RECOMMENDATIONS FOR GRASSLAND BIRD SPECIES CONSERVATION IN THE NORTHERN GREAT PLAINS (NGP) BUSINESS PLAN

Final Report

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BIRD CONSERVANCY OF THE ROCKIES

Mission: conserving birds and their habitats through science, education and land stewardship

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.

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.

Bird Conservancy accomplishes its mission by:

Monitoring long-term bird population trends to provide a scientific foundation for conservation action

Researching bird ecology and population response to anthropogenic and natural processes to evaluate and adjust management and conservation strategies using the best available science

Educating people of all ages through active, experiential programs that create an awareness of and appreciation for birds

Partnering with state and federal natural resource agencies, private citizens, schools, universities and other non-governmental organizations to build synergy and consensus for bird conservation

Fostering good stewardship on private and public lands through voluntary, cooperative partnerships that create win-win situations for wildlife and people

Sharing the latest information on bird populations, land management and conservation practices to create informed publics

Delivering bird conservation at biologically relevant scales by working across political and jurisdictional boundaries in western North America and beyond

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EXECUTIVE SUMMARY

1. We used a Structured Decision-Making (SDM) approach to select focal bird species for inclusion in the Northern Great Plains (NGP) business plan. Following the SDM model we 1) developed a matrix of quantifiable selection criteria, 2) used expert opinion to assign weights to those criteria, and 3) ensured that the focal group included species associated with a range of grassland habitat types by including habitat associations in the selection process. By using a formal framework, we provide a transparent and repeatable method for the prioritization and selection of focal species that are associated with the diversity of grassland habitats across the NGP. These efforts resulted in the selection of Baird's Sparrow, Chestnut-collared Longspur, Lark Bunting, McCown's Longspur, and Sprague's Pipit as the five grassland bird focal species.

2. We used the Integrated Monitoring in Bird Conservation Regions (IMBCR) database to model 1) bird abundance across the surveyed sections of the NGP for the five selected species and 2) model habitat relationships of each species using a hierarchical modeling approach. We used the resulting models to create spatially explicit abundance maps for each species and the community as a whole, and used conservation planning software to identify potential focal areas for the NGP business plan using the program Zonation. We found that abundance increased with the amount of grassland at the large scale for all species reflecting a strong landscape-scale relationship, and that individual species had varying relationships with shrub cover, consistent with their natural histories. The majority of the identified priority areas occurred in the northern half of the NGP area, highlighting the importance for additional data about northern portion of the NGP, including those in Canada.

3. We used a combination of informal stakeholder interviews to identify conservation threats and actions for grassland birds in the NGP, and found that grassland conversion and fragmentation were the most commonly identified threats to grassland birds in the NGP.

4. We mapped the current coverage of private lands biologists in the NGP to identify unvisited areas to target for conservation work. These gaps exist across the NGP. We identified a clear knowledge gap in outreach effort in the Canadian provinces.

5. We reviewed current bird monitoring initiatives active in the NGP (Breeding Bird Survey, IMBCR). We found that although there are fewer years of data available from the IMBCR program, the robust sampling design provides accurate estimates of populations sizes and population trends across spatial scales which will allow managers to identify regions that are contributing the most to NFWF's population goals.

6. We surveyed an additional 101 grids using the IMBCR sampling scheme in BCRs 11 and 17 from 2014 – 2016 to increase coverage of lands within the NGP. These surveys occurred in Montana, North Dakota, Nebraska, South Dakota, and Wyoming.

ACKNOWLEDGEMENTS

We would like to thank the Northern Great Plains Joint Venture (NGPJV), World Wildlife Fund (WWF), and informal interview participants for significant feedback that contributed to the findings reported here. We thank Intermountain Bird Observatory (IBO) for coordinating on surveys during IMBCR data collection. We would also like to thank the countless private landowners who allowed access to their properties for Integrated Monitoring in Bird Conservation Regions (IMBCR) surveys. Finally, we would like to thank Marisa Sather for making her bird predictive surfaces available for use, as well as all collaborators who facilitated access to their spatial data for this project.

INTRODUCTION

Grassland-nesting birds are declining faster than any bird guild in North America, and actions must be taken soon to avoid further losses. Strategic conservation planning is a vital first step for success, and has recently been used to develop and implement business plans for vulnerable ecosystems across North America. We propose, in conjunction with partners, to support the development of a ten-year plan for grassland bird conservation in the Northern Great Plains (NGP). This plan will form the basis for on-the-ground conservation activities that will benefit not only grassland bird communities but also the entire NGP grassland ecosystem.

Objectives

We identified six objectives integral to the development of a successful 10-year plan for conservation of grassland birds in the NGP:

1. Recommend focal bird species and multi-species indices for NGP Initiative, determine baseline bird populations for entire Initiative area and each focal area, and develop ten-year grassland bird population goals for the NGP and each focal region.

2. Identify priority focal landscapes for grassland bird conservation in the NGP.

3. Develop comprehensive list of conservation actions. This will identify those actions that will best address and mitigate forces that are driving grassland bird population declines in the NGP to help NFWF rank prospective projects according to their potential to advance grassland bird conservation.

4. Develop an outreach strategy to implement conservation actions. This will increase capacity for new private lands biologists in the region who will work with private landowners to implement on- the-ground habitat enhancement using NFWF support and other conservation funding for priority species in focal landscapes.

5. Develop and recommend a bird-monitoring plan. This will allow NFWF and project managers to measure the success of projects and to use an adaptive management process to improve the likelihood of a successful conservation outcome.

6. Expand existing long-term bird monitoring project (IMBCR) in the entire NGP and in focal areas, especially on private and tribal lands. BCR has been conducting bird monitoring in the Great Plains since 1998, and has been monitoring bird populations in the NGP using the IMBCR.

In this report we addressed Objective 1 using a Structured Decision-Making (SDM) approach to select a community of five grassland species for prioritization in the business plan. We addressed Objective 2 using IMBCR data and habitat covariates to model the distribution and abundance of the selected species in the region currently surveyed by IMBCR. The maps of the individual species were then combined zonation software to identify broad-scale patterns in grassland bird biodiversity. We also included a list of spatial data resources available for use by NFWF as needed. We addressed Objective 3 by conducting stakeholder interviews within the NGP and applying a standardized framework for identifying common elements of conservation threats to our findings. We addressed Objective 4 by mapping current outreach activities by private lands biologists in the NGP to identify any existing gaps in coverage and help guide outreach strategies into the future. We addressed Objective 5 by recommending a monitoring framework through collection and analysis of IMBCR data to utilize the scalar inference capability of this dataset. Finally, we addressed Objective 6 by expanding the IMBCR program in 2014 - 2016 to include a more substantial portion of NGP lands.

PART 1: SPECIES SELECTION

Introduction

We used an SDM approach to select focal species (Williams et al. 2002, Nichols and Williams 2006, Lyons et al. 2008, Conroy and Peterson 2013). The act of decision-making is simply making connections between decisions and objectives, and SDM is a formal approach to this process. SDM consists of a large set of tools but more generally involves process of breaking a decision down into its basic elements, analyzing those elements separately, and integrating all the elements to find a solution. By using a formal decision-making framework, we were able to provide an objective, transparent, and defensible justification for the selection of focal species with a variety of characteristics that may or may not make them a candidate focal species.

Methods

The first step to the SDM process is identifying explicit objectives. The objectives are the criteria with which different decisions are evaluated, and it is crucial that the objectives accurately reflect the desired outcomes of all stakeholders in the decision. Staff from NFWF, the Bird Conservancy of the Rockies (Bird Conservancy), World Wildlife Fund (WWF), and the Northern Great Plains Joint Venture (NGPJV, hereafter, the working group) identified 11 characteristics thought to be important in identifying focal species for the NGP (Table 1). Our criteria generally described the vulnerability of populations through small population sizes, small geographic ranges, increased threats to populations, and declining populations. We also considered criteria reflecting stakeholder interest in each species, our ability to monitor the species and detect changes in their populations, and each species' ability to serve as an umbrella species for other grassland birds.

For each criterion, we developed or identified a measurable attribute that provided a quantitative measure of that criterion (Table 2) and then assessed each criterion for all species either obligate or dependent on grasslands within the NGP (n = 27, see Table 2 for complete species list). We excluded the Greater Prairie Chicken from this list of considered species because (1) only a very small portion of its range overlaps the NGP as delineated by NFWF, and (2) conservation of this species' habitat is covered under other sections of this plan. Most of our measurable attributes were taken from the Partners in Flight (PIF) Species Assessment Database (PIF Science Committee 2012) and results from the Breeding Bird Survey (BBS; Sauer et al. 2014). However, we were required to develop more specific measurable attributes for several of the criteria. To assess or ability to monitor each species, we averaged the coefficient of variation ($CV = \sigma/\mu$) in density estimates from 2010-2015 based on the Bird Conservancy's Integrated Monitoring in Bird Conservation Regions program, with a lower CV indicating an increased ability to monitor that species. We quantified stakeholder interest by tallying the number of times each species was listed in US State Wildlife Action Plans, Canada's SARA and COSEWIC acts, US Forest Service Sensitive Species Region 1 and Region 2 lists, US Fish and Wildlife Service Birds of Conservation Concern (BCC), and the International Union for the Conservation of Nature (IUCN) Red List; a larger score in this attribute reflected a greater stakeholder interest in the species. We attempted to assess the ability of each species to serve as an umbrella species by calculating the Spearman correlation coefficients (ρ) for the number of detections of each species at the transect-level from the IMBCR data set for all 2-species combinations.

Table 1. Description of criteria and their measurable attributes used to identify focal species for the Northern Great Plains.

Criterion	Measurable attribute	Data source
Grassland specialization and diversity	Habitat requirements	BCR[1] report
Global breeding range size	Area (km^2) of breeding range	BBS/PIF
Global population size	Total breeding population size	BBS[3]
Population trend	Survey-wide trend	BBS
Threats to the breeding population	Threats to breeding, continental score	PIF
Importance of NGP	Proportion of population in BCRs 11 and 17	BBS
Ability to monitor	Mean coefficient of variation in density estimates	IMBCR[4]
Stakeholder interest	Count of number of times included in SWAP, SARA, COSEWIC, USFWS, USFS, and IUCN lists	State, federal, and IUCN reports
Ability to serve as umbrella species	Correlation in counts between species	IMBCR
Ability to impact populations through management	Qualitative 1-5 score	expert opinion
Landowner recognition	Qualitative 1-5 score	expert opinion

[1] Bird Conservancy of the Rockies
[2] Partners in Flight
[3] Breeding Bird Survey
[4] Integrated Monitoring in Bird Conservation Regions

Each species then received a score corresponding to the number of species with which it was positively correlated ($\rho \geq 0.33$), indicating that those species were more often seen in the same locations. We did not have quantifiable metrics for landowner recognition and our ability to impact species. Therefore, we asked members of the working group to assign each species a score for each criterion, with a score of 1 representing no landowner recognition and no ability to impact, respectively, and a score of 5 representing high landowner recognition and a very high ability to impact the species, respectively. We then averaged all responses to get a score for each species for each criterion.

Table 2. Values of measurable attributes used to quantify criteria used to identify focal grassland species in the Northern Great Plains. “Weights” indicate the relative importance of each criterion to the working group in determining a focal species. The weight for the habitat components was applied to the group habitat score when calculating overall group scores. Information on habitat requirements were not available for four species.

