔAIC<1; Appendix IV). For chestnut-collared longspur, nesting success was best explained by time of season, and declined as the season progressed (β= -0.46 ±0.09); all three date terms were equivalent (ΔAIC<2; Appendix IV) and performed substantially

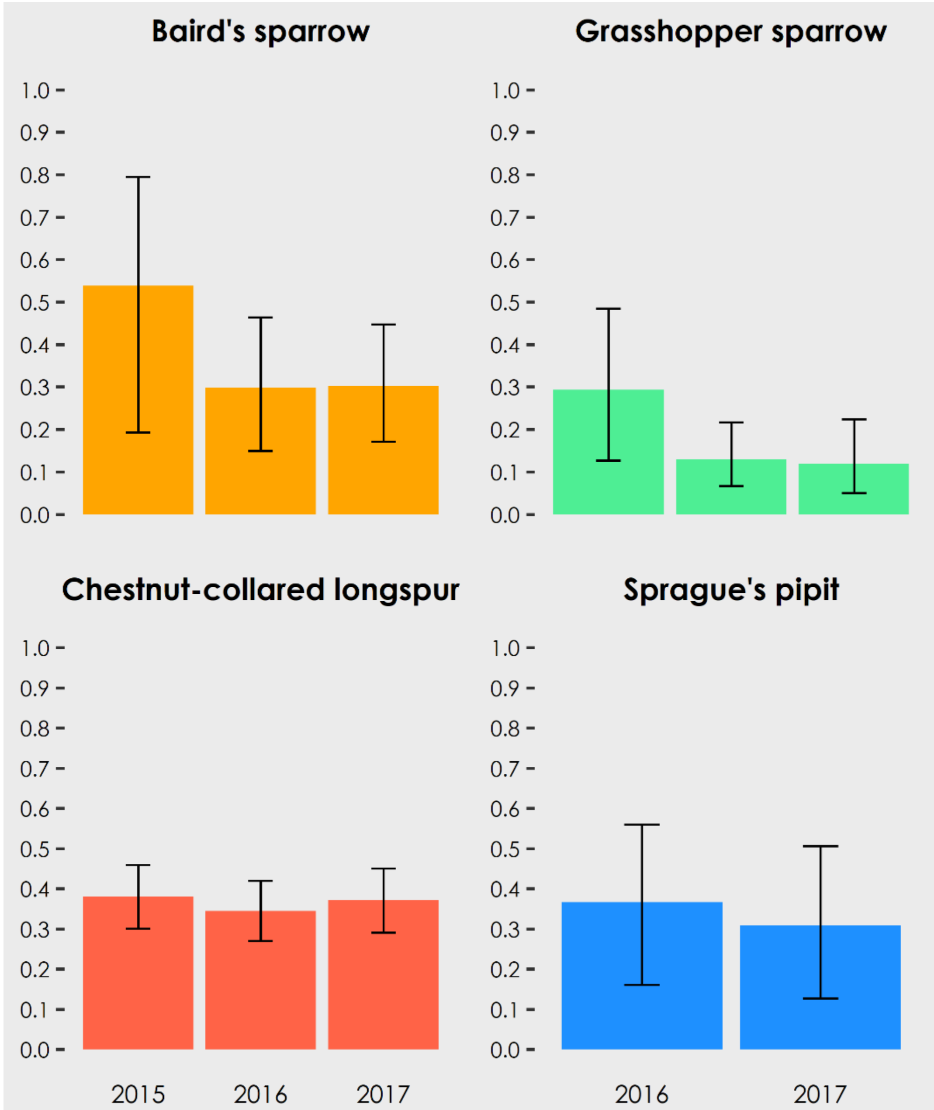

Figure 14: Nesting success estimates by year and species for songbird nesting in North Dakota and Montana, 2015-2017. Probability of success is shown on the Y-axis, and year on the X-axis. Estimates shown are from most explanatory models selected by AIC.

better than the null model (ΔAIC= 25; Appendix IV). Finally, there was weak support for an effect of temperature on Sprague pipit nesting success (ΔAIC= 3.93; Appendix IV), as success decreased with increasing temperature (β= -0.61 ±0.25) We did not attempt to analyze other main effects for these species, as we were primarily interested in establishing baseline rates at this time. Nesting success estimates were within ranges established by existing literature for all species though confidence intervals are large for species with smaller sample sizes. Grasshopper sparrow nesting success was exceptionally low, though not unprecedented (Table 3). Determining the drivers of low nesting success for this species at our sites may be useful in identifying potential management strategies, particularly in the context of an integrated population model.

