SDGFP Region 1 GPA Breeding Bird Inventory and Monitoring:

Final Report

September 2021

Connecting People, Birds and Land

Bird Conservancy of the Rockies

Connecting people, birds and land

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

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.

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Executive Summary

Critical to implementation of adaptive management practices is science-based feedback on the effectiveness of management actions. Game Production Areas (GPAs) in South Dakota are extensively managed by South Dakota Game, Fish and Parks (SDGFP) for game species, but little is known about the value of these managed lands to non-game bird species, or how they respond to management practices, such as timber thinning or prescribed grazing. The analyses in this report attempt to quantify the contributions SDGFP-managed lands to regional bird populations, and assess avian response to two types of land management practices (timber thinning and grazing).

We found that the GPAs in the Black Hills that were selected for this study contribute, in some cases substantially, to regional bird populations within the Black Hills National Forest. We also quantified avian response to two management practices (timber thinning and grazing) by estimating habitat-specific densities for the primary habitats targeted by management actions (i.e., ponderosa pine and grassland), and comparing these density estimates between control and treatment strata.

We found that Western Wood-pewee and Chipping Sparrow responded positively to timber thinning treatments, while Northern Flicker showed a negative response. Grazing treatments produced positive responses in Dickcissel, Grasshopper Sparrow, Upland Sandpiper, and Western Meadowlark.

We additionally conducted area searches on GPAs throughout SDGFP Region 1, and quantified the number of confirmed or probably breeding bird species on each GPA surveyed.

Acknowledgements

We are grateful to South Dakota Game, Fish and Parks for funding this project, and in particular Eileen Down for her support. We thank Nancy Drilling for project development and collaboration with SDGFP. Special thanks to David Pavlacky Jr. of Bird Conservancy of Rockies for his assistance in developing analysis strategies. We thank Bird Conservancy's Rob Sparks, Alex Van Boer, and Eric Chabot for their GIS skills. Thank you to Jenny Berven for her program management, and Matthew McLaren and Chris White for their guidance. And finally we thank David Sandahl for his leadership in the field, and numerous field technicians for collecting the data needed for this project.

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Introduction

Game Production Areas (GPAs) in South Dakota are public lands owned and managed by the South Dakota Department of Game, Fish and Parks (SDGFP). Generally, GPAs are managed for the production and maintenance of all wildlife. GPAs in SDGFP's Region 1 (those in western South Dakota and the Black Hills) contain diverse habitat types, and as a result, host a variety of breeding bird species. However, most information on wildlife species presence and abundance on Region 1 GPAs are of game species, especially ungulates and upland game birds. No systematic surveys of breeding bird populations have occurred on these GPAs. Thus, managers are not certain of the value of these public lands to non-game bird species or to the state's overall breeding bird diversity.

Some GPAs, such as those found in the Black Hills, are managed for certain wildlife species, with the assumption that all wildlife will benefit from management actions. In the northern Black Hills, timber management, primarily thinning and cutting of ponderosa pine, is used to encourage oak, aspen, and birch growth; reduce fire danger; and thin overly dense pine stands. In the southern Black Hills, GPAs are grazed by livestock to reduce invasive exotic grass species, reduce fire danger, and mimic natural ecological processes (e.g., large herbivore grazing). These management tools are thought to improve habitat for game species, but impacts on non-game species, including Species of Greatest Conservation Need (SOGCN) are unknown (SDGFP 2014). Ideally, habitat management programs incorporate adaptive management (SDGFP 2014: 192) which provides a scientific basis for management decisions. Documenting species' responses to management actions is part of the adaptive management framework but has never been attempted for breeding bird species in the Black Hills GPAs.

Therefore, our objectives were to: 1) monitor breeding landbirds within GPAs in the northern and southern Black Hills in treatment (timber thinning or grazing) and control areas using the Integrated Monitoring in Bird Conservation Regions (IMBCR) framework; 2) determine the value of these GPAs to non-game bird species; and 3) assess the impacts of timber thinning and grazing on non-game bird species.

The study design implemented within the Black Hills GPAs is the same used by Bird Conservancy of the Rockies to monitor breeding birds throughout portions of 16 states in 2019 (Figure 1). This monitoring effort, known as Integrated Monitoring in Bird Conservation Regions (IMBCR), is a long-term collaborative effort among multiple partners including governmental and non-governmental organizations. Bird Conservation Regions (BCRs) provide a spatially consistent framework for bird conservation in North America, as they represent distinct ecological regions with similar bird communities, vegetation types and resource management interests (US North American Bird Conservation Initiative 2000). Within BCRs, we monitor bird populations with a flexible hierarchical framework of nested units, where information on status of bird populations can be partitioned into smaller units for small-scale conservation planning, or aggregated to support large-scale conservation efforts.

In South Dakota, we have monitored breeding landbirds in BCR17 (the Badlands and Prairies BCR) using the IMBCR program since 2009. The project area for the Black Hills GPAs represents an "overlay" project, meaning the project area was laid over an existing IMBCR stratum, Black Hills National Forest. Using the IMBCR design and field methods for the Black Hills GPAs project provides several advantages:

1.   Black Hills GPAs data are pooled with the larger IMBCR data set, resulting in larger samples sizes, and thus population estimates for more species than would have been possible using only the Black Hills GPAs data set;
2.   We can determine the contribution of the Black Hills GPAs to bird populations within the overall Black Hills National Forest to identify those species for which the GPAs are relatively more important; and
3.   We can leverage observer training and skill from the larger IMBCR program to conduct surveys within the Black Hills GPAs, and also leverage statistical analyses and expertise from the IMBCR program to inform population estimates and treatment effects within the Black Hills GPAs.