Species	Breeding range (km^2)	Global population	BBS trend	Breeding threats	Prop. Pop. In NGP	Density CV	Number of SOC lists
American Kestrel	24,137,348	4,000,000	-1.46	3	0.057	0.490	1
Baird's Sparrow	827,483	2,000,000	-2.74	4	0.996	0.359	8
Bobolink	3,873,291	8,000,000	-2.05	3	0.426	0.359	4
Burrowing Owl	14,203,527	2,000,000	-0.97	4	0.019	1.026	9
Chestnut-collared Longspur	797,094	3,000,000	-4.25	3	0.966	0.350	10
Common Nighthawk	13,162,934	16,000,000	-1.96	3	0.067	0.445	2
Dickcissel	3,458,339	20,000,000	-0.34	3	0.094	0.874	4
Ferruginous Hawk	2,435,600	80,000	0.76	4	0.480	1.138	9
Golden Eagle	23,242,678	300,000	-0.14	3	0.054	1.023	4
Grasshopper Sparrow	5,209,138	31,000,000	-2.59	3	0.334	1.138	4
Greater Sage-Grouse	1,407,633	150,000	-3.26	4	0.257	0.144	9
Horned Lark	20,824,080	120,000,000	-2.39	2	0.183	0.180	0
Lark Bunting	1,825,915	9,100,000	-4.31	3	0.591	0.221	2
Loggerhead Shrike	8,849,539	5,800,000	-2.98	3	0.101	0.549	7
Long-billed Curlew	1,831,989	140,000	0.23	4	0.329	0.486	9
McCown's Longspur	684,343	600,000	-6.12	3	0.599	0.587	8
Mountain Plover	671,992	18,000	-3.12	4	0.084	1.059	9
Northern Harrier	24,607,876	1,400,000	-1.06	3	0.200	0.440	2
Prairie Falcon	3,793,485	80,000	0.79	3	0.116	1.138	2
Savannah Sparrow	13,727,335	180,000,000	-1.14	2	0.171	0.294	1
Sharp-tailed Grouse	3,021,798	600,000	0.40	3	0.757	1.138	3
Short-eared Owl	62,415,997	3,000,000	-2.07	3	0.034	0.417	7
Sprague's Pipit	1,157,665	900,000	-3.10	4	0.956	0.889	9
Swainson's Hawk	5,226,232	580,000	0.68	3	0.340	0.691	2
Upland Sandpiper	3,283,142	750,000	0.53	2	0.837	0.332	3
Vesper Sparrow	6,346,442	28,000,000	-0.80	3	0.496	0.124	0
Western Meadowlark	6,708,072	85,000,000	-1.24	3	0.381	0.068	0
Weights	**0.042**	**0.052**	**0.098**	**0.073**	**0.154**	**0.112**	**0.101**

Table 2 continued

Species	Correlated species	Ability to impact	Landowner recognition	Low herb	Mod herb	High herb	Shrub
American Kestrel	0	3.0	3.2	-	-	-	-
Baird's Sparrow	6	3.7	1.1	0	2	3	1
Bobolink	4	4.0	2.6	0	2	2	0
Burrowing Owl	0	4.0	3.8	2	1	1	0
Chestnut-collared Longspur	7	2.3	1.3	1	3	1	0
Common Nighthawk	0	1.7	2.5	-	-	-	-
Dickcissel	0	3.7	1.9	0	2	2	0
Ferruginous Hawk	0	2.3	2.8	1	1	1	1
Golden Eagle	0	1.0	3.4	-	-	-	-
Grasshopper Sparrow	8	3.7	1.0	0	1	3	1
Greater Sage-Grouse	0	4.0	4.3	2	3	3	3
Horned Lark	8	1.7	2.1	3	1	0	1
Lark Bunting	4	2.7	3.1	3	1	1	3
Loggerhead Shrike	0	2.0	2.4	2	1	0	2
Long-billed Curlew	1	2.3	4.1	2	2	1	0
McCown's Longspur	0	2.7	1.3	3	0	0	0
Mountain Plover	0	3.7	2.0	3	1	0	1
Northern Harrier	2	2.0	2.3	1	1	2	0
Prairie Falcon	0	2.0	2.4	1	1	1	1
Savannah Sparrow	5	2.0	1.0	-	-	-	-
Sharp-tailed Grouse	1	4.0	4.3	2	2	2	1
Short-eared Owl	0	2.7	2.6	0	2	1	1
Sprague's Pipit	1	2.7	1.0	2	2	0	0
Swainson's Hawk	1	3.0	2.7	1	1	1	1
Upland Sandpiper	3	2.0	2.9	2	2	2	1
Vesper Sparrow	0	1.7	1.1	2	2	1	2
Western Meadowlark	4	1.7	3.3	0	3	2	1
Weights	**0.061**	**0.101**	**0.112**	**0.094**			

To prioritize variety of grassland habitats within the NGP, we identified four habitat types to represent the diversity of grassland habitats: 1) low herbaceous cover, 2) moderate herbaceous cover, 3) high herbaceous cover, and 4) shrub cover. To quantify habitat preferences, we calculated habitat scores for each species based a literature review of their habitat requirements (Table 4 in VerCauteren and Gillihan 2004). The importance of each habitat component was designated by “used”, “required”, and “indicator species/required,” which we assigned scores of 1, 2, 3, respectively. Unused habitat components received a score of 0. For shrub cover, we used the same scoring system for the highest code in the moderate and high shrub cover columns. We assumed herbaceous cover categories were mutually exclusive but each of those may or may not have a shrub component. Therefore, we rescaled the herbaceous cover categories to sum to 1, reflecting the relative importance of each component to that species (Table 3).

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Table 3. Example of scoring methods to quantify the importance of low, moderate (mod), and high herbaceous habitat components to Lark Bunting in the Northern Great Plains. Raw data comes from Table 4 in VerCauteren and Gillihan 2004, with "I/R" indicating indicator species/required and "U" indicating used. Raw score is the values assigned based on the descriptions in the raw data. Rescaled score are the raw scores scaled to sum to 1.

	Low	Mod	High
Raw data		I/R	U
Raw score	0	3	1
Rescaled score	0	0.75	0.25

In order to evaluate the trade-offs between criteria in selecting a group of focal species, we first needed to transfer values for each criterion into a common currency. A common method for doing this is to rescale the values within a criterion from 0 to 1, with the "worst" and "best" values being rescaled to 0 and 1, respectively (Conroy and Peterson 2013):

$$U_j = \frac{x_j - \text{worst}(x_j)}{\text{best}(x_j) - \text{worst}(x_j)},$$

where U_j is the rescaled score for species j, x_j is the measurement on the original scale, and $\text{worst}(x_j)$ and $\text{best}(x_j)$ are the least and most desired outcomes of the attribute over the range of that attribute's values. We used this method to rescale all criteria not already on a 0-1 scale (i.e., all criteria except the proportion of the population in BCRs 11 and 17 and the 3 herbaceous cover categories).

After scoring all criteria, the next step in the SDM process is to evaluate trade-offs between conflicting criteria. It is likely that a particular species has a high score for one criterion and a low score for another. Therefore, we must identify the importance of each criterion to the stakeholders so we can identify which group of focal species balances these competing objectives. We did this by asking all working group members to assign weights to each criterion reflecting their personal value of the criterion in identifying a focal species, such that the weights sum to 1. We then took an average of the weights, with NFWF staff weights receiving twice the influence of others' weights, to calculate the final criteria weights (Table 2).

Finally, we combined the criteria scores and weights to evaluate how well groups of five species collectively met all the objectives identified at the beginning of the process. For each species, we multiplied all non-habitat criteria scores by their respective weights and summed those values to get an overall score for each species. We then evaluated each group of species to determine how well it represented a diversity of habitats. For each group we took the sum of the maximum scores across all five species in each of the four habitat categories and multiplied this by the habitat criterion weight (i.e., 0.094, Table 2). We then summed the overall species score for all species within a group and the group habitat score to get an overall group score, which represents how well each species balances all non-habitat criteria and how well the group as a whole reflects a diversity of habitats.

Results

The group that best balanced all criteria included Baird's Sparrow (BAIS), Chestnut-collared Longspur (CCLO), Lark Bunting (LARB), McCown's Longspur (MCLO), and Sprague's Pipit (SPPI; Table 4).

Table 4. Overall scores for the best 10 groups of five grassland bird species representing the ability of the group to balance the criteria identified by the working group. "Species" columns identify the species in each group and their respective scores, not including habitat criteria, are shown in the "Species overall score" columns. The "Group habitat score" quantifies the ability of each group to represent a diversity of grassland habitats. The "Group overall scores" combines all species overall scores and the group habitat score. Species include: Baird's Sparrow, BAIS; Bobolink, BOBO; Burrowing Owl, BUOW; Chestnut-collared Longspur, CCLO; Ferruginous Hawk, FEHA; Grasshopper Sparrow, GRSP; Lark Bunting, LARB; Long-billed Curlew, LBCU; McCown's Longspur, MCLO; Mountain Plover, MOPL; Sprague's Pipit, SPPI; Sharp-tailed Grouse, STGR; Upland Sandpiper, UPSA; Western Meadowlark, WEME.

	Species					Species overall score						
Group	1	2	3	4	5	1	2	3	4	5	Group habitat score	Group overall score
1	BAIS	CCLO	LARB	MCLO	SPPI	0.671	0.641	0.564	0.525	0.550	3.20	4.158
2	BAIS	CCLO	LARB	LBCU	MCLO	0.671	0.641	0.564	0.542	0.525	3.20	4.150
3	BAIS	BOBO	CCLO	LARB	MCLO	0.671	0.540	0.641	0.564	0.525	3.20	4.148
4	BAIS	CCLO	LARB	MCLO	STGR	0.671	0.641	0.564	0.525	0.502	3.20	4.110
5	BAIS	BUOW	CCLO	LARB	MCLO	0.671	0.484	0.641	0.564	0.525	3.20	4.092
6	BAIS	CCLO	GRSP	LARB	MCLO	0.671	0.641	0.409	0.564	0.525	3.35	4.074
7	BAIS	CCLO	LARB	MCLO	UPSA	0.671	0.641	0.564	0.525	0.460	3.20	4.068
8	BAIS	CCLO	LARB	MCLO	MOPL	0.671	0.641	0.564	0.525	0.459	3.20	4.067
9	BAIS	CCLO	FEHA	LARB	MCLO	0.671	0.641	0.438	0.564	0.525	3.20	4.046
10	BAIS	CCLO	LARB	MCLO	WEME	0.671	0.641	0.564	0.525	0.432	3.20	4.040

Discussion

The top species group we selected (BAIS, CCLO, LARB, MCLO, SPPI) represents a suite of grassland species that utilize a wide range of grassland types, from species found in short-grass prairie (MCLO) to those that utilize tall grass vegetation (BAIS). The four habitat categories we quantified were best represented by Grasshopper Sparrow (GRSP), CCLO, LARB, and MCLO because they had the highest values for each of those criteria. Baird's Sparrow had the second highest score in high herbaceous cover, behind Grasshopper Sparrow (GRSP), and scored higher in other heavily-weighted criteria, such as the importance of the NGP and global population size. These non-habitat criteria outweighed the gain in habitat diversity, so BAIS, rather than GRSP, came out in the top 20 species groups. Because of the high group habitat score for groups containing BAIS, CCLO, LARB, and MCLO, these four species were in the top 10 species groups, with the fifth species varying based on their overall species scores (Table 4).

Other iconic species of the NGP, such as Long-billed Curlew (LBCU), Mountain Plover (MOPL), Ferruginous Hawk (FEHA), Burrowing Owl (BUOW), and Greater Prairie-Chicken (GRPC), were not included in the top species group. However, BUOW, LBCU, and FEHA were in the second, fifth, and ninth best species groups. These species did not perform as well as SPPI because a smaller percentage of their populations are found in the NGP and their populations are fairly stable (Table 2). These species, in addition to MOPL, are also not well monitored using the IMBCR survey protocols, contributing to their lower species scores. Finally, BUOW, LBCU, and FEHA utilize habitat very similar to the Black-footed Ferret, a species prioritized in a different section the NGP business plan. BUOW, LBCU, MOPL, and FEHA will likely benefit from conservation actions directed towards this mammal species.

The methods we used identified a select combination of species that serve as a single unit for prioritization (the grassland bird community) while at the same time identifying individual species that can be monitored and followed over time. The SDM methods we used provide a roadmap not only for prioritization of grassland bird species but also offer a transparent, repeatable method of selection focal species in other ecosystems.

PART 2: STATUS OF GRASSLAND SPECIES IN THE NGP

Methods

Study Design

Following the IMBCR sampling design (White et al. 2010), we defined the sampling frame by superimposing a 1 km X 1 km grid over the study area. The sampling units correspond to the 1 km^2 grid cells. We selected sample units using a stratified-random design. First, the sample frame was divided into strata defined by each State/Bird Conservation Region (BCR) intersection within the study area. Sample units within each strata were then selected using generalized random-tessellation stratification (Stevens and Olson 2004, package spsurvey, R Development Core Team 2014). Each 1 km^2 sampling unit contained 16 point count locations separated by 250 m, and each point count plot consisted of a 125 m-radius circular plot (4.9 ha). The point counts for each sampling unit were surveyed on a single day during the avian breeding season from June to July and from 2010 (n = 324), 2011 (n = 376), 2012 (n = 308), 2013 (n = 525), 2014 (n =78), and 2015 (n = 179). We sampled avian abundance and occurrence using 6-min point counts (Alldredge et al. 2007) between one-half hour before sunrise and 1100 h at each accessible point count location, and measured the distance to each bird detection using a laser rangefinder. We binned bird observations during the six minute point count duration into three, two-minute time occasions (Alldredge et al. 2007).

Statistical Analyses

We extended an open population *N*-mixture model developed by Chandler et al. (2011) to estimate population density, and probabilities of availability and detection using five years of data (2010-2015) from the IMBCR program. Our parameterization of the open population N-mixture model (Chandler et al. 2011) estimated the availability parameter using spatial rather than temporal replicates. We estimated average density, availability and detection probability within the 1 km sampling grid. Density was modeled using the Poisson distribution. The availability parameter, the probability of being exposed to sampling within a sampling unit, was modeled with the Binomial distribution, which can also be interpreted as small-scale occupancy. The detection component was modeled using a removal model where the vector of counts was considered to be multinomial. We estimated parameters of the generalized multinomial mixture model by maximizing the integrated likelihood function in the R package unmarked (Fiske and Chandler 2011, R Development Core Team 2015). We used information-theoretic model selection (Burnham and Anderson 2002) to estimate the relative loss of Kullback–Leibler Information (Kullback and Leibler 1951, Burnham and Anderson 2001) when models were used to approximate conceptual truth. We ranked models by the Akaike Information Criterion (AIC) (Akaike 1973) and model averaged the predictions for models with a ΔAIC < 2. We assessed the strength of evidence for effect sizes by evaluating the model parameter estimates ($\hat{\bar{\beta}}$) with respect to zero using standard errors and 95% confidence intervals (Burnham and Anderson 2002). We model averaged predictions for the competing model set to create the predicted distribution map within the study area. Predicted densities are displayed using raster images with cell sizes of 1 km^2, generated from USNG grid layers for the NGP area (BCR 17, Montana BCR 11, and Nebraska and South Dakota BCR 18). The data are symbolized by equal quantiles representing 10% of the values across the study area for each species. The legend for each species map reports the minimum, mean, and maximum predicted densities. We limited McCown's Longspur maximum to 300 birds/km^2 for optimal display and report that 0.3% of grids had densities > 300 birds/km^2 for this species.