Table 3: Range of existing nesting success estimates for four species of grassland songbird nesting in the Great Plains. Note that this is not an exhaustive list.

Species	Studies	Locations	Range
Baird's sparrow	Davis 2003, Jones *et* al. 2010, Ludlow et al. 2014	Saskatchewan, Montana, Alberta	26-43%
Grasshopper sparrow	DeLisle and Savidge 1996, Jones et al. 2010, Hovick et al. 2012	Nebraska, Montana, Iowa	14-52%
Chestnut-collared longspur	Davis 2003, Lloyd and Martin 2005, Jones et al. 2010	Saskatchewan, Montana	29-44%
Sprague's pipit	Davis 2003, Jones et al. 2010, Ludlow et al. 2014	Saskatchewan, Montana, Alberta	30-52%

Mapping migratory pathways

Bird Conservancy deployed 71 units on adult Baird's and grasshopper sparrows in 2017, in addition to the 144 deployed in 2016. Of all geolocators deployed across both years, 58 were manufactured by Migrate Technology, and 157 were manufactured by Dr. Eli Bridge at the University of Oklahoma. We recovered 5 units from returning Baird's Sparrows and 6 from returning grasshopper sparrows for a combined total of 11 geolocator units from returning birds in 2017. Of the units recovered, we were able to recover data suitable for analysis from 9 of 11 units. We analyzed all geolocator data in Program R (R Core Team 2017) using the TwGeos (Wotherspoon et al. 2016) and GeoLight (Lisovski and Hahn 2013) packages. As a result of drift on the internal clocks of the University of Oklahoma geolocators, all data from the University of Oklahoma units were calibrated to the internal clocks of the Migrate Technology units during analysis. Baird's sparrows appear to maintain a dog-legged pattern at the beginning of their migratory route in the NGP, and then travel directly to their wintering grounds. Light readings on several of the recovered tags indicated significant shading during daylight hours once birds reached the wintering grounds. We speculate that birds sought shelter during the day, presumably to escape from the elements and to avoid detection by predators, more than during the breeding season when birds are particularly vigilant on their territories. It also possible that timing of molt or habitat differences between the breeding and wintering grounds could explain this phenomena. Because of this shading, wintering ground locations are likely skewed northward of their actual locations. We are currently exploring the use of spatial masks and Markov Chain Monte Carlo (MCMC) methods using the SGAT package (Sumner et al. 2009) to account for this bias in the recovered geolocator data. We also hope to recover additional units in 2018 to make our dataset more robust.

Mapping sparrow habitat using UASs

We created 3-dimensional Digital Surface Models (2 cm resolution, Figure 15) and calculated NDVI (11 cm resolution) for all field sites using imagery flown in August 2017. We processed all collected imagery in Pix4d photogrammetry software. We estimate raster horizontal geospatial accuracy at 5m.

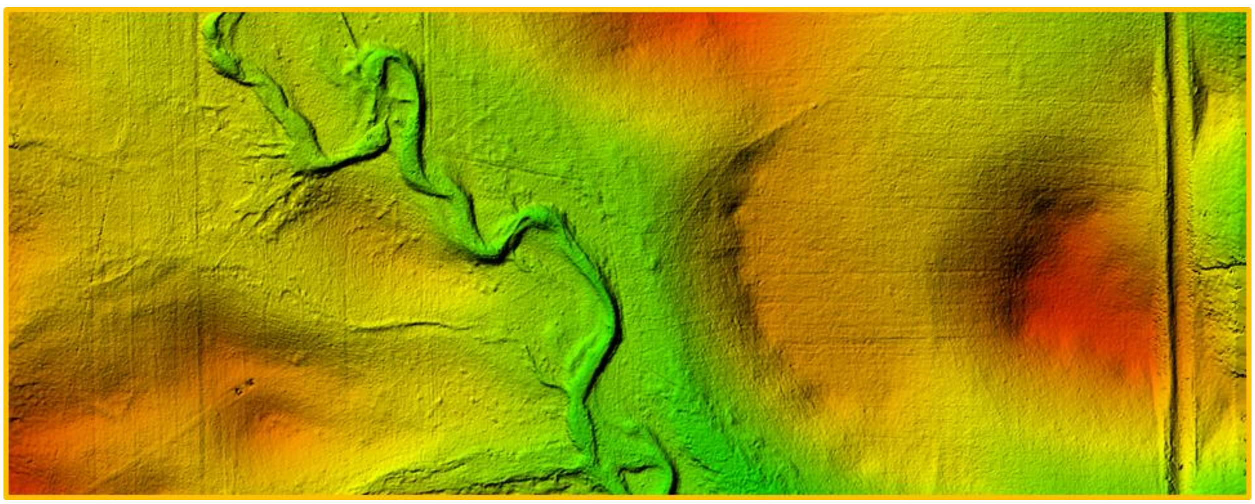

Figure 15: A digital surface map of a Bird Conservancy study plot in the NGP created using drone collected imagery.