To read more about the IMBCR program, please refer to the IMBCR page on Bird Conservancy's website:
https://birdconservancy.org/what-we-do/science/monitoring/imbcr-program/

Methods

Study Area

We conducted breeding bird surveys on GPAs in western South Dakota within BCR17 and SDGFP Region 1 (Figures 1 & 2). The region is made up of semi-arid, rolling mixed-grass prairies and badlands, with some conifer-dominated forests (Bird Studies Canada and NABCI 2021). Outside of the Black Hills, it is primarily characterized by expansive grass-shrub systems with interspersed riparian zones. In the southwest portion of Region 1 are the Black Hills, which are dominated by forested systems (SDGFP 2014).
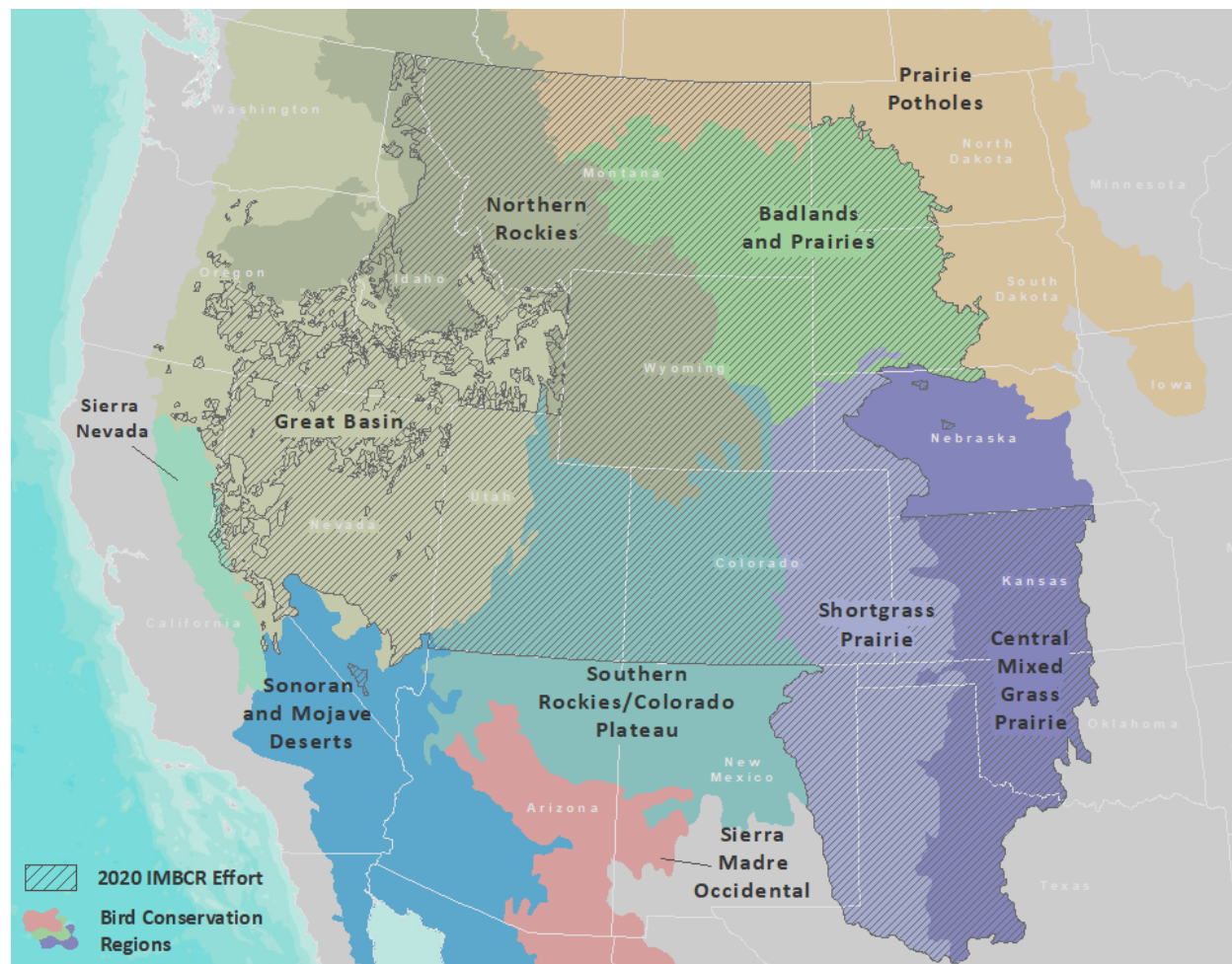
Figure 1. Location and extent of Bird Conservation Region 17 (Badlands and Prairies) with the 2020 Integrated Monitoring in Bird Conservation Regions (IMBCR) survey effort shown with hatching.
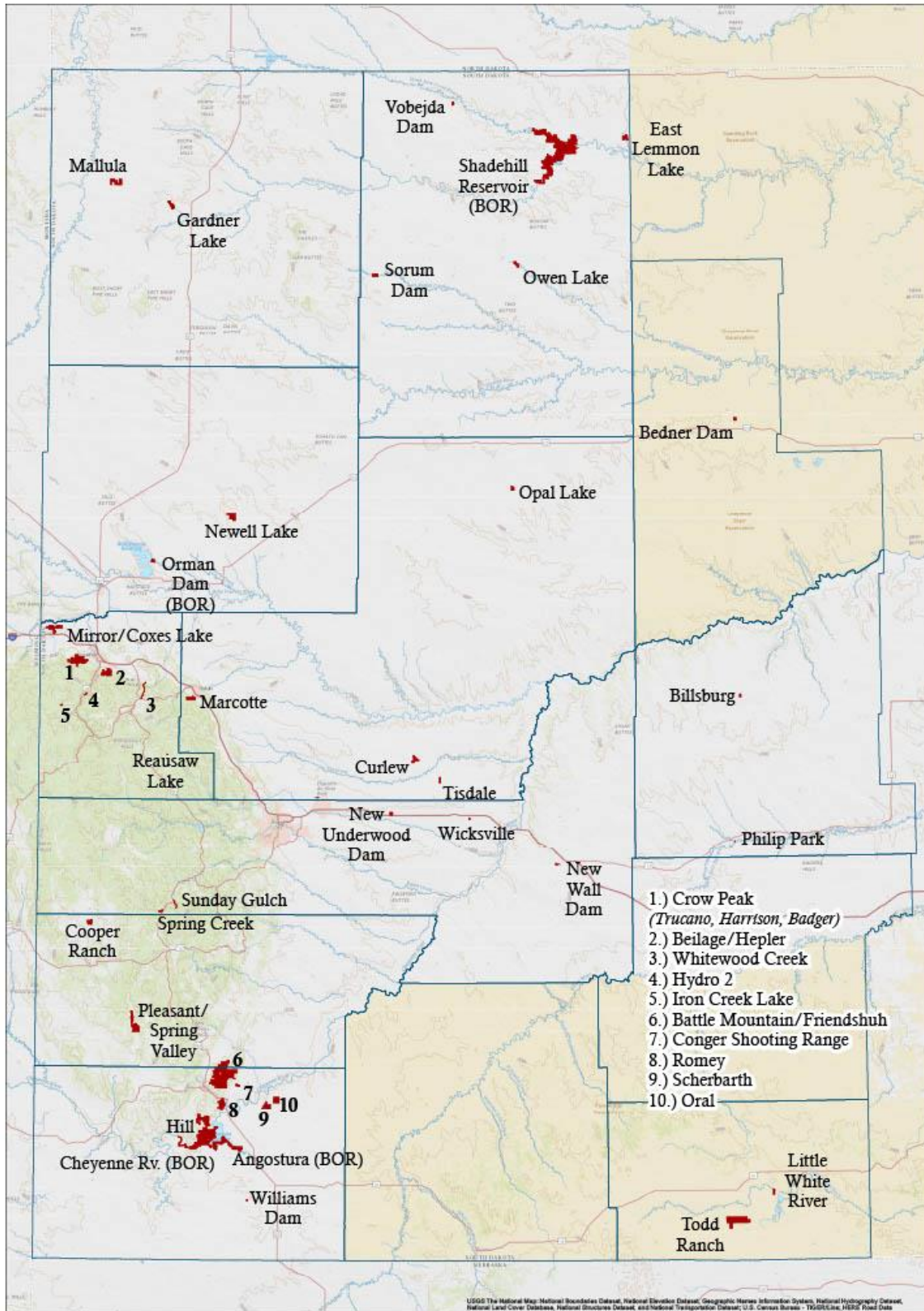
Figure 2. Region 1 Game Production Areas surveyed by area search 2019 – 2020 (see Appendix A for more information on area searches).