Model Justification and Construction

We used the method of multiple working hypotheses (Chamberlin 1965) to develop alternate *a priori* hypotheses for the effects of covariates on detection, availability, and abundance of 5 focal grassland species. We evaluated spatial variation in detection by allowing detection probability to vary by grass height and shrub cover. We modeled the spatial variation in the availability parameter as a function of local vegetation condition within a 125 m radius. Vegetation covariates included percent grass cover, grass height, herbaceous cover and shrub cover. We allowed abundance to vary by proportion of grassland cover, proportion of shrubland cover, and Longitude, Latitude coordinates within the 1 km sampling grid.

We used a sequential, parameter-wise model building strategy to determine the strength of evidence within the model set (Lebreton et al. 1992, Doherty et al. 2010). First, we constructed detection models using all subsets of covariates for detection (including a constant model), while holding availability and abundance constant at the global models. Second, we built availability models using all subsets of covariates for availability (including a constant model), while holding detection constant at the most parsimonious detection model and abundance constant at the global model. Third, we developed abundance models using all subsets of covariates for abundance (including a constant model), while holding detection and availability constant at the most parsimonious models.

Priority Conservation Areas

We prioritized potential bird conservation areas in our study area using the software Zonation (v. 4.0, Moilanen et al. 2005, Lehtomaki and Moilanen 2013). This software has been used to identify potential priority conservation areas for multiple species and maximizes connectivity between potential conservation areas. Zonation software prioritizes the landscape by ranking all grid cells using a hierarchical process. The hierarchical ranking process removes grid cells with the lowest biodiversity rank, while minimizing the marginal loss of biodiversity (Moilanen et al. 2005). We used the added benefit function with the five focal species predicted density maps, which takes into account all feature proportions in a given cell, emphasizing species richness. The additive benefit function usually results in potential conservation areas with higher values over all features but retains a lower minimum proportion of single species distributions (Moilanen 2007). The main output from the zonation software is a map with values from 0-1. Low values represent low conservation priority across species and values close to 1 represent areas of high conservation priority across species.

We also constructed a simple species richness map by overlaying the predicted distributions of the 5 focal species using a density threshold. We assigned raster grids that had a predicted value greater or equal to 2 individual birds per km^2 for each species a value of 1 (presence), all other cells were assigned a value of 0. The cell values were then summed across species to estimate species richness.

Results

The top density model for Lark Bunting, McCown's Longspur, Chestnut-collared Longspur and Baird's Sparrow contained the global model indicating that the proportion of grassland and shrubland, as well as the X, Y coordinates, influenced density (Table 1.A-D). The top density model for Sprague's Pipit did not include proportion of shrubland (Table 1.E), however the second top model included shrubland indicating a weak negative relationship to shrubland habitat. The proportion of grassland cover had a strong positive effect for all species (Table 1.A-E). The proportion of shrubland had a strong positive effect on Lark Bunting and a strong negative effect on McCown's Longspur (Table 1.C-D).

The top availability model for Lark Bunting and Sprague's Pipit included grass cover, grass height and herbaceous cover (Table 1.C, 1.D). The top availability model for Baird's Sparrow and Chestnut-collared Longspur included grass cover, herbaceous cover and shrub cover (Table 1.A-B). The top availability model for McCown's Longspur included grass cover, grass height, herbaceous cover and shrub cover (Table 1.D).

The top model for the detection probability parameter was a constant model for McCown's Longspur, Lark Bunting and Sprague's Pipit (Table 1.D, 1.C, 1.E). Detection probability varied with grass height for Chestnut-collared Longspur and Baird's Sparrow, however, the grass height confidence interval for Baird's Sparrow overlapped zero indicating a weak effect (Table 1.A). Model selection results are presented in Appendix 1.

The predicted density maps for Sprague's Pipit, Baird's Sparrow and Chestnut-collared Longspur had higher concentrations of density in Montana, North Dakota and South Dakota (Fig. 1, 2,5). Lark Bunting had higher concentrations of density in Montana, Wyoming and Nebraska (Fig. 3) and McCown's Longspur had higher concentrations of density in Montana (Fig. 4).

Montana Prairie Potholes contained the highest proportion of McCown's Longspur, Sprague's Pipit and Baird's Sparrow populations compared to other state/Bird Conservation Regions (Fig. 6). Lark Bunting had a higher proportion of its population in Montana Badlands and Prairies (Fig. 6) and Chestnut-collared Longspur's population showed an even proportion across Montana and South Dakota (Fig. 6).

The zonation priority conservation areas based on the 5 focal species and the species richness overlay maps showed similar hotspots (Fig.7).

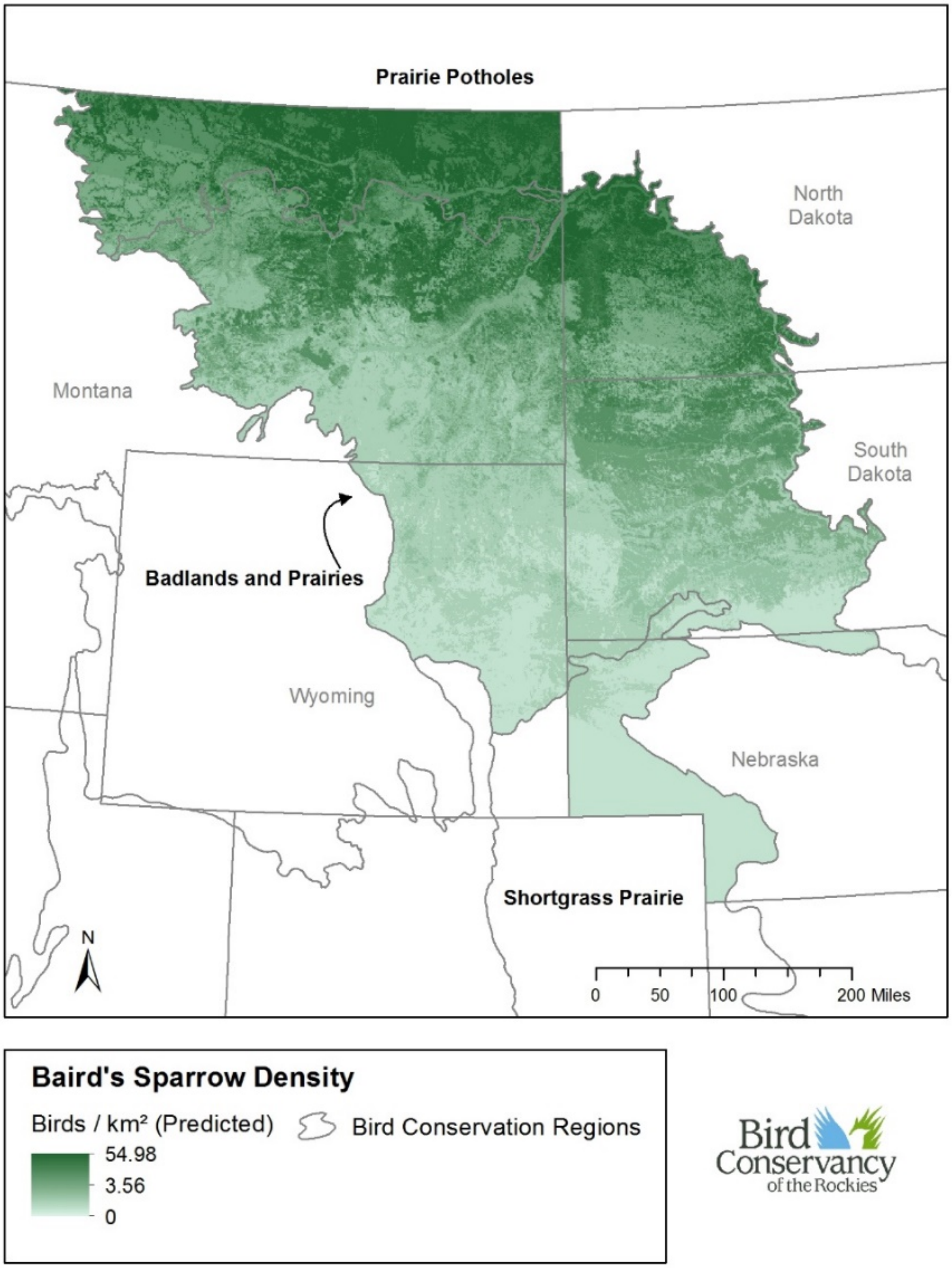


Figure 1. Baird's Sparrow predicted density in the Northern Great Plains.

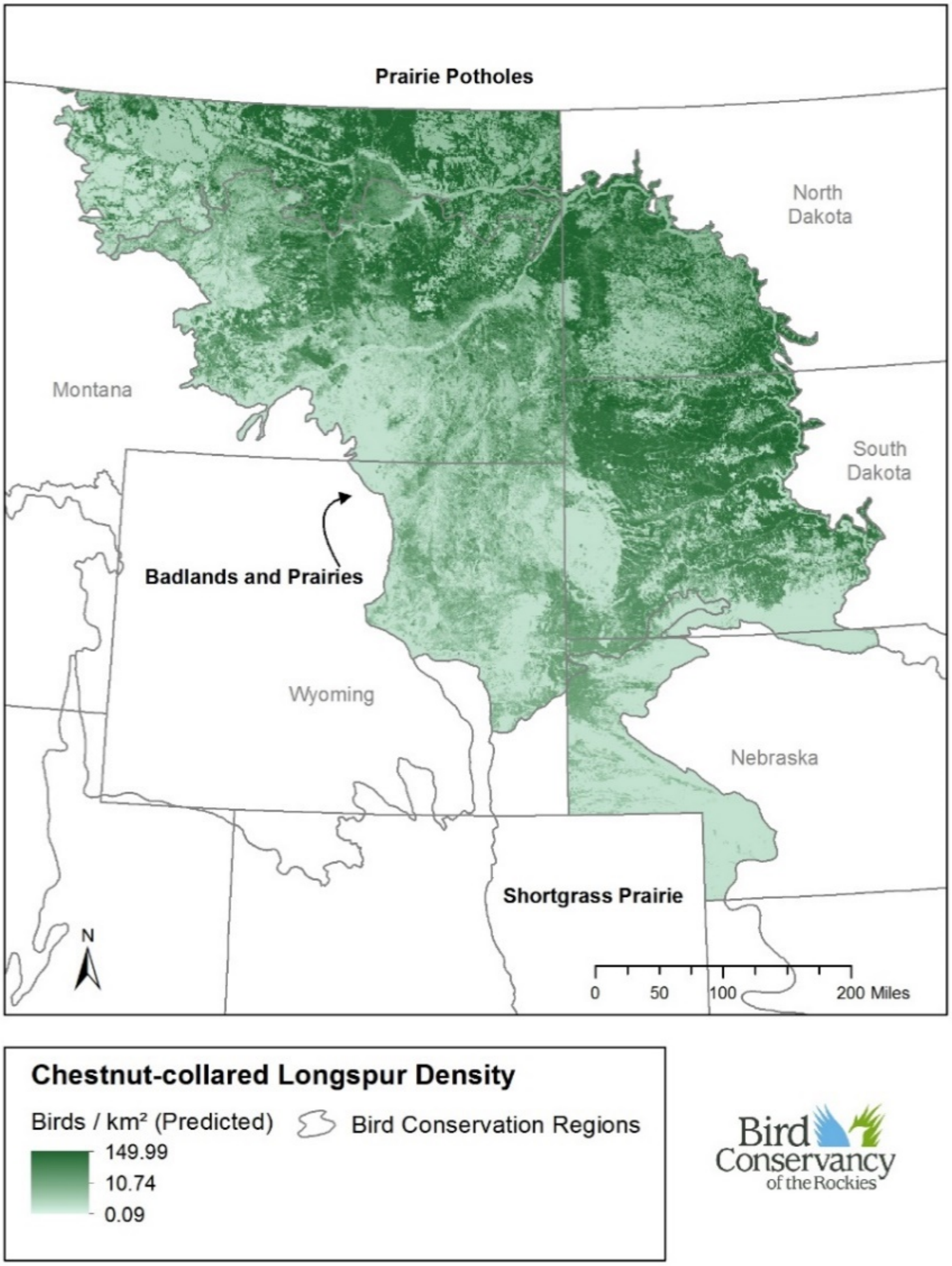


Figure 2. Chestnut-collared Longspur predicted density in the Northern Great Plains.