We encountered some issues with the timing of imagery collection due to weather, where high winds and rain limited imagery collection on some days and forced us to spread data collection over several days for one plot, introducing error to our NDVI estimates. We plan to increase our capacity for efficient UAS data collection in 2018 by using an eBee Plus fixed-wing drone in conjunction with a Sensor Optimized for Drone Applications (SODA) camera for red green blue imagery and our Sequoia cameras. This change in methods will produce comparable rasters to those produced in 2017 but allow additional data collection across the season to measure change in NDVI on our sites across the breeding season. Nicole Guido will be heading this effort as part of her MS thesis.

Future directions

Development of IPMs for an FAC approach to bird conservation

We plan to combine the data presented in this report with similar demographic data from the wintering grounds (Strasser and Panjabi 2016) 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. The development of these models will help isolate limiting factors within the context of the full annual cycle of these species (Figure 16), and will help to focus conservation effort where it is most needed. We currently have all the data necessary to populate this model but are still seeking additional funding to support staff time to put towards model development, analysis, and interpretation.

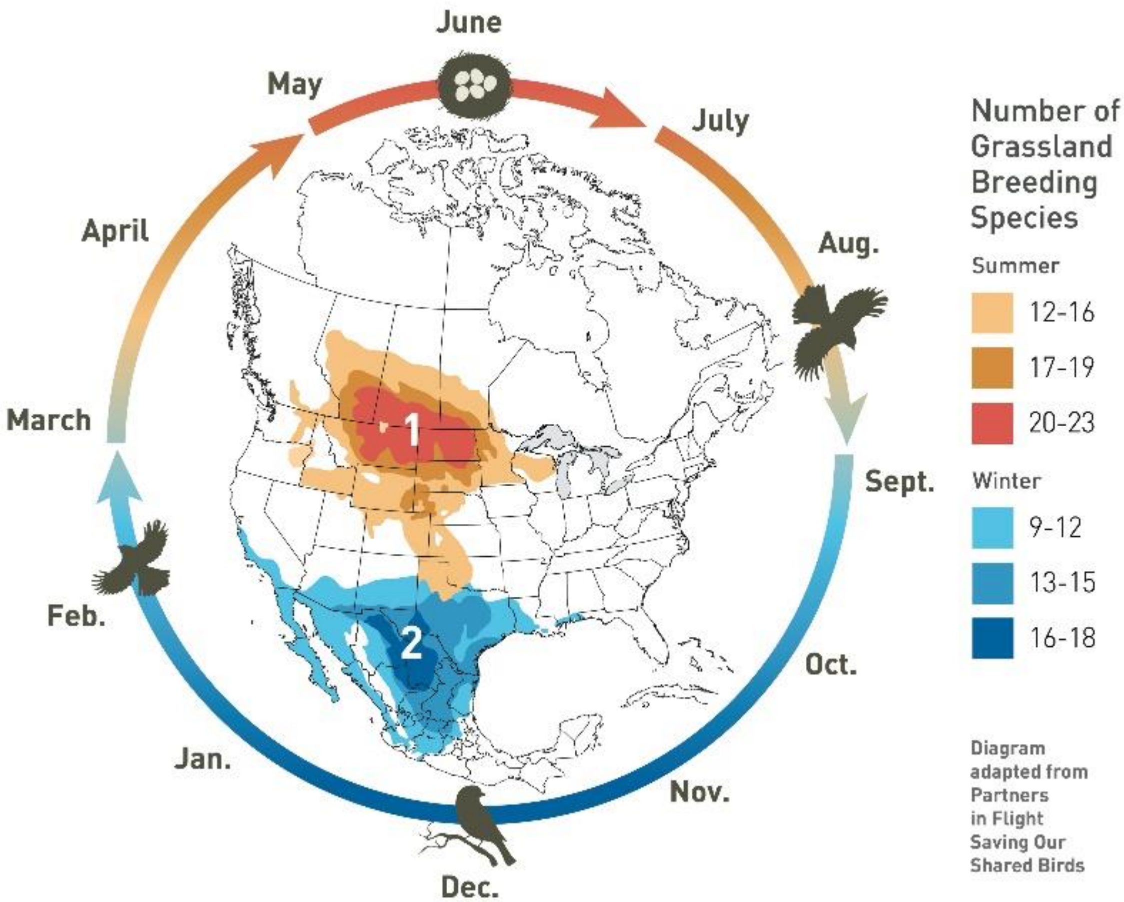

Figure 16: a visualization of the FAC monitoring approach, depicting the connection between grassland habitat on the breeding grounds in the NGP (1), and wintering grounds in the southwestern United States and Mexico (2).

Juvenile survival

We plan to produce juvenile survival estimates comparable to the adult survival estimates presented in this report in upcoming years of the project. Juvenile survival is an important and often understudied life history stage during which mortality tends to be high. This is a knowledge gap that may be of particular importance for our species and an important input for the upcoming integrated population model we plan to build. We plan to experiment with alternate and novel field methods for tracking juvenile survival during the upcoming 2018 field season.

Adult home ranges and habitat selection

We plan to use our existing adult telemetry dataset to create home range estimates for Baird's and grasshopper sparrows and combine these data with vegetation data to determine what habitat characteristics birds are selecting when establishing territories.

Vegetation characteristics and nesting success