Sampling Design
Sampling Frame and Stratification

To estimate population densities and assess the impacts of management practices on non-game bird species in GPAs in the northern and southern Black Hills, we used the boundaries of the GPAs as the sampling frame, and created four separate strata within it– one for each treatment (grazing or timber thinning) and one control associated with each treatment (no grazing or no timber thinning).

Sampling Units and Sample Selection

We conducted breeding bird surveys according to the IMBCR framework, which defines sampling units as 1 km² cells, each containing 16 evenly spaced sample points, 250 meters apart. We defined potential sampling units by superimposing a uniform grid of cells over the sampling frame. For areas too small for, or otherwise not suitable for the use of 1 km^2 grid cells as the sampling unit, we used the individual point location as the sampling unit (Table 1). We then assigned each cell or point to one of four strata using ArcGIS version 10.X and higher (Environmental Systems Research Institute 2017). For the southern Black Hills GPAs (Figure 3), we assigned a grid cell to the treatment stratum if >50% of the grid cell was contained within the treatment area; otherwise it was assigned to the control stratum. We selected sampling units using a generalized random-tessellation stratification (GRTS) spatially balanced sampling algorithm (Stevens and Olsen 2004).

Table 1. GPA and type of sampling unit used.

Game Production Area	Sample Type
Beliage-Hepler	Point
Harrison-Badger-Trucano	Point
Marcotte	Point
Angostura	Grid cell
Battle Mountain	Grid cell
Friendshuh	Grid cell
Hill Ranch	Grid cell
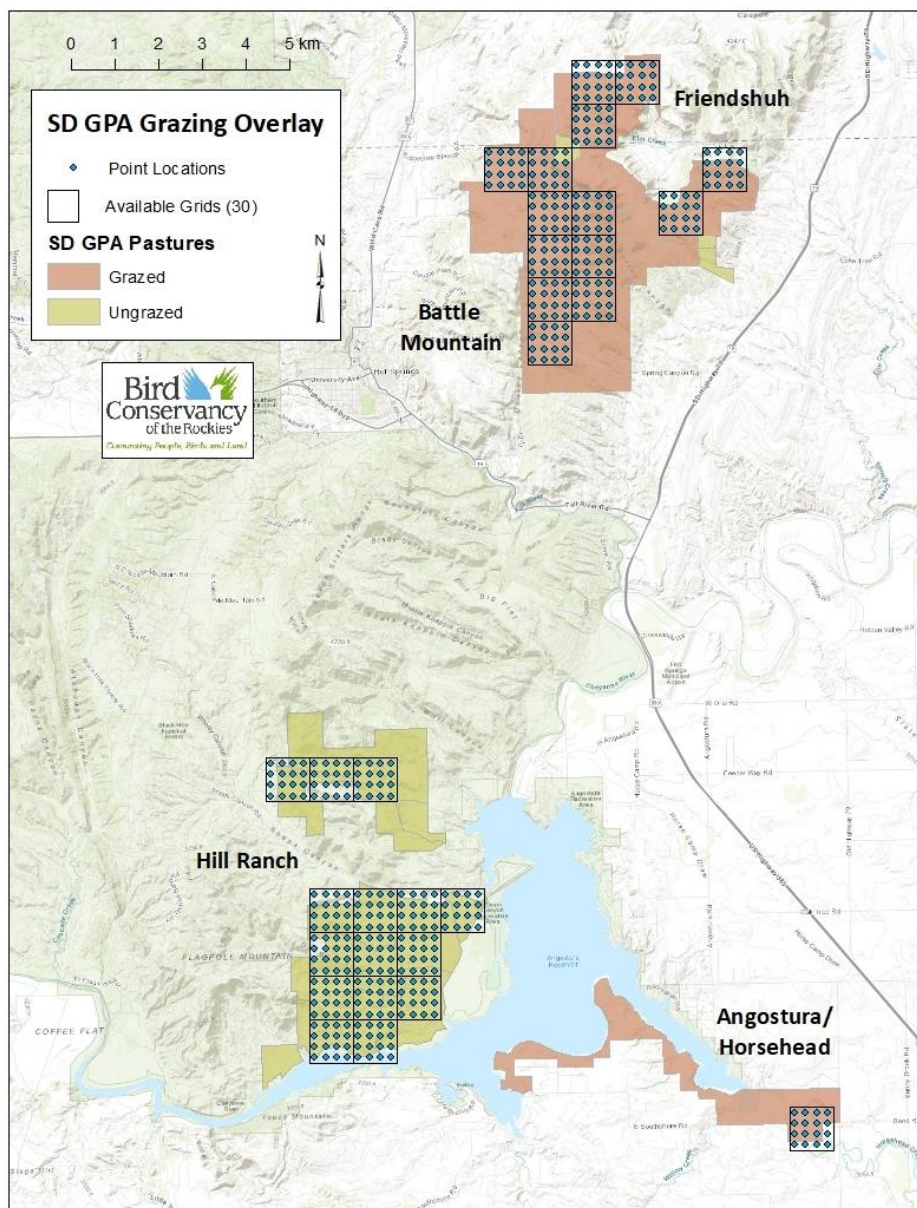
Figure 3. Southern Black Hills sampling units.