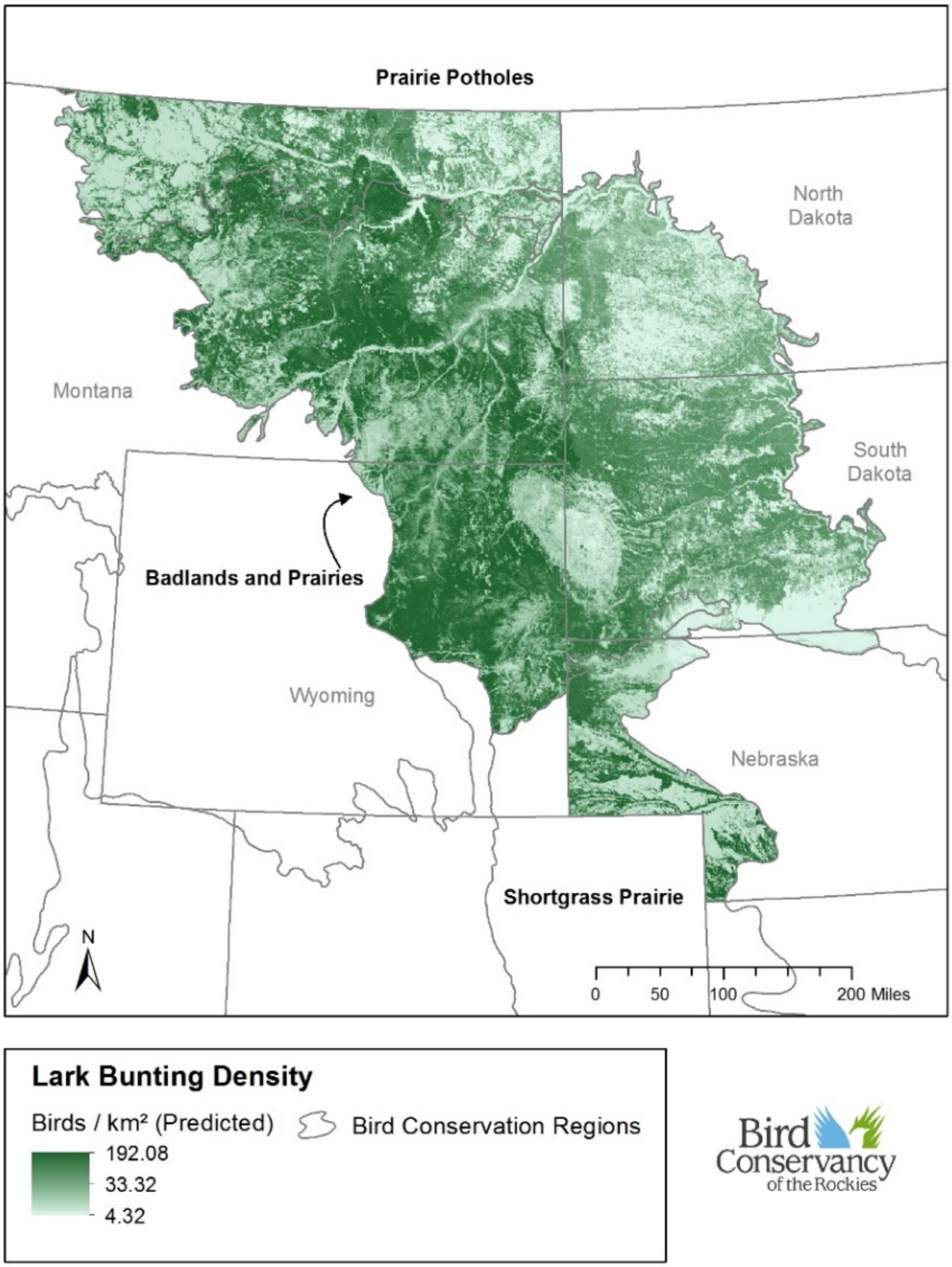


Figure 3. Lark Bunting predicted density in the Northern Great Plains.

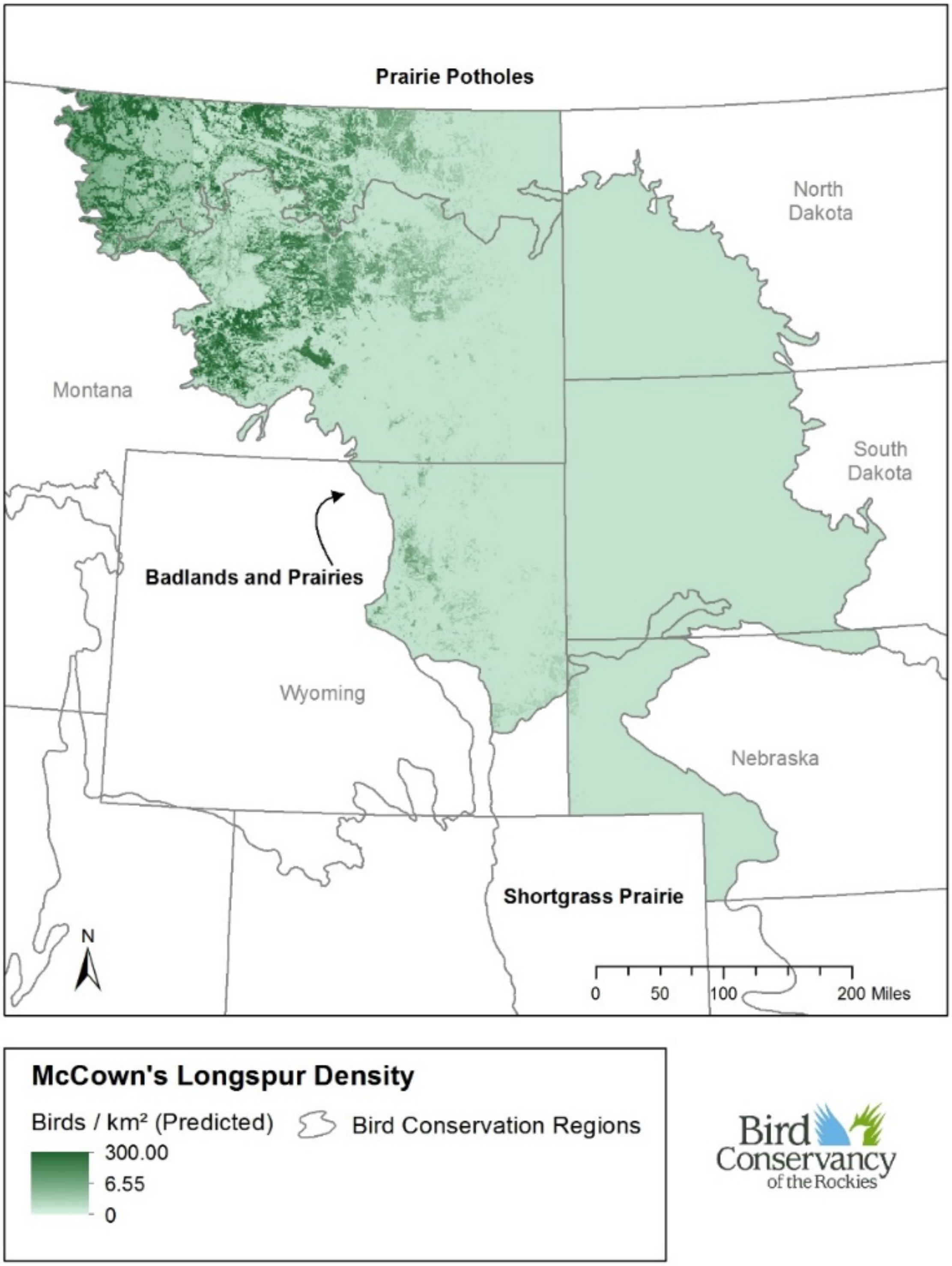


Figure 4. McCown's Longspur predicted density in the Northern Great Plains.

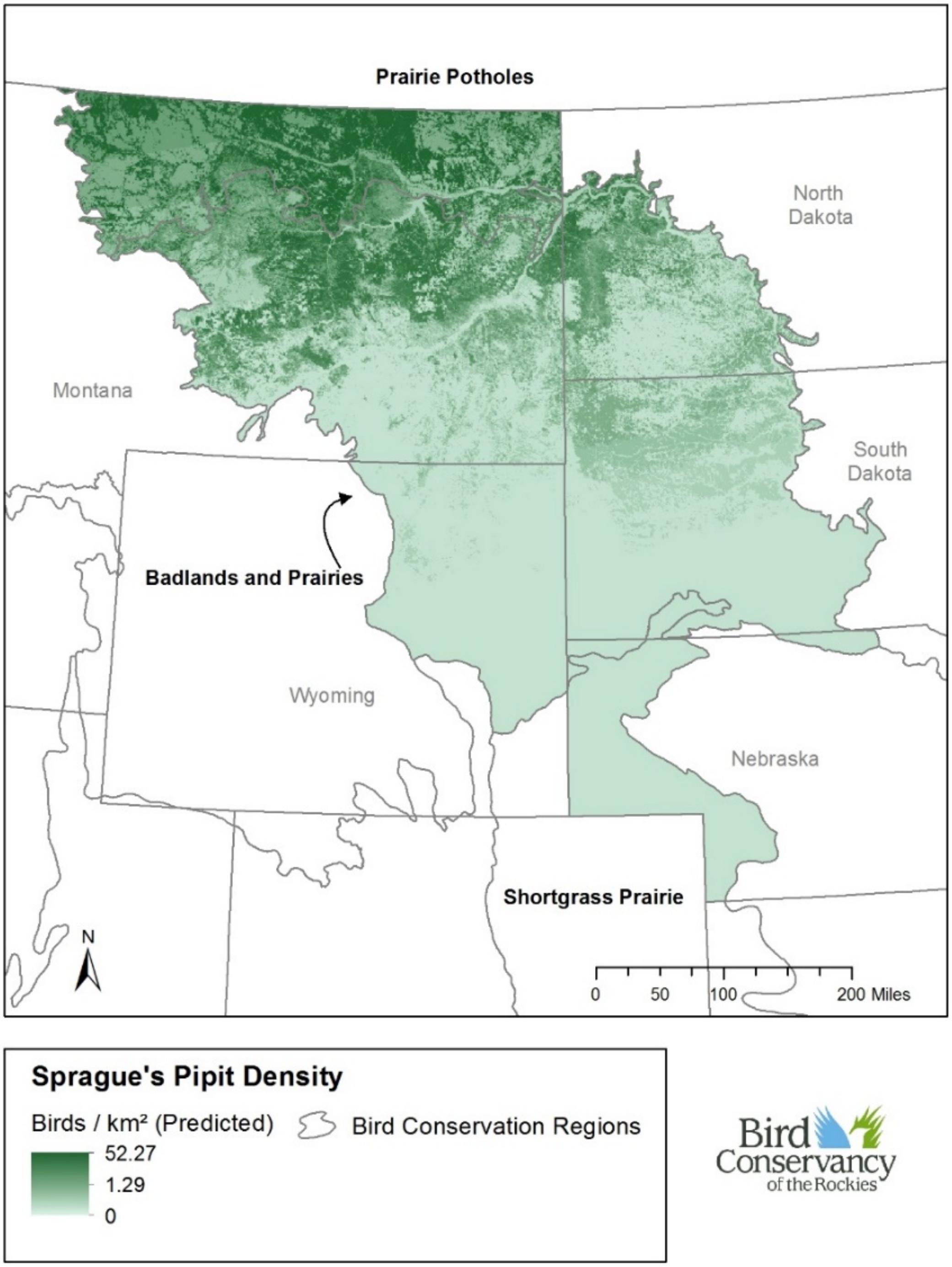


Figure 5. Sprague's Pipit predicted density in the Northern Great Plains.