Now that we have established baseline nesting-success rates we are ready move forward with identifying factors affecting these success rates. We plan to conduct further analysis in the coming year to examine the effects of a suite of vegetation variables on nesting success. Vegetation variables are of particular importance because they are directly connected to management practices, such as fire and grazing regimes.

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Appendices

Appendix I: *Delta AIC and AIC model weights of fitted adult survival logistic exposure models for Baird's sparrow and grasshopper sparrow monitored at both North Dakota and Montana sites, 2015-2017. Global models included year, site, a standard date term, and either daily or weekly precipitation and temperature variables (e.g. Global climate). In cases where collinearity (>0.6) between date term and a climate variable occurred, either precipitation or temperature had to be dropped.*

Species	Model	Weight	ΔAIC
Baird's sparrow	Null†	0.218	0.00
	Date	0.101	1.53
	Date quadratic	0.101	1.54
	Date cubic	0.096	1.65
	Day precip	0.092	1.73
	Site	0.091	1.75
	Weekly avg temp	0.085	1.88
	Weekly avg precip	0.082	1.95
	Daily avg temp	0.080	2.00
	Year	0.045	3.17
	Year + site + date + wkprecip	0.009	6.27
	Year + site + date + daprecip + datemp	0.008	6.49
Grasshopper sparrow	Daily precipitation‡	0.369	0.00
	Null	0.132	2.06
	Date	0.092	2.78
	Weekly avg temperature	0.071	3.28
	Date quadratic	0.071	3.31
	Weekly avg preciptitation	0.069	3.34
	Site	0.065	3.49
	Date cubic	0.058	3.69
	Daily avg temperature	0.049	4.05
	Year	0.019	5.92
	Year + site + date + daprecip + datemp	0.002	8.58
	Year + site + date + wkprecip + wktemp	0.001	11.82

†Top model AIC= 128.1 ‡Top model AIC= 89.4

Appendix II: *Delta AIC and AIC model weights of fitted adult survival logistic exposure models for Baird's sparrow and grasshopper sparrow monitored in North Dakota only, 2015-2017. Global models included year, a standard date term, and either daily or weekly precipitation and temperature variables. In cases where collinearity (>0.6) between date term and climate variables occurred, either precipitation or temperature had to be dropped.*

Species	Model	Weight	ΔAIC
	Null†	0.226	0.00
	Weekly avg preciptitation	0.127	1.15
	Year	0.104	1.54
	Date cubic	0.092	1.81
	Daily avg temperature	0.087	1.90
Baird's sparrow	Date quadratic	0.086	1.93
	Weekly avg temperature	0.085	1.95
	Date	0.084	1.99
	Daily avg precipitation	0.083	2.00
	Year + date + wkprecip	0.018	5.03
	Year + date + daprecip + datemp	0.007	6.99
	Daily precipitation‡	0.304	0.00
	Null	0.146	1.46
	Date	0.111	2.02
	Weekly avg temperature	0.099	2.23
	Date quadratic	0.090	2.43
Grasshopper sparrow	Date cubic	0.075	2.80
	Daily avg temperature	0.070	2.93
	Weekly avg preciptitation	0.056	3.38
	Year	0.024	5.09
	Year + date + daprecip + datemp	0.020	5.45
	Year + date + wkprecip	0.006	7.92