In the northern Black Hills GPAs, most timber management parcels were smaller than 1 km^2. Therefore, in these GPAs, we overlaid a grid of points, each spaced 250 m apart (Figure 4). We selected and surveyed all points within timber management parcels, and then used the GRTS algorithm to select survey points that did not receive timber management treatments for the control stratum.
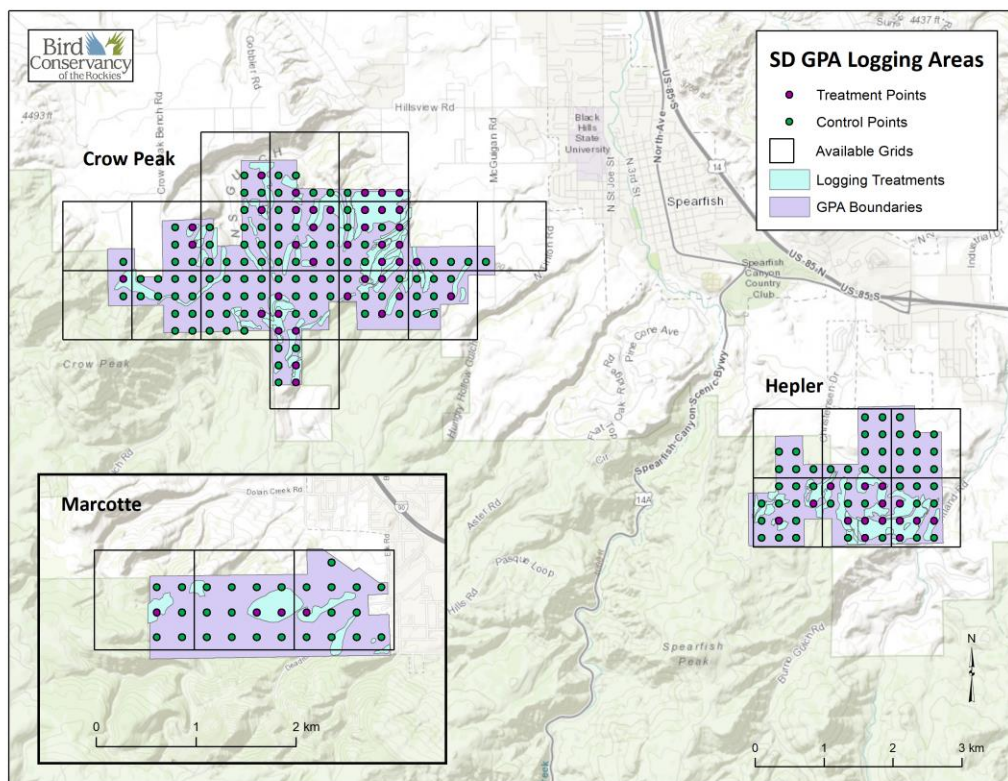
Figure 4. Northern Black Hills GPA sampling units.

Sampling Methods

Point Counts

On selected Black Hills GPAs, trained IMBCR observers with excellent aural and visual bird-identification skills conducted field work in 2019 and 2020. Prior to conducting surveys, observers completed an intensive training program that was largely virtual to ensure full understanding of the field protocol and review bird and plant identification. Observers were also shadowed by a crew leader at the start of the field season to ensure they understood the protocol and could identify all birds within the region.

Observers conducted point counts (Buckland et al., 2001) following protocols established by IMBCR partners (Hanni, White, Birek, Van Lanen, & McLaren, 2012). Observers conducted surveys in the morning, beginning one-half hour before sunrise and concluding no later than five hours after sunrise. Observers recorded the start time for every point count conducted. For every bird detected during the six-minute period, observers recorded species, sex, horizontal distance from the observer, minute, type of detection (e.g., call, song, visual), whether the bird was thought to be a migrant, and whether the observer was able to visually identify each record.

Observers measured distances to each bird using laser rangefinders when possible. When it was not possible, observers estimated the distance by measuring to some object near the bird using a laser rangefinder. In addition to recording all bird species detected in the area during point counts, observers recorded birds flying over but not using the immediate surrounding landscape. Observers also recorded American red squirrel (*Tamiasciurus hudsonicus*). While observers traveled between points within a sampling unit, they recorded the presence of any species not recorded during a point count. The opportunistic detections of these species are used for distribution purposes only.

Observers considered all non-independent detections of birds (i.e., flocks or pairs of conspecific birds together in close proximity) as part of a "cluster" rather than as independent observations. Observers recorded the number of birds detected within each cluster along with a letter code to distinguish between multiple clusters.