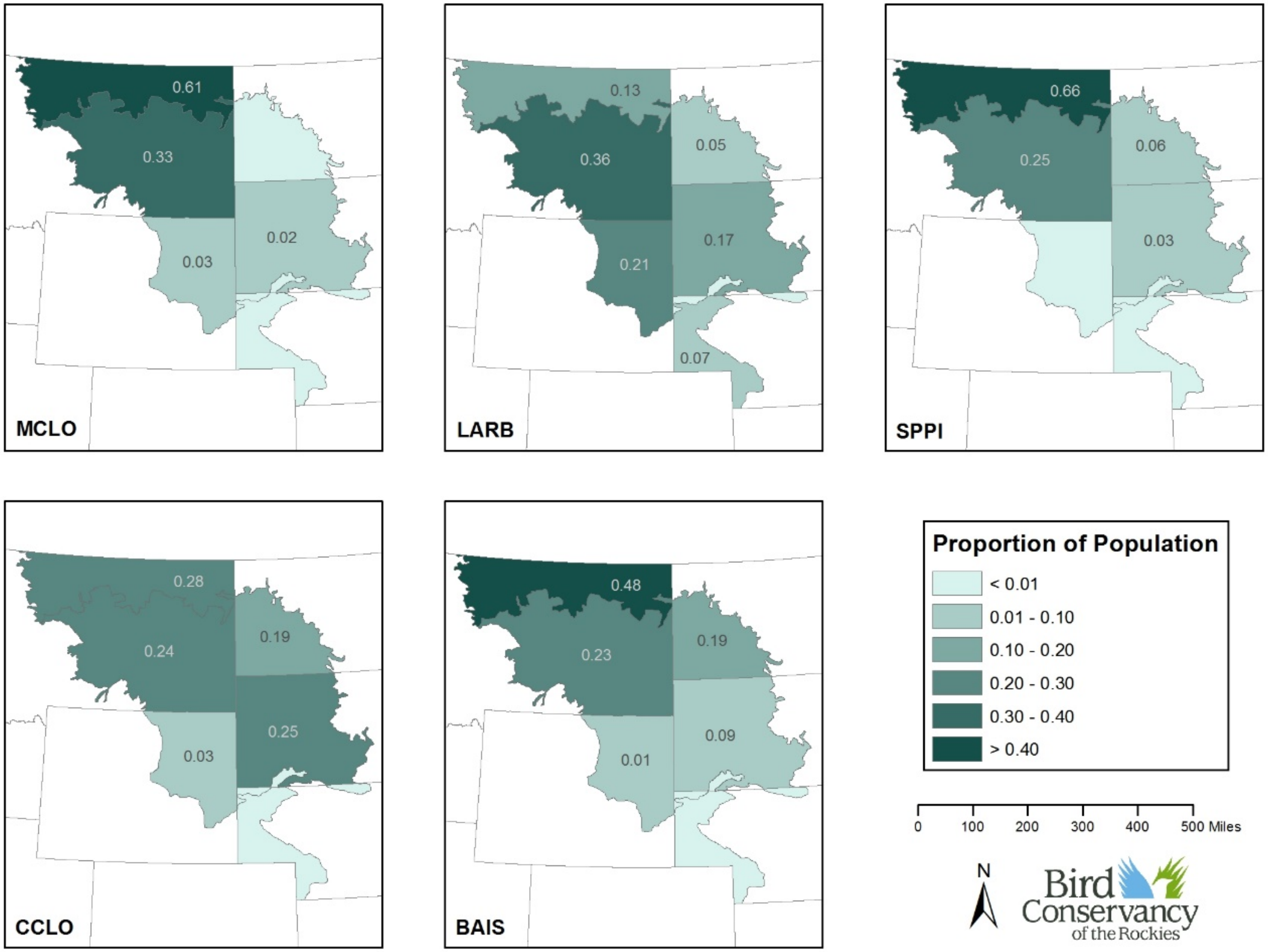


Figure 6. The proportion of the predicted total population for each species within each state/BCR. Proportion equals the predicted number of individuals in each state/BCR divided by the total predicted population in the study area. MCLO = McCown's Longspur, LARB = Lark Bunting, SPPI = Sprague's Pipit, CCLO = Chestnut-collared Longspur, BAIS = Baird's Sparrow.

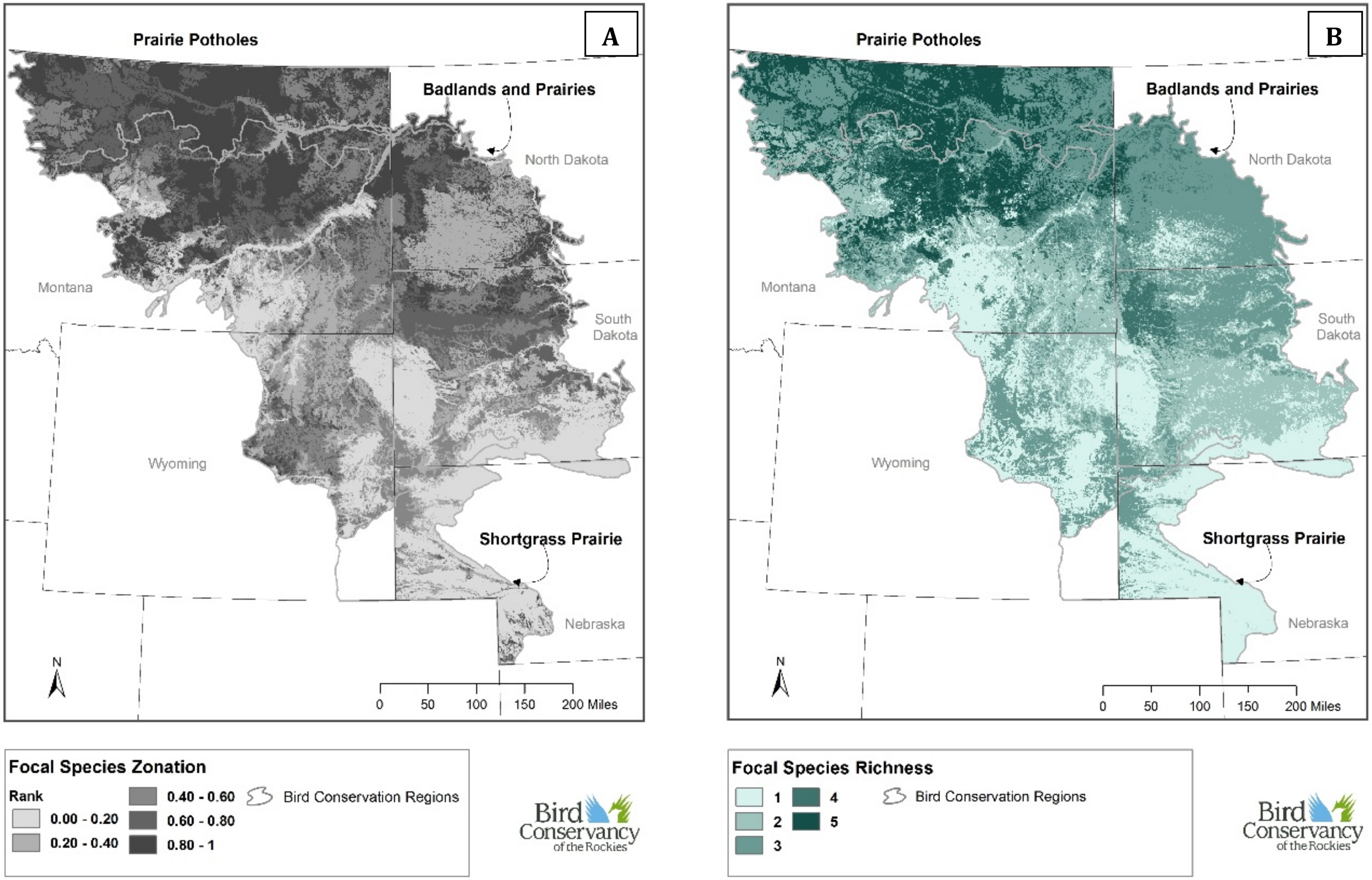


Figure 7. A) Potential priority conservation areas using Zonation software and B) species richness overlay for the 5 focal grassland species. Zonation is ranked on a scale from 0 (low conservation priority) to 1 (high conservation priority)

Table 5. Best model parameter estimates, standard errors (SE) and lower and upper 95% confidence limits (LCL and UCL, respectively) for the density (λ), availability (Φ) and detection probability (p) of, A) Baird's Sparrow, B) Chestnut-collared Longspur, C) Lark Bunting, D) McCown's Longspur and E) Sprague's Pipit. Lat = Latitude and Long = Longitude.

5.A

Model – Baird's Sparrow Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Lat + Long + Shrubland)				
Intercept	-4.19	0.27	-4.72	-3.68
Grassland	0.64	0.11	0.42	0.85
Lat	2.45	0.22	2.01	2.89
Long	0.19	0.08	0.01	0.33
Shrubland	-0.27	0.16	-0.58	0.05
Φ (Grass Height + Shrub Cover)				
Intercept	-2.03	0.16	-2.35	-1.72
Grass Height	0.13	0.07	-0.01	0.26
Herbaceous Cover	-0.05	0.06	-0.16	0.07
Shrub Cover	-1.11	0.20	-1.51	-0.71
p (Grass Height)				
Intercept	0.22	0.17	-0.11	0.56

5.B

Model – Chestnut-collared Longspur Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Lat + Long + Shrubland)				
Intercept	-2.23	0.09	-2.41	-2.04
Grassland	1.26	0.07	1.12	1.40
Lat	1.56	0.07	1.42	1.70
Long	0.29	0.04	0.21	0.37
Shrubland	0.11	0.07	-0.03	0.24
Φ (Grass Cover + Herbaceous Cover + Shrub Cover)				
Intercept	-0.93	0.06	-1.04	-0.82
Grass Cover	0.05	0.03	0.00	0.10
Herbaceous Cover	0.13	0.04	0.05	0.21
Shrub Cover	-0.41	0.07	-0.55	-0.28
p (Grass Height)				
Intercept	-0.09	0.06	-0.21	0.02
Grass Height	-0.28	0.05	-0.37	-0.18

5.C

Model – Lark Bunting Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Lat + Long + Shrubland)				
Intercept	0.59	0.02	0.54	0.64
Grassland	0.70	0.02	0.65	0.75
Lat	-0.29	0.02	-0.32	-0.25
Long	-0.15	0.02	-0.20	-0.11
Shrubland	0.49	0.02	0.46	0.52
Φ (Grass Cover + Grass Height + Herbaceous Cover)				
Intercept	-0.98	0.02	-1.02	-0.94
Grass Cover	0.02	0.01	-0.01	0.05
Grass Height	0.03	0.02	0.00	0.06
Herbaceous Cover	0.03	0.01	0.01	0.06
p (.)				
Intercept	0.05	0.02	0.01	0.10

5.D

Model – McCown's Longspur Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Lat + Long + Shrubland)				
Intercept	-3.00	0.15	-3.43	-2.81
Grassland	1.41	0.10	1.20	1.61
Lat	-0.30	0.09	-0.45	-0.11
Long	-1.41	0.10	-1.55	-1.18
Shrubland	-0.48	0.15	-0.78	-0.17
Φ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)				
Intercept	-1.99	0.16	-2.29	-1.68
Grass Cover	-0.10	0.04	-0.18	-0.03
Grass Height	-0.29	0.06	-0.40	-0.18
Herbaceous Cover	-0.14	0.04	-0.22	-0.05
Shrub Cover	-1.48	0.20	-1.87	-1.09
p(.)				
Intercept	-0.12	0.11	-0.33	0.09

5.E

Model – Sprague's Pipit Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Lat + Long)				
Intercept	-6.47	0.63	-7.70	-5.23
Grassland	1.14	0.22	0.72	1.57
Lat	2.83	0.51	1.83	3.83
Long	-0.26	0.16	-0.58	0.05
Φ (Grass Cover + Grass Height + Herbaceous Cover)				
Intercept	-1.84	0.26	-2.35	-1.33
Grass Cover	0.25	0.11	0.03	0.47
Grass Height	-0.16	0.10	-0.35	0.03
Herbaceous Cover	0.28	0.10	0.09	0.47
p (.)				
Intercept	0.69	0.19	0.31	1.07

Discussion

We developed hierarchical density models for 5 focal grassland bird species: Lark Bunting, McCown's Longspur, Chestnut-collared Longspur, Baird's Sparrow, and Sprague's Pipit. Hierarchical density models are powerful tools for summarizing the abundance and distribution of species within the study area. The ability to characterize spatial variation in density at the 1 km^2 scale across the Northern Great Plains will help inform conservation planning and quantify species response to vegetation and habitat covariates.

These models can also be used for adaptive management (Lyons et al. 2008, Conroy et al. 2012) and systematic landscape conservation (Margules and Pressey 2000, Westphal et al. 2007). The distribution models have utility for prioritizing management actions and landscapes, effectively addressing the "what to do" and "where to do it" questions in conservation planning (Wilson et al. 2007). The predicted distribution maps (population size or density) can be summarized for any area of interest, such as administrative boundaries or management units, and confidence intervals can be computed with the parametric bootstrap (Sillette et al. 2012, Royle et al. 2007).

We found that abundance increased with the amount of grassland at the large scale (1 km^2) for all species reflecting a strong landscape-scale relationship. Larger grassland tracks have been found to support higher densities of breeding sparrows (Johnson and Igl 2001). The amount of shrubland had a strong positive relationship with Lark Bunting abundance and a negative relationship with McCown's Longspur abundance at the 1 km^2 scale, consistent with their natural history. The absence of shrub cover at the small scale occupancy for Lark Bunting suggests that when managing habitat for this species the amount of shrubland at the landscape scale (1 km^2) is important and shrub canopy cover at the small scale (4.9 ha) may not be as important. McCown's Longspur, Chestnut-collared Longspur and Baird's Sparrow small scale occupancy declined as percent shrub cover canopy increased reflecting a preference for open habitat at the small scale consistent with findings from past studies (With 2010, Davis 2005, Dechant et al. 2003). The landscape scale relationships are tied to the covariates spatial distributions across the landscape and can be visualized in the predicted distribution maps.