†Top model AIC= 71.2 ‡Top model AIC= 55.7

Appendix III: *Delta AIC and AIC model weights of fitted adult survival logistic exposure models for Baird's sparrow and grasshopper sparrow monitored in Montana only, 2016-2017. Global models included year, a standard date term, and either daily or weekly precipitation and temperature variables. In cases where collinearity (>0.6) between date term and climate variables occurred, either precipitation or temperature had to be dropped.*

Species	Model	Weight	ΔAIC
Baird's sparrow	Daily precipitation†	0.206	0.00
	Null	0.151	0.62
	Date cubic	0.142	0.75
	Date quadratic	0.122	1.04
	Date	0.099	1.46
	Weekly avg preciptitation	0.062	2.42
	Daily avg temperature	0.061	2.42
	Weekly avg temperature	0.058	2.53
	Year	0.056	2.59
	Year + date + daprecip + datemp	0.028	3.96
	Year + date + wkprecip	0.014	5.36
Grasshopper sparrow	Null‡	0.230	0.00
	Daily precipitation	0.121	1.29
	Weekly avg preciptitation	0.105	1.56
	Daily avg temperature	0.103	1.61
	Year	0.088	1.93
	Date cubic	0.086	1.98
	Date	0.085	2.00
	Weekly avg temperature	0.084	2.01
	Date quadratic	0.084	2.01
	Global daily climate	0.008	6.74
	Global weekly climate	0.005	7.55

†Top model AIC= 58.0 ‡Top model AIC= 35.7

Appendix IV: *Delta AIC and AIC model weights of fitted nesting success logistic exposure models for Baird's sparrow, grasshopper sparrow, chestnut-collared longspur, and Sprague pipit monitored in Montana and North Dakota, 2015-2017. Global models included year, site, a standard date term, and either daily or weekly precipitation and temperature variables. In cases where collinearity (>0.6) between date term and climate variables occurred, either precipitation or temperature had to be dropped. In some cases, both climate variables were correlated with date at a given temporal scale (daily or weekly), thus the model was dropped.*

Species	Model	Weight	ΔAIC
Baird's sparrow	Date†	0.187	0.00
	Date quadratic	0.162	0.28
	Date cubic	0.140	0.58
	Null	0.120	0.88
	Daily avg temperature	0.073	1.89
	Site	0.065	2.10
	Weekly avg temperature	0.063	2.19
	Daily precipitation	0.054	2.46
	Weekly avg preciptitation	0.044	2.90
	Year	0.042	3.00
	Year + site + date + daprecip + datemp	0.037	3.23
	Year + site + date + wkprecip	0.013	5.31
Grasshopper sparrow	NUll‡	0.176	0.00
	Year	0.147	0.36
	Daily avg temperature	0.114	0.87
	Weekly avg preciptitation	0.101	1.11
	Date	0.086	1.43
	Date quadratic	0.081	1.54
	Date cubic	0.078	1.63
	Site	0.069	1.86
	Weekly avg temperature	0.067	1.93
	Daily precipitation	0.066	1.97
	Year + site + date + daprecip + datemp	0.008	6.09
	Year + site + date + wkprecip + wktemp	0.007	6.36
Chestnut-collared longspur	Date quadratic*	0.359	0.00
	Date	0.304	0.33
	Date cubic	0.216	1.01
	Year + site + date + wkprecip	0.088	2.81
	Year + site + date + daprecip + datemp	0.033	4.79
	Daily avg temperature	0.000	17.18
	Weekly avg temperature	0.000	17.31
	Site	0.000	22.48
	Null	0.000	25.76
	Daily precipitation	0.000	27.53
	Weekly avg preciptitation	0.000	27.74
	Year	0.000	29.43
Sprague's pipit	Weekly temperatureΦ	0.512	0.00
	Daily temperature	0.156	2.38
	Null	0.072	3.93
	Date	0.067	4.08
	Date quadratic	0.045	4.88
	Date cubic	0.034	5.45
	Year	0.032	5.52
	Site	0.028	5.78
	Weekly avg precipitation	0.026	5.97
	Daily precipitation	0.026	5.99
	Year + site + date + daprecip + datemp	0.003	10.08

†Top model AIC= 309.2 ‡Top model AIC= 453.0 *Top model AIC= 791.6 ΦTop model AIC= 100.7