At the start and end of each survey, observers recorded time, ambient temperature, cloud cover, precipitation, and wind speed. Observers navigated to each point using hand-held Global Positioning System units. Before beginning each six-minute count, surveyors recorded vegetation data within a 50-m radius of the point via ocular estimation. Vegetation data included the dominant habitat type, percent cover and mean height of trees and shrubs by species, grass height, and ground cover. Observers recorded vegetation data quietly to allow birds time to return to their normal habits prior to beginning each count.

For more detailed information about survey methods and vegetation data collection protocols, refer to Hanni, White, Birek, Van Lanen, & McLaren (2012)

Data Analysis

Density estimation

To estimate bird density within the four strata, we used established analysis methods from the IMBCR program. We used a Bayesian, zero-inflated N-mixture model (Royle et al. 2004, Sillet et al. 2012) to estimate density and abundance across all species with sufficient data. We used distance sampling to estimate detection probabilities and adjust counts accordingly. Distance sampling theory was developed to account for the decreasing probability of detecting an object of interest (e.g., a bird) with increasing distance from the observer to the object (Buckland et al. 2001).The detection probability is used to adjust the count of birds to account for birds that were present but undetected.

We fit a series of models to the data from each species that had the same model structure describing density estimation but varied in detection structure (see *Observation process* section below). We used zero-inflation to account for excess zeros in the data, where abundance at a point count location (N) is conditional on the point's true occupancy state (z) of a species at the point count location.

All points within a grid cell shared a mean abundance to account for the lack of independence of those points, but abundance was allowed to vary spatially within a grid cell (i.e., by point) through Poisson variation. To avoid predicting species occurrence outside of observed ranges, we fixed occupancy probabilities to 0 for all strata in which the species was never observed and used a prior informed by the observed proportion of grid-year combinations in a stratum in which the species was detected.

We derived density at the point count location by dividing the estimated abundance by the area of the point count circle (see *Observation process* section below) and multiplying by cluster size. We derived stratum-level density estimates by averaging all point-level density estimates within each stratum. We estimated species' abundances by multiplying each density estimate by the appropriate stratum area.

Observation process
We estimated the probability of detecting an independent cluster of individuals by fitting distance functions to the distance data collected during surveys (Buckland et al. 2001). We fit four detection models including: 1) half-normal constant (HN(.)), 2) hazard rate constant (Haz(.)), 3) half-normal year (HN(t)), and 4) hazard rate year (Haz(t)).

We removed the furthest 10% of observed detection distances from the data set and binned the remaining detections into 10 evenly spaced distance classes. The furthest remaining detection distance became the radius of the point count circle with which we estimated density.

Detection model selection
To minimize computing time but find the most parsimonious detection function, we fit detection-only models to the distance data, using the four model structures described above. We used the Watanabe-Akaike Information Criterion (WAIC; Watanabe 2010, Hooten and Hobbs 2015) to select the most parsimonious detection structure and then used that structure for detection probabilities in the full model to estimate density and abundance.

For more information on density estimation, please see the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2020 Field Season Report (McLaren et al. 2021).

Species Selection and Post-Stratification

To better assess the impacts of management practices, we estimated habitat-specific densities for the primary habitats targeted by management actions (i.e., ponderosa pine and grassland), and compared these density estimates between control and treatment strata. We selected species based on their habitat associations that the management practices were intended to target.

Species selection
To better assess bird response to management, we selected species that were adapted to the primary habitats targeted by management action (i.e., ponderosa pine forest and grassland). We used a species specialization index (Correll et al. 2019) to quantify the degree of specialization in each species for which we had sufficient data to produce density estimates. We then selected species with a specialization index value >0.6 for the post-stratification analysis.

Post-stratification
To compare bird response between control and treatment strata for birds associated with the primary habitat targeted by management actions, we post-stratified survey points by primary habitat type to estimate habitat-specific densities. For the northern Black Hills GPAs, we post-stratified points with ponderosa pine recorded as the primary habitat, and compared point-based density estimates between the control (unlogged) and treatment (logged) strata. For the southern Black Hills GPAs, we post-stratified points with grassland recorded as the primary habitat, and compared density estimates between the control (ungrazed) and treatment (grazed) strata.

Results

Point Count Surveys

We conducted point counts in 2019 and 2020 on four southern Black Hills GPAs (Angostura, Battle Mountain, Friendshuh, and Hill Ranch), and three GPAs in the northern Black Hills (Beilage-Hepler, Harrison-Badger-Trucano, and Marcotte). In the southern Black Hills, we completed surveys in 11 of 15 grazed grid cells, and eight of 15 ungrazed grid cells in 2019. We completed surveys in 15 of 15 grazed grid cells, and 15 of 15 ungrazed grid cells in 2020. In the northern Black Hills, we completed surveys on 47 of 58 logged points, and 42 of 47 unlogged

(control) points in 2019. We completed surveys on 39 of 58 logged points and 41 of 47 unlogged points in 2020.

In 2019, technicians recorded 6,052 individuals of 101 species during point counts across the four strata. In 2020, 6,935 individuals of 116 species were recorded. We detected five Species of Greatest Conservation Need (SDGFP 2014): American White Pelican *(Pelecanus erythrorhynchos)*, Black-backed Woodpecker *(Picoides arcticus)*, Lark Bunting *(Calamospiza melanocorys)*, Long-billed Curlew *(Numenius americanus)*, and Osprey *(Pandion haliaetus)*.

Density Estimates
We produced density estimates for a total of 118 bird species (including 4 SOGCN; Appendix B) that were detected on the northern and southern Black Hills GPAs in either 2019 or 2020. We also produced density estimates for American red squirrel. Please see Appendix C for a table of occupancy estimates and an occupancy analysis description.