The predicted distribution maps characterized the spatial variation in density across the IMBCR Northern Great Plains study area for the 5 focal grassland species. Each species showed spatial variation in density. Baird's Sparrow, Sprague's Pipit and McCown's Longspur densities were concentrated in Montana's Prairie Potholes and Badlands and Prairies Bird Conservation Regions. Chestnut-collared Longspur predicted distribution map showed areas of high density in Montana's Bird Conservation Regions and extended west into the Dakota's Badlands and Prairies. Lark Bunting's predicted distribution showed areas of high density spread throughout the study area. In general, the Montana portion of the Northern Great Plains showed areas of high density for all 5 focal species. This pattern may be reflective of larger grassland tracts and less conversion to agriculture in this region.

It is important to note that there are known populations of McCown's Longspurs in Western Nebraska that use farmlands as their primary habitat during the breeding season. These isolated populations are hard to visualize on the broad scale NGP map, however they are present in small numbers. In 2016 IMBCR increased sampling on private lands in western Nebraska, however these data are not included in this mapping effort due to our reporting timeline. A reanalysis of IMBCR data inclusive of 2016 sampling will likely result in refined distribution model of these Nebraskan McCown's Longspur populations.

We also demonstrated how the predicted distribution maps could be used for landscape prioritization to inform conservation planning. The Zonation software identified priority areas based on the core areas of the predicted distribution across all 5 focal species. The additive benefit solution used results in potential priority conservation areas based on all 5 of the focal species but retains a lower minimum proportion of single species distributions (Moilanen 2007). The type of zonation solution used in the analysis depends on the objectives of the landscape prioritization plan. Here, we were interested in prioritizing the landscape across all 5 focal species.

In summary, we demonstrated how to estimate abundance/density using a hierarchical abundance modeling framework while accounting for landscape and local scale spatial variation. In addition, we developed predicted distribution maps to identify potential conservation areas. This modeling framework addressed two important issues in wildlife population monitoring: spatial sampling and detection probability (Yoccoz et al. 2001). These results can be used as a foundation for bird conservation planning in the Northern Great Plains Region.

Existing threats and potential conservation actions

Stakeholder interviews

We directly queried the opinion of partners currently active in this geographic area as part of the process to identify existing threats and potential conservation strategies in the NGP. To this end, we conducted a series of informal interviews and surveys through email and in-person discussions in the spring of 2015. Partners in the region were sent a form letter (Appendix 2) explaining the NGP business plan and asking for their input on the best way to spend available grant monies for grassland bird conservation. Partners had the choice of responding via email, personal phone call, or face-to-face visit. The results of these interviews (n=19 respondents, respondent affiliations and responses summarized in Appendix 3) were added to ideas generated during the SD NGPJV Working Group meeting, held in Rapid City April 15, 2015.

The informal interviews revealed five general categories of conservation action priorities:

1. Prevent grasslands from being converted
   - Easements (where there are agencies, orgs that can hold easements)
   - Develop capacity to hold easements
   - Grassland banking, land exchanges, carbon credits
2. Improve, restore degraded rangelands
   - Native plant seeding
   - Improved grazing management/sustainable ranching practices
   - Set-aside (pay ranchers not to graze)
   - Bird-friendly beef
   - Energy development mitigation
3. Increase number of personnel working with producers to help them with grassland management
   - Increase the number of private lands biologists/field staff talking to land owners
   - Hire a coordinator who doesn't enroll producers in programs but facilitates enrollment
   - Include individuals not associated with any one program
4. Better communication to producers/land managers on the known science and available programs of good grassland management
   - Provide better access to information about available programs
   - Better communication about how good grass benefits both producers and birds/wildlife
   - More access to expertise, best management practices information, other resources
   - Decision-support tools for land managers, agency staff, biologists, etc.
5. Identify why grassland bird populations are declining

Existing threats and conservation action summary

In an effort to fully consider possible threats and actions and to keep with a standard classification system for conservation problems, we followed Salafsky et al. (2008) to help set conservation priorities and effectively allocate limited resources based on conclusions drawn from our stakeholder interviews. Tables 6 and 7 are the result of this standardized effort. Some threats, such as energy production and mining, may only be prevalent in certain regions of the NGP. It is important to note in these cases to apply tools appropriate to their particular geographies.

Table 6. Common elements to conservation threats (adapted from Salafsky et al. 2008) as they pertain to grassland bird habitat in the Northern Great Plains.

Threats	Sub-threats
Residential and commercial development	housing and urban areas
	commercial and industrial areas
Agriculture	annual or perennial crops
	unsustainable livestock farming and ranching
Energy production and mining	oil and gas drilling
	mining and quarrying
Transportation and service corridors	roads/railroads
	utility and service lines
Biological resource use	NA
Human intrusions and disturbance	NA
Natural system modifications	fire and fire suppression
	dams and water management/use
	other ecosystem modifications
Invasive and other problematic species	invasive non-native species
	problematic native species
	introduced genetic material
Pollution	agricultural effluents (pesticides)
	excess energy (noise & light)
Geological events	NA
Climate change and severe weather	habitat shifting and alteration
	droughts
	temperature extremes
	storms and flooding

Table 7. Common elements to conservation actions (adapted from Salafsky et al. 2008) as they pertain to grassland bird habitat in the Northern Great Plains.

Conservation Actions	Sub-actions
Land/water protection	NA
Land/water management	site management invasive species control habitat and natural processes restoration
Species management	NA
Education and awareness	NA
Law and policy	Legislation policies and regulations private sectors standards and codes compliance and enforcement
Livelihood, economic and other incentives	linked enterprises and livelihood market forces nonmonetary values
External capacity building	institutional and civil society development alliance and partnership development conservation finance

In addition to the direct threats to grassland birds we also considered indirect or contributing factors that guide the intensity or frequency of threats. It is also possible that contributing factors, and not direct threats, are what managers have the capability of controlling or influencing over time. Table 8 provides some examples for contributing factors. Specific conservation actions to address conservation threats and contributing factors need to be identified to fully execute conservation strategies and projects. Table 9 provides examples of specific actions.

Table 8. Examples of factors contributing to threats within the NGP to grassland birds.

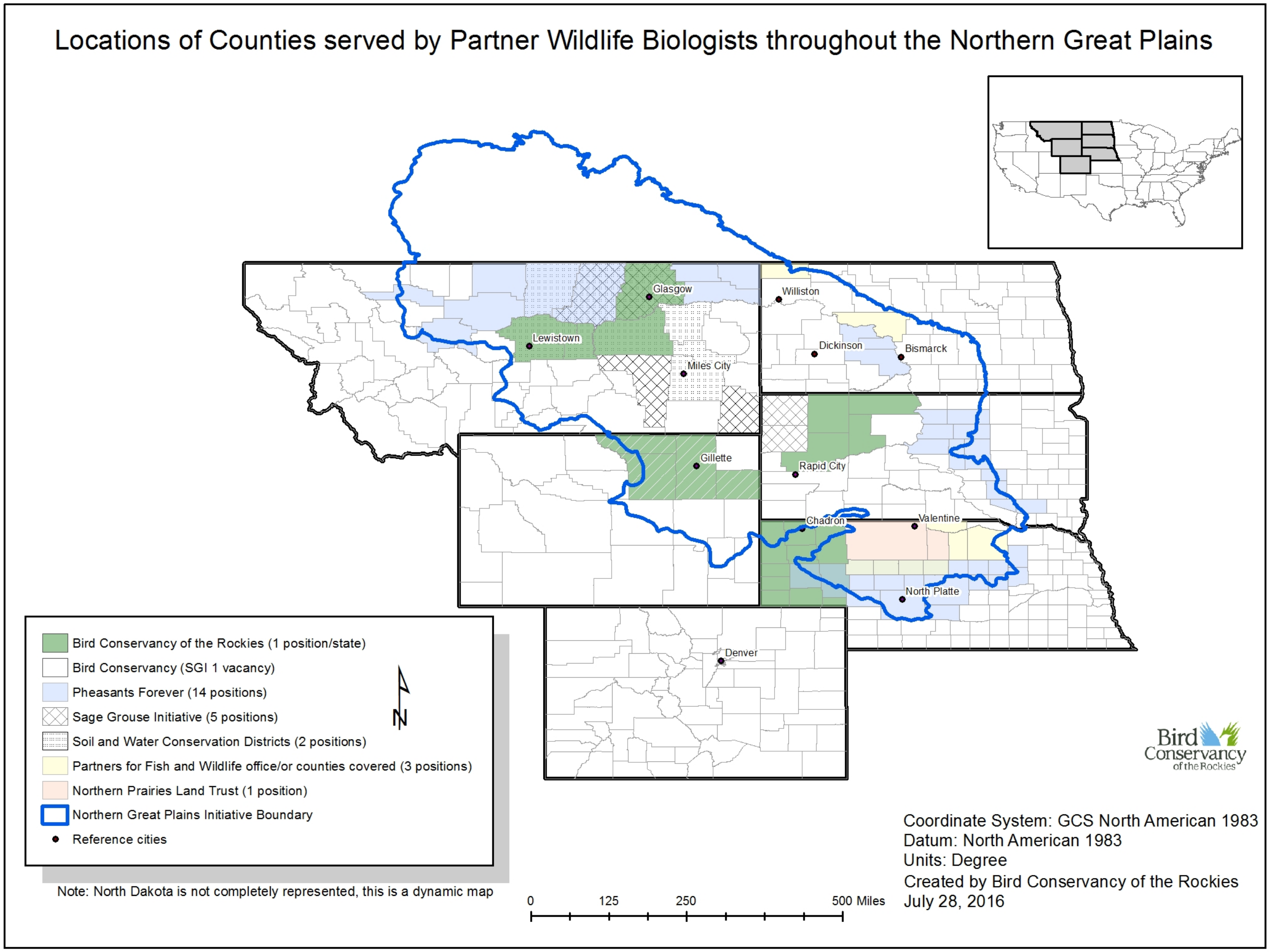
Threats	Contributing factors
Residential and commercial development	NA
Agriculture	• 2018 Farm Bill at risk • Commodity prices • Lack of good insurance for ranching • Policies (insecticide, ESA, renewable fuel standards) • Transition in ownership • Water rights • Lack of knowledge • No incentive to do the right thing (no insurance for ranching; not enough FB incentives) • Aquifer depletion • Agricultural technology • Taxation on lands that encourages cropping
Energy production and mining	• Lack of knowledge/tools • Market forces • Policies
Transportation and service corridors	• Lack of knowledge/tools • Policies
Biological resource use	NA
Human intrusions and disturbance	NA
Natural system modifications	• Sylvatic plague
Invasive and other problematic species	• Lack of knowledge/tools
Pollution	• Policies • Agricultural technology
Geological events	NA
Climate change and severe weather	• Lack of knowledge/tools

Table 9. Examples of specific conservation actions to address threats within the NGP to grassland birds.

Education and awareness	Land/water protection	Land/water management	Law and policy	Livelihood, economic and other incentives	External capacity building
private lands biologists	ID and protect large intact native grasslands	ID potential corridors between native grasslands	need more incentives (FB, ranching insurance)	ecotourism opportunities	AFWA, NABCI, NGPJV to advocate for FB initiatives
landowner visits	easements - need more groups to offer a buffet to landowners	ID important areas that need enhancing	energy development mitigation	conservation-friendly beef	NPCN - partnership development
workshops & trainings	grassland banking	work with private landowners to implement BMPs, habitat enhancement, grassland management	carbon credit system	sourcing big buyers of beef (broaden dialogue with commodity groups)	more funding sources (Land and Water Conservation Fund)
make our outcomes clear to agricultural community		restore/reseed old trails, roads, RRs	National Grassland Conservation Act	playa purchasing	state technical committees
DSTs/ Conservation Tools		invasive species treatments		rental rate disparity	crop consultants should have conservation tools
BMPs for species		sources/sinks (connectivity) of nomadic birds			Farmers Union; NRCS grassland issues
NGP "Campaign" for public and legislators		redefine CRP with more options			Congress
work with energy companies to reduce siting on and fragmenting native grasslands, reducing footprint					
NPCN - information portal					
Increased research efforts					

Existing conservation outreach effort within the NGP

Figure 8. Map of locations of biologists working in a partner position with multiple entities to achieve on-the-ground wildlife conservation on private working farms and ranches. When information about the specific counties covered by biologists was not available, county of home office was included.



Risks to migratory grassland birds outside the NGP

Grassland birds breeding in the NGP migrate to the southern Great Plains and Chihuahuan Desert where they spend the majority of the calendar year. Adequate habitat in the wintering grounds, particularly in the highly threatened grasslands of the Chihuahuan Desert is therefore essential to sustaining bird populations that breed in the NGP. All of the focal species selected in our SDM exercise (and 90% of all grassland bird species breeding in the NGP) spend more than 8 months per year on these wintering grounds.

Recent work identifies core wintering areas, key threats, and priority conservation needs for grassland bird species in the Chihuahuan Desert (Pool and Panjabi 2011, Pool et al. 2014). Increasing evidence suggests the wintering grounds may play a key role in regulating population trends of migratory species (Calvert et al. 2009) as over-winter survival is essential for maintenance and growth of the population. This is currently the focus of a long-term study being directed by Bird Conservancy of the Rockies, together with U.S., Mexican and Canadian colleagues. This study could ultimately help identify where and when to direct conservation investments in order to most effectively reverse population declines.