Contributions to Regional Bird Populations
We compared estimated population sizes within Black Hills GPAs to regional populations within the Black Hills National Forest (BHNF;), which is a stratum surveyed in annually in the IMBCR program (Table 2). Notably, GPAs accounted for 17% of the BHNF Canyon Wren *(Catherpes mexicanus)* population in 2019, and 34% and 18% of the Common Grackle *(Quiscalus quiscula)* population in 2019 and 2020, respectively. They accounted for 46% of the BHNF Grasshopper Sparrow *(Ammodramus savannarum)* population in 2019, and had an even greater population size estimate in 2020 (2,166 birds) when the BHNF population was estimated at zero. Additionally, GPAs accounted for 74% of the BHNF Lark Sparrow *(Chondestes grammacus)* population in 2019, and 24% in 2020. Also notable is that GPAs provided habitat for a Western Meadowlark *(Sturnella neglecta)* population equal to 16% of the BHNF population in 2019, and 27% of the BHNF Wild Turkey *(Meleagris gallopavo)* population.

Table 2. Comparison of population sizes (N) between the Black Hills GPAs and the Black Hills National Forest (BHNF) and GPA proportions of the BHNF populations.

Species	Black Hills GPAs		Black Hills NF		% of BHNF Pop.	
	N		N			
	2019	2020	2019	2020	2019	2020
American Crow	27	35	3,557	3,997	1%	1%
American Goldfinch	1,135	797	44,703	42,546	3%	2%
American Kestrel	24	24	1,058	2,561	2%	1%
American Redstart	156	62	34,423	46,702	0%	0%
American Robin	668	755	207,101	207,495	0%	0%
Baltimore Oriole*	7	0	0	0	-	-
Bank Swallow*	13	0	0	0	-	-
Barn Swallow	0	30	28,298	57,021	0%	0%
Black-and-white Warbler	14	80	636	0	2%	-
Black-backed Woodpecker*	13	0	0	0	-	-
Black-billed Magpie	93	82	1,183	4,561	8%	2%
Black-capped Chickadee	986	1,851	234,903	325,615	0%	1%
Black-headed Grosbeak	343	356	10,242	18,357	3%	2%
Blue Grosbeak	0	4	1,229	0	0%	-
Blue Jay	88	147	8,360	12,440	1%	1%
Blue-gray Gnatcatcher	358	152	3,899	0	9%	-

Species	Black Hills GPAs		Black Hills NF		% of BHNF Pop.	
	N		N			
	2019	2020	2019	2020	2019	2020
Bobolink*	0	7	0	0	-	-
Brewer's Blackbird	36	53	2,073	0	2%	-
Brown Creeper	119	179	19,936	60,420	1%	0%
Brown Thrasher*	42	19	0	0	-	-
Brown-headed Cowbird	1,803	931	156,447	128,116	1%	1%
Bullock's Oriole*	191	181	0	0	-	-
Canada Goose	10	5	0	133	-	4%
Canada Jay	0	10	41,310	10,722	0%	0%
Canyon Wren	13	22	75	3,128	17%	1%
Cedar Waxwing	980	550	38,799	30,255	3%	2%
Chipping Sparrow	1,991	1,226	349,822	341,652	1%	0%
Clay-colored Sparrow	0	3	285	0	0%	-
Cliff Swallow	0	12	12,511	65,144	0%	0%
Common Grackle	360	246	1,056	1,351	34%	18%
Common Nighthawk	147	62	4,209	2,065	3%	3%
Common Poorwill*	3	2	0	0	-	-
Common Yellowthroat	10	39	19,717	14,097	0%	0%
Cooper's Hawk	13	22	0	1,448	-	2%
Cordilleran Flycatcher	225	380	45,407	62,071	0%	1%
Dark-eyed Junco	80	223	365,983	352,807	0%	0%
Dickcissel*	71	534	0	0	-	-
Downy Woodpecker	5	19	33,420	46,654	0%	0%
Dusky Flycatcher	77	46	66,233	84,081	0%	0%
Eastern Bluebird	86	115	1,852	8,388	5%	1%
Eastern Kingbird	289	80	3,435	14,594	8%	1%
Eastern Phoebe*	0	4	0	0	-	-
Eurasian Collared-Dove*	31	59	0	0	-	-
European Starling	58	97	6,594	0	1%	-
Field Sparrow	141	185	2,419	0	6%	-
Golden-crowned Kinglet	0	42	9,762	1,125	0%	4%
Grasshopper Sparrow	1,972	2,166	4,311	0	46%	-
Gray Catbird	50	27	410	0	12%	-
Great Blue Heron	0	0	105	0	0%	-
Great Crested Flycatcher*	0	2	-	-	-	-
Great Horned Owl*	1	1	0	0	-	-
Hairy Woodpecker	78	99	32,163	26,679	0%	0%
House Finch	47	77	21,387	0	0%	-
House Wren	1,031	947	75,040	159,423	1%	1%
Indigo Bunting*	43	26	0	0	-	-
Killdeer	2	6	463	0	0%	-
Lark Bunting	0	3	336	0	0%	-
Lark Sparrow	1,646	1,048	2,227	4,311	74%	24%
Lazuli Bunting	262	453	861	0	30%	-

Species	Black Hills GPAs N		Black Hills NF N		% of BHNF Pop.	
	2019	2020	2019	2020	2019	2020
Least Flycatcher	34	7	8,852	1,326	0%	1%
Lesser Goldfinch*	0	13	-	-	-	-
MacGillivray's Warbler	13	0	2,896	20,035	0%	0%
Mallard*	4	6	0	0	-	-
Mountain Bluebird	101	64	59,476	26,847	0%	0%
Mourning Dove	629	418	13,455	14,479	5%	3%
Northern Cardinal*	0	1	-	-	-	-
Northern Flicker*	120	117	32,943	32,148	0%	0%
Northern Rough-winged Swallow	35	47	9,589	9,071	0%	1%
Olive-sided Flycatcher*	0	1	0	0	-	-
Orchard Oriole*	130	121	0	0	-	-
Osprey	0	0	0	0	-	-
Ovenbird	411	484	43,912	28,681	1%	2%
Pine Siskin	183	213	76,060	95,425	0%	0%
Plumbeous Vireo	153	281	9,111	19,722	2%	1%
Prairie Falcon*	1	0	-	-	-	-
Pygmy Nuthatch	134	211	31,847	0	0%	-
Red Crossbill	620	1,051	301,746	190,594	0%	1%
Red-breasted Nuthatch	562	1,129	174,987	246,142	0%	0%
Red-eyed Vireo	107	114	3,338	7,055	3%	2%
Red-headed Woodpecker	31	25	4,841	4,479	1%	1%
Red-naped Sapsucker	0	9	51,016	83,639	0%	0%
Red-tailed Hawk	28	31	461	432	6%	7%
Red-winged Blackbird	109	147	35,317	43,260	0%	0%
Ring-necked Pheasant*	4	8	-	-	-	-
Rock Pigeon*	33	45	0	0	-	-
Rock Wren	44	123	18,141	8,107	0%	2%
Ruby-crowned Kinglet	5	7	16,586	24,376	0%	0%
Savannah Sparrow	118	0	0	11,488	-	0%
Say's Phoebe*	13	8	0	0	-	-
Sharp-tailed Grouse*	1	0	0	0	-	-
Song Sparrow	28	1	44,342	43,974	0%	0%
Sora*	0	1	0	0	-	-
Spotted Sandpiper*	0	2	-	-	-	-
Spotted Towhee	1,884	2,435	35,327	32,633	5%	7%
Swainson's Thrush	3	25	15,753	16,135	0%	0%
Townsend's Solitaire	0	6	5,923	10,432	0%	0%
Tree Swallow	2	36	10,450	21,673	0%	0%
Turkey Vulture	16	18	1,212	1,138	1%	2%
Upland Sandpiper*	31	22	0	0	-	-
Vesper Sparrow	88	192	10,170	6,365	1%	3%
Violet-green Swallow	55	100	26,035	44,249	0%	0%

Species	Black Hills GPAs		Black Hills NF		% of BHNF Pop.	
	N		N			
	2019	2020	2019	2020	2019	2020
Warbling Vireo	46	51	92,810	87,092	0%	0%
Western Grebe*	0	0	0	0	-	-
Western Kingbird	97	73	2,749	0	4%	-
Western Meadowlark	1,114	597	6,937	9,587	16%	6%
Western Tanager	225	553	55,182	58,699	0%	1%
Western Wood-Pewee	454	632	81,016	116,497	1%	1%
White-breasted Nuthatch	184	288	25,732	58,133	1%	0%
White-throated Swift	8	6	14,392	0	0%	-
Wild Turkey	24	3	91	56	27%	5%
Willow Flycatcher	17	0	0	8,557	-	0%
Wood Duck*	5	0	-	-	-	-
Yellow Warbler	138	152	3,224	1,047	4%	15%
Yellow-billed Cuckoo	2	5	0	0	-	-
Yellow-breasted Chat	198	275	299	136	66%	202%
Yellow-headed Blackbird	0	6	0	0	-	-
Yellow-rumped Warbler	131	406	216,379	169,190	0%	0%

Species for which we did not produce a population size estimate in BHNF, or the estimate was zero in both 2019 and 2020

Analysis of Bird Response to Management Practices

Timber Treatments
We produced post-stratified density estimates for 14 ponderosa pine specialist bird species detected on northern Black Hills GPAs and calculated the difference in estimated density between the control (unlogged) and treatment strata (Table 3). Comparisons were made only between points recorded as ponderosa pine (92) for the primary habitat.

Table 3. Density estimates (birds/km^2) for control and treatment (logged) strata with effect size and 90% credible intervals shown in parenthesis. An asterisk indicates species that have a significant difference in density between treatment and control strata.

Species	Treatment (LCI, UCI)	Control (LCI, UCI)	Effect (LCI, UCI)
Cordilleran Flycatcher	13.71 (10.02, 18.99)	14.07 (10.4, 19.58)	-0.19 (-6.84, 5.84)
Pine Siskin	12.66 (8.97, 40.78)	5.14 (3.06, 17.96)	7.59 (2.5, 22.99)
Plumbeous Vireo	6.73 (4.97, 9.36)	11.19 (8.48, 14.59)	-4.13 (-8.09, -0.34)
Red-breasted Nuthatch	39.55 (33.78, 49.68)	40.63 (33.56, 50.73)	-0.79 (-10.46, 8.64)
Red Crossbill	28.85 (21.16, 229.19)	16.2 (10.58, 122.03)	14.04 (4.93, 94.54)
Western Tanager	16.27 (12.97, 19.57)	13.01 (9.95, 16.58)	3.29 (-1.66, 8.17)
Western Wood-Pewee*	21.02 (17.93, 25.22)	12.15 (9.75, 15.27)	8.98 (4.81, 13.46)
Yellow-rumped Warbler	9.7 (6.47, 14.32)	9.64 (6.43, 15)	-0.26 (-6.25, 5.03)
Chipping Sparrow*	71.91 (59.69, 91.66)	44.79 (35.67, 58.7)	27.3 (12.11, 46.16)
House Wren	6.41 (4.04, 9.5)	12.95 (9.37, 18.46)	-6.6 (-12.37, -2.18)
Northern Flicker*	0.5 (0.19, 1.07)	1.96 (1.16, 3.22)	-1.43 (-2.78, -0.44)
Ovenbird	25.86 (21.46, 30.62)	32.2 (27.42, 38.6)	-6.49 (-13.11, -0.04)

White-breasted Nuthatch	7.95 (5.97, 12.54)	6.92 (4.94, 11.13)	0.86 (-2.4, 4.84)
Wild Turkey	0.27 (0.11, 0.58)	0.62 (0.35, 1.22)	-0.37 (-0.87, 0.01)

Grazing Treatments

We produced post-stratified density estimates for four grassland specialist bird species detected on the southern Black Hills GPAs and calculated the difference in estimated density between control (ungrazed) and treatment (grazed) strata (Table 4). Comparisons were made only between points classified as grassland (225) for the primary habitat.

Table 4. Density estimates (birds/km^2) for control and treatment (grazed) strata with effect size. An asterisk indicates species that have a significant difference in density between treatment and control strata.