Ongoing loss and degradation of grasslands in the Chihuahuan Desert poses a significant risk to grassland bird conservation investments in the NGP, and should be considered as part of any strategic conservation plan for this suite of species. Cropland development in areas such as the Valles Centrales Grassland Priority Conservation Area (GPCA) in Chihuahua, Mexico are expanding at a rate of more than 6%/year. At this rate, the remaining flat grasslands in this region will disappear by 2025 (Pool et al. 2014) eliminating habitat for an estimated 44% of Baird's Sparrows, 59% of Chestnut-collared Longspurs, 27% of Sprague's Pipits, and 9% of Lark Buntings that winter in Chihuahuan Desert GPCAs. The GPCAs represent the most extensive, intact and highest-quality grasslands in the region (Pool et al. 2012) and similar rates of habitat loss are expected in other GPCAs. With the exception of McCown's Longspur, all proposed NGP focal species are grassland specialists throughout their annual cycle, and are largely dependent on Chihuahuan Desert grasslands for their survival.

Improving the condition and productivity of Chihuahuan Desert grasslands would reduce risks to NGP grassland birds by lowering the probability of winter habitat loss to cropland through improved economic competitiveness of livestock production. It could also increase the carrying capacity of desert grasslands for increased support of wintering birds, potentially compensating in part for habitat lost to cropland. Although interest and investment in Chihuahuan Desert grassland conservation by governments and foundations is growing, the scope of these efforts must be quickly scaled up and expanded to meet the growing challenge of land use change in the region. Protection of highly vulnerable grasslands (through fee-title acquisition or easement) is also needed when keeping land in the hands of ranchers is not possible.

Additional data resources for the NGP

We conducted a search of additional spatial layers that could inform identification of threats and potential conservation actions (including the selection of focal areas). The following list summarizes additional spatial resources available through the Bird Conservancy of the Rockies.

Bird distributions

- Marisa Sather's (nee Lipsey) distribution models: contact marisa_sather@fws.gov.
- Breeding Bird Survey (BBS) relative abundance index: http://www.mbr-pwrc.usgs.gov/bbs/geographic_information/GIS_shapefiles_2013.html.
- NatureServe range maps: http://www.birdlife.org/datazone/info/spcdownload.

Bird priority areas

- Sage Grouse Initiative Priority Areas of Conservation (PAC's): http://map.sagegrouseinitiative.com/.
- TNC Sage Grouse Population Index: request from jeffrey_evans@TNC.ORG.
- Audubon Important Bird Areas—
    - Canada: http://www.ibacanada.ca/explore_how.jsp?lang=en
    - USA: ArcGIS map service: http://gis.audubon.org/arcgisweb/services or request from csanchez@audubon.org.
- HAPET Grassland Bird Conservation Areas—request from adam_ryba@fws.gov.

Other priority areas

- CEC Grassland Priority Conservation Areas (GPCA's): http://www.cec.org/tools-and-resources/map-files/priority-conservation-areas-grasslands-2010.
- TNC ecoregional assessment portfolio of conservation areas: http://www.uspriorityareas.tnc.org/.
- Partners for Fish & Wildlife draft focus areas: MT, ND, SD, NE, WY: request from randy_gazda@fws.gov, steve_fairbairn@fws.gov, Mark_J_Hogan@fws.gov, kirk_d_schroeder@fws.gov, boyd_schulz@fws.gov.
- SWAP priority areas: MT, ND, SD, NE, WY—
    - SD: view at http://arcgis.sd.gov/server/gfp/wap/Ecology.aspx#, request from Heather.Berg@state.sd.us.
    - Other states: ArcGIS map service: http://maps.natureserve.org/landscope3/services.
- WWF's areas of high species richness of focal species in intact habitat and "Areas of High Conservation Opportunity" where they have low risk of threats: view at http://npcn.net/npcnWebmap/index.html, request from sarah.olimb@wwfus.org.

Threats

- U.S. DOE shale plays, coal mines, wind turbines, pipelines, transmission lines, oil and gas wells, coal fields, solar potential, wind potential: ArcGIS map service: https://eia-ms.esri.com/arcgis/services.

- TNC model of oil & gas potential: view at http://npcn.net/npcnWebmap/index.html, request from jeffrey_evans@TNC.ORG.
- Geological Atlas of the Western Canada Sedimentary Basin's Alberta coal fields: In ArcMap, "Add Data from ArcGIS Online", search for "Coalfields of the Western Canada Sedimentary Basin".
- WWF PlowPrint: view at http://npcn.net/npcnWebmap/index.html, request from sarah.olimb@wwfus.org.
- TNC cultivation risk: http://www.sagegrouseinitiative.com/sgi-map-description-and-instructions/#CultivationRisk.

Reference

- Bird Conservation Regions (BCR's): http://www.pwrc.usgs.gov/bba/index.cfm?fa=bba.getdata.
- NCED Conservation easements: ArcGIS feature service: http://services2.arcgis.com/5I7u4SJE1vUr79JC/arcgis/rest/services/National_Conservation_Easement_Database_(NCED)_2015/FeatureServer.
- PADUS Protected areas: ArcGIS map service: http://gis1.usgs.gov/arcgis/rest/services.
- CEC Grassland cover: extracted from http://www.cec.org/tools-and-resources/map-files/land-cover-2010.

Miscellaneous layers

- WWF fragmentation index: request from Kevin.Ellison@WWFUS.ORG.
- Ben Rashford's model of climate change, commodity prices, and government payments on grassland conversion: request from brashfor@uwyo.edu.
- Audubon's model of bird distribution shifts resulting from climate change: request from cwilsey@audubon.org.
- WWF analysis of BBS source vs. sink areas for bird populations: view at http://npcn.net/npcnWebmap/index.html, request from Kevin.Ellison@WWFUS.ORG.
- WWF grassland conversion rates by county: request from Kevin.Ellison@WWFUS.ORG.

PART 3: RECOMMENDED MONITORING INITIATIVE FOR THE NGP

Monitoring & Evaluation Plan

NFWF uses a three-pronged approach to monitor and evaluate progress towards the program's conservation goals and provide feedback on whether the implementation strategies and their underlying assumptions are working as expected. First, data sets from large-scale monitoring programs will be aggregated annually into a scorecard providing a snapshot of progress on the program's primary strategies and outcomes. In addition, at a key stage in the program's lifecycle, NFWF might conduct an in-house assessment or commission a third-party evaluation to examine the outcomes achieved and factors that have facilitated or hindered implementation to inform future decision-making and adaptive management. In some cases, these course corrections may warrant increased investment; however, it is also possible that NFWF would reduce or eliminate support if periodic evaluation indicates that further investments are unlikely to achieve intended outcomes.

Population and Project Outcomes

NFWF plans to use large-scale, long-term bird monitoring programs to monitor changes in bird populations across the Northern Great Plains (NGP) and to evaluate conservation outcomes in the region. Monitoring is necessary for evaluating conservation progress and is useful for determining management appropriate for the status of populations in different regions, informing management through conservation science, and evaluating management effectiveness (Lyons et al. 2008). The data sources to address the conservation outcomes will include the Breeding Bird Survey (BBS) and the Bird Conservancy's Integrated Monitoring in Bird Conservation Regions (IMBCR 2008) program. Each monitoring program comes with certain abilities to address the conservation outcomes.

The BBS has been conducted annually since 1966, and currently, there are 4,100 survey routes across the continental U.S. and Canada, with approximately 420 located within the NGP. Analyses of BBS data can provide long-term trends at the state, Bird Conservation Region, and continental scales, based on an index of bird abundance. However, because surveys are conducted along roads and do not account for incomplete detection of birds, it is difficult to make inferences to larger areas of interest about how bird populations respond to changing landscapes (Buckland et al. 2008). Additionally, several sources of uncertainty in the estimates of trend result in the need of several years of increasing populations to detect a change in the overall trends of a species. This slow response time, along with the inability to make explicit connections between trends and environmental and habitat characteristic, makes it difficult to use BBS results to evaluate the response of bird populations to management practices (Nichols and Williams 2006).

The IMBCR program has only been conducted annually since 2010 in the NGP and does not have the spatial extent of BBS, though most of the U.S. portion of the NGP has been surveyed during this time period (Fig X2). Unlike BBS, IMBCR does not rely on roadside surveys and surveys are nested within a hierarchical structure from BCR and state levels down to the immediate area around a survey location. With this design, analyses can provide information

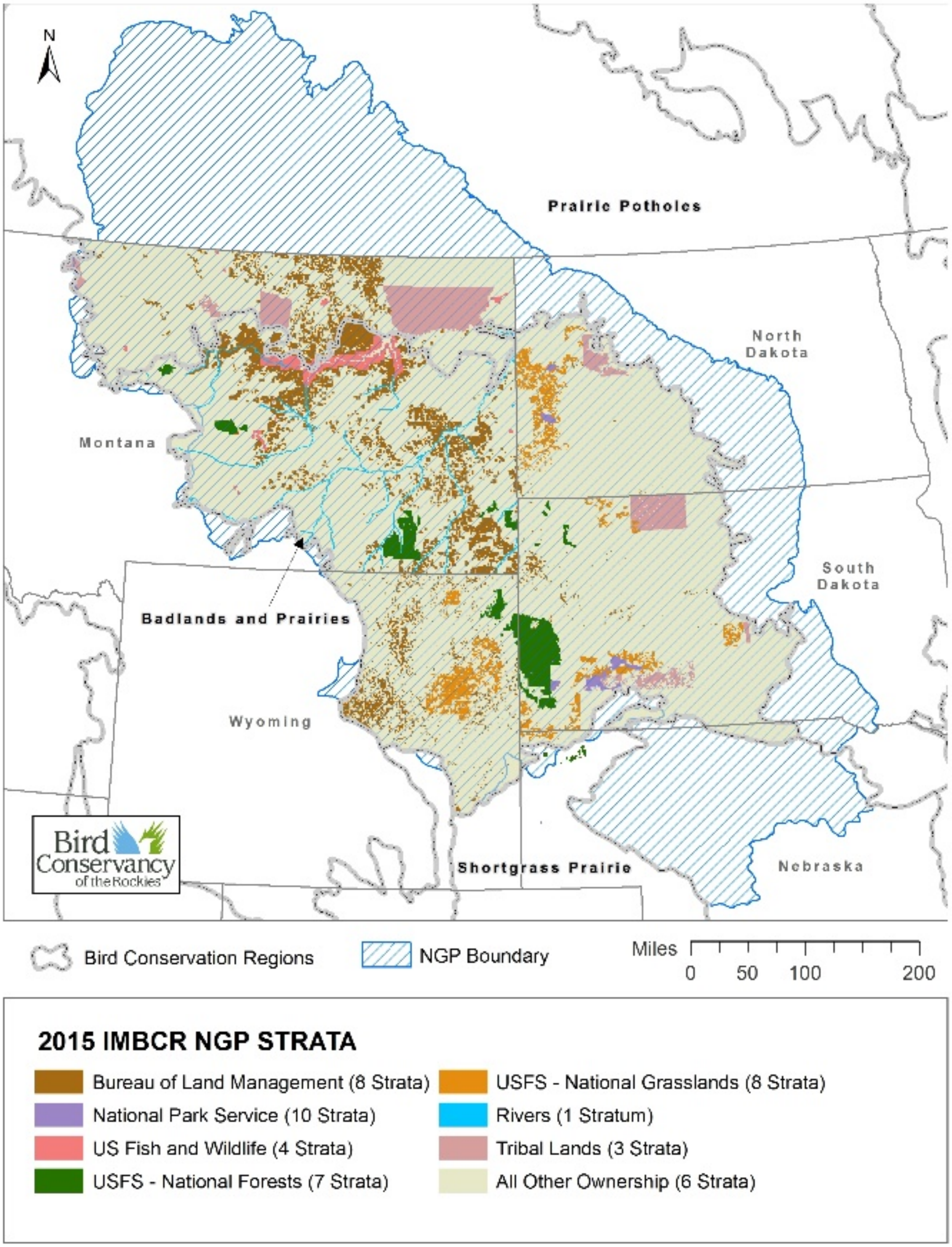


Figure 9. IMBCR program survey coverage and strata within the Northern Great Plains.

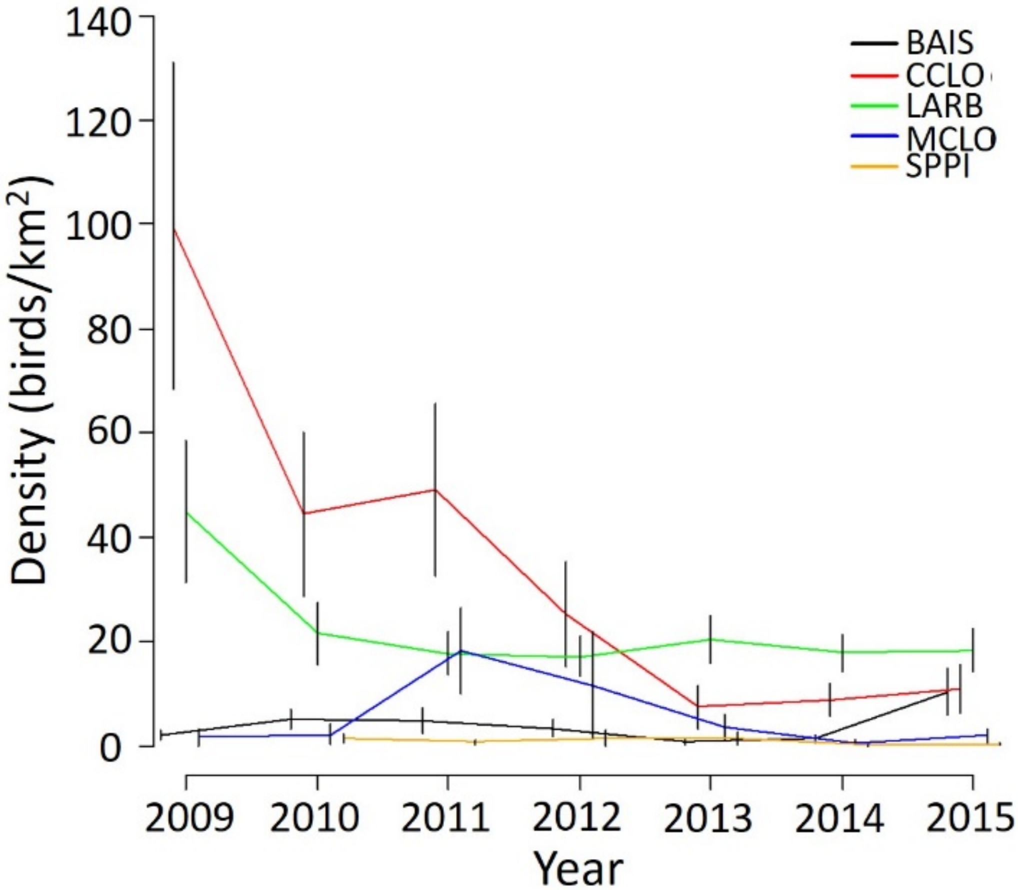


Figure 10. Density (birds/km^2; $\pm$1 SE) of focal species within the Northern Great Plains based on data from the IMBCR program. BAIS, Baird's Sparrow; CCLO, Chestnut-collared Longspur; LARB, Lark Bunting; MCLO, McCown's Longspur; SPPI, Sprague's Pipit.

on the entire area of interest, from urban to agricultural to public lands and across all levels of the hierarchy. The IMBCR survey design also allows for the estimation of detection probabilities, which in turn allows for the estimation of bird abundance, density, and distribution from local- to Bird Conservation Region-level scales (Fig. 9). Though there are fewer years of data available from the IMBCR program, the robust sampling design allows for the evaluation of population trends across all spatial scales to identify which areas are contributing most to regional populations.

Recent developments in analytical approaches may provide even more opportunities to use IMBCR data to better understand how bird populations respond to local- and landscape-level habitat characteristics and changes in management practices. These newer methods allow us to evaluate the impact of variables of interest on the changes in bird populations from one year to the next. We can then make predictions about the amount and quality of certain habitats that are necessary to slow or reverse declining populations from the local to regional level. Information from these types of analyses can also be used within a decision analysis framework to identify areas that should be protected because they already provide high-quality habitat, as well as areas that could benefit from the implementation of NFWF management practices or contribute to the overall landscape-level habitat configuration.

There are three objectives for monitoring programs (Lyons et al. 2008): 1) assess the state of the system to inform state-dependent management decisions, 2) facilitate improved management through learning, and 3) evaluate management through learning. Results from analyses of IMBCR data can be used to address each of these objectives, evaluate the contribution of NFWF programs to bird populations in the NGP, and identify where and which management practices to implement (Table 10).

Using the current IMBCR sampling design, bird densities and distributions can be used to address Objective 1 by comparing them across areas of interest and to larger regional estimates. Differences in the distributions and abundance of birds on the landscape may highlight where grassland birds may benefit most from protection or management. The IMBCR program can help achieve Objective 2 by establishing relationships between bird populations and landscape and habitat characteristics. Landscape analyses can highlight areas that may benefit from habitat management. For example, by quantifying the proportion of the landscape that is enrolled in NFWF programs and examining how that landscape configuration influences populations in the immediate area, we can compare the expected changes in populations if NFWF management practices are implemented. At the finer scale, we can quantify relationships between habitats and bird populations, and population responses can be predicted in response to expected habitat changes under different management practices.

Working in tandem with landscape-level analyses, which identify where management should occur, habitat-level analyses identify which practices should be implemented in those locations. With newer methodological approaches, we can also combine analyses across these spatial scales to identify areas on the landscape where bird populations are resilient to annual fluctuations in environmental and habitat conditions. To address Objective 3, additional resources would be required to explicitly evaluate the effectiveness of NFWF management practices. The first would consist of drastically increasing the number of IMBCR surveys conducted on private lands in the NGP. Because survey locations are randomly selected, it is unlikely that surveys fall on lands enrolled in NFWF programs under current survey efforts. Increasing the number of survey locations would increase the probability that these lands were sampled, and changes in bird populations on and off managed lands could be compared. Finally, a more focused study could explicitly investigate differences between bird populations on and off NFWF-enrolled lands. These results could then be applied to other areas implementing similar management practices.

All approaches outlined to address each objective allow us to estimate the contribution of NFWF lands to regional bird populations and to assess the investment needed across the NGP to slow or reverse declining grassland bird populations. No matter the objective, it is crucial that well-formulated monitoring objectives are identified so that monitoring programs can be tailored to address those objectives and management can be efficiently implemented (Lindenmayer and Likens 2009).

Funded IMBCR effort report 2014 - 2016

Funds provided by NFWF through this grant award supported increased coverage of BCRs 11 and 17 in the NGP. Table 11 shows the breakdown of 16-point grids completed by sampling strata.

Table 10. Program metrics for the Integrated Monitoring in Bird Conservation Regions (IMBCR) program.

Category	Strategies and Outcomes	Metrics	Baseline (2015)	Goal (year achieved)	Data source(s)
State-dependent management	IMBCR estimation at multiple spatial and temporal scales	Density Occupancy	Varies spatially and by species	Estimates produced annually	Avian Data Center
Conservation science to inform management	Landscape analyses	Quantify relationship between landscape characteristics and bird populations	Specific to management objectives and species	Analyses performed as needed	Bird Conservancy of the Rockies
	Habitat analyses	Quantify relationship between habitat characteristics and bird populations			
	Dynamic population analyses	Quantify annual changes in bird use and abundance on the landscape			
Effectiveness monitoring	Focused study of impacts of management practices	Quantify response of bird populations to management practices	Specific to management objectives and species	Analyses performed as needed	Bird Conservancy of the Rockies, IMBCR

Table 11. Summary of NFWF-funded Integrated Monitoring in Bird Conservation Regions (IMBCR) sampling grids (1 grid = 16 point count locations).

BCR	State	2014	2015	2016	Grand Total
11	MT	6		6	12
17	MT	8	27	6	41
	ND	5	4		9
	NE	4	2		6
	SD	12			12
	WY	4	17		21
	Grand Total	**39**	**50**	**12**	**101**

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APPENDICES

Appendix 1. Model selection for the density (λ), availability (Φ.) and, detection probability (p) for Baird's Sparrow, Chestnut-collared Longspur, Lark Bunting, McCown's Longspur and Sprague's Pipit. The model selection metrics are the number of parameters (*K*), value of the Akaike Information Criterion (AIC), difference between model and minimum AIC values (ΔAIC). Models with $\Delta AIC_c < 4$ are shown. Lat = Latitude and Long = Longitude.

Model	*K*	*AIC*	*ΔAIC*
Baird's Sparrow			
λ (Grassland + Lat + Long + Shrubland)	10	2371.99	0
λ (Grassland + Lat + Long)	9	2372.99	1
Φ (Grass Height + Herbaceous Cover + Shrub Cover)	12	2356.77	0
Φ (Grass Cover + Shrub Cover)	10	2359.37	2.6
p (Grass Height)	12	2363.31	0
p(.)	11	2363.59	0.28
p (Grass Height + Shrub Cover)	13	2364.96	1.65
p (Shrub Cover)	12	2365.56	2.25
Chestnut-collared Longspur			
λ (Grassland + Lat + Long + Shrubland)	11	9124.73	0
λ (Grassland + Lat + Long)	10	9125.10	0.37
Φ (Grass Cover + Herbaceous Cover + Shrub Cover)	11	9124.73	0
Φ (Grass Height + Herbaceous Cover + Shrub Cover)	11	9125.18	0.45
Φ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	12	9125.26	0.53
Φ (Herbaceous Cover + Shrub Cover)	10	9126.43	1.7
p (Grass Height)	12	9125.26	0
p (Grass Height + Shrub Cover)	13	9126.85	1.6
p(.)	11	9141.91	16.66
p (Shrub Cover)	12	9143.84	18.59
Lark Bunting			
λ (Grassland + Lat + Long + Shrubland)	10	33920.02	0
Φ (Grass Cover + Grass Height + Herbaceous Cover)	10	33920.02	0
Φ (Grass Height + Herbaceous Cover)	9	33920.32	0.31
Φ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	11	33922.02	2
Φ (Grass Height + Herbaceous Cover + Shrub Cover)	10	33922.31	2.29
Φ (Grass Cover + Herbaceous Cover)	9	33922.34	2.33
p(.)	11	33922.02	0
p (Shrub Cover)	12	33922.9	0.88
p (Grass Height)	12	33923.45	1.43
p (Grass Height + Shrub Cover)	13	33924.09	2.07

McCown's Longspur			
λ (Grassland + Lat + Long + Shrubland)	12	1519.3	0
λ (Grassland + Lat + Long)	11	1522.06	2.76
Φ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	11	3760.25	0
p(.)	12	3740.46	0
p (Grass Height)	13	3741.14	0.67
p (Shrub Cover)	13	3742.36	1.9
p (Grass Height + Shrub Cover)	14	3743.13	2.66

Sprague's Pipit			
λ (Grassland + Lat + Long)	9	1011.69	0
λ (Grassland + Lat + Long + Shrubland)	10	1013.57	1.88
Φ (Grass Cover + Grass Height + Herbaceous Cover)	10	1013.57	0
Φ (Grass Cover + Herbaceous Cover)	9	1014.46	0.9
Φ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	11	1015.43	1.86
Φ (Grass Cover + Herbaceous Cover + Shrub Cover)	10	1016.46	2.89
Φ (Grass Height + Herbaceous Cover)	9	1016.88	3.32
Φ (Herbaceous Cover)	8	1016.98	3.42
p(.)	11	1015.43	0
p (Grass Height)	12	1016.89	1.46
p (Shrub Cover)	12	1017.08	1.66
p (Grass Height + Shrub Cover)	13	1018.46	3.03

Appendix 2. Email and letter text for stakeholder survey to partners within the Northern Great Plains (NGP).

Dear _______,

As you probably have already heard, the National Fish and Wildlife Foundation (NFWF) has launched their Northern Great Plains Initiative. They are in the process of developing the grassland bird portion of the business plan to guide funding decisions, which may be up to $1.5 million/year for projects that help grassland-nesting songbirds in western SD, northeast WY, and eastern MT. RMBO has been contracted to help with this and I'm leading that effort.

For the business plan, NFWF has asked us to think about and develop ideas on the best ways we could use their ~$1.5 million per year that would have the most impact on grassland-nesting songbird populations. There already are a lot of efforts, admittedly underfunded, in the region, especially related to Farm Bill programs. The $$ that NFWF can provide is a drop in the bucket of what is needed, so what would be the most strategic and targeted way to use this money to make a measureable difference? The upside is that this funding is flexible and could be used to do some cool things that other programs can't/won't fund. So we need to brainstorm on innovative, targeted ways that a relatively limited pot of money could make a difference for grassland birds.

I hope that you or your colleagues would be willing to contribute ideas, thoughts, and opinions on this. Would you be interested in chatting on the phone about this, say in a week or two? Or shoot me an email with your thoughts. Also please feel free to forward this message to other folks that you think would have some ideas, or give me their contact info so I can contact them.

Nancy Drilling

Appendix 3. Summary of informal interviews conducted in April 2015 to identify and prioritize existing threats and conservation actions within the Northern Great Plains (NGP).

<u>Respondent category: (organization-number of people)</u>

NGO: (BCR-3, TNC-1, ABC-1, Audubon-2, MT Aububon-1, SD Grassland Coalition-1, WWF-1)
State agencies: (MtFWP-1, SDGFP-1, WYGF-1)
Federal agencies: (NRCS-1, USFWS Partners-2, USFWS-1)
Academics: 2
SD NGJV Working Group Meeting (~27 attendees)

Responses* ranged from very short emails to 45-minute telephone conversations:

Email response: 4
Telephone discussion: 8
In-person discussion: 7 + SD NGPJV Working Group meeting discussion

*Notes from all responses were organized into similar topics, names were removed, and the responses were converted into bulleted points to produce the final summary.