Species	Treatment (LCI, UCI)	Control (LCI, UCI)	Effect (LCI, UCI)
Dickcissel*	14.73 (12.93, 17.21)	0 (0, 0.07)	14.73 (12.85, 17.21)
Grasshopper Sparrow*	92.47 (85.58, 98.88)	42 (37.58, 46.93)	50.6 (41.95, 57.98)
Upland Sandpiper*	1.53 (1.18, 2.12)	0.08 (0.03, 0.21)	1.43 (1.08, 2.05)
Western Meadowlark*	31.48 (29.91, 33.58)	19.85 (18.59, 21.38)	11.69 (9.77, 14.11)

Discussion

We found that the Black Hills GPAs made measurable contributions to regional populations for several non-game bird species. Grasshopper Sparrow and Western Meadowlark are of particular note as grassland specialists and given recent evidence of grassland bird declines (Rosenberg et al. 2019). Evident in these comparisons is the habitat value of SDGFP-managed lands within the Black Hills National Forest, providing significant forage, nesting, and sheltering opportunities for a wide array of bird species (Table 2).

We found that bird response to management treatments varied considerably between species and management type. The greatest variability occurred between the two timber strata (unlogged and logged), where some ponderosa pine specialist species responded positively and some negatively to the treatment. Conversely, all grassland-specialist species responded positively to the grazing treatment.

Western Wood-pewee *(Contopus sordidulus)* responded positively to thinning treatments, and may benefit from reduction in stand density as well as sapling and shrub cover if tall, mature trees are maintained (Latif and Pavlacky Jr. 2020). Chipping Sparrow *(Spizella passerina)* responded positively to timber thinning, and may have benefited from reduction in stand density and heterogeneity, given their preference for more open forest, edge habitat, and deciduous vegetation (Latif and Pavlacky Jr. 2020). Northern Flicker *(Colaptes auratus)* responded negatively to the timber treatments, possibly reflecting removal of snags and reduced stand density (Latif and Pavlacky Jr. 2020), which may reduce available nesting and foraging opportunities.

While we were able to assess impacts for fewer grassland species in the grazing strata, all responded positively to the treatment to varying degrees. Dickcissel *(Spiza americana)* and Grasshopper Sparrow have previously shown preference for conservatively grazed grasslands (Pavlacky et al. 2019) and responded positively to grazing treatments on southern Black Hills GPAs. Western Meadowlark's preference for lower grass heights and reduced herbaceous cover was likely reflected in the positive relationship to the grazing treatments (Pavlacky et al.

2019). Upland Sandpiper *(Bartramia longicauda)* likewise showed a positive response to grazing treatments, consistent with previous analyses (Grigaltchik et al. 2018).

This study was largely limited by the duration of monitoring given that many bird species exhibit site fidelity during the breeding season (Gauthreaux, 1982). However, by leveraging detections from the larger IMBCR program, we were able to estimate population densities for more species than through a stand-alone monitoring project. To better assess the contributions of GPAs to regional bird populations, as well as avian response to management treatments, we recommend longer term monitoring across several breeding seasons. In addition, the development of bird-habitat relationships would allow us to better understand the mechanisms behind avian response to treatments, and thus inform the adaptive management of GPAs for non-game bird species. Adaptive management of avian populations overall could be further informed by developing community models to determine species richness and diversity in response to timber thinning and grazing treatments.

Literature Cited

Bird Studies Canada and NABCI. 2021. Bird Conservation Regions. Bird Conservation Regions. <https://www.birdscanada.org/bird-science/nabci-bird-conservation-regions/>. Accessed 21 Sep 2021.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK.

Correll, M. D., E. H. Strasser, A. W. Green, and A. O. Panjabi. 2019. Quantifying specialist avifaunal decline in grassland birds of the Northern Great Plains. Ecosphere 10. Wiley-Blackwell.

Drilling, N. E., R. A. Sparks, B. J. Woiderski, and J. P. Beason. 2016. South Dakota Breeding Bird Atlas II: Final Report. Brighton, Colorado, USA.

Environmental Systems Research Institute. 2017. ArcGIS, version 10.X. Environmental Systems Research Institute, Incorporated, Redlands, California.

Gauthreaux, S. A. 1982. The ecology and evolution of avian migration systems. In Avian biology, Vol. VI, ed. D. S Farner and J. R. King. Academic Press, New York, pp. 93-168.

Green, A. W., D. C. Pavlacky, and T. L. George. 2019. A dynamic multi-scale occupancy model to estimate temporal dynamics and hierarchical habitat use for nomadic species. Ecology and Evolution 9:793–803.

Grigaltchik, V., J. Timmer, and A. M. Dwyer. 2018. Avian Monitoring Report for Range Monitoring Group.

Hanni, D., C. White, R. Sparks, J. Blakesley, J. Birek, N. van Lanen, J. Fogg, J. Berven, and M. McLaren. 2012. Integrated Monitoring in Bird Conservation Regions (IMBCR): Field protocol for spatially balanced sampling of landbird populations. Unpublished report. Bird Conservancy of the Rockies, Brighton, Colorado, USA.

Hooten, M. B., and N. T. Hobbs. 2015. Bayesian models: a statistical primer for ecologists. Princeton University Press, Princeton, New Jersey, USA.

Latif, Q. F., and D. C. Pavlacky Jr. 2020. Avian multi-scale habitat relationships for the Four-Forest Restoration Initiative: Final report.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier.

Mordecai, R. S., B. J. Mattsson, C. J. Tzilkowski, and R. J. Cooper. 2011. Addressing challenges when studying mobile or episodic species: Hierarchical Bayes estimation of occupancy and use. Journal of Applied Ecology 48:56–66.

Nichols, J. D., L. L. Bailey, A. F. O'Connell, N. W. Talancy, E. H. C. Grant, A. T. Gilbert, and A. T. Hines. 2008. Multi-scale occupancy estimation using multiple detection methods. Journal of Applied Ecology 45:1321–1329.

Pavlacky, D. C., J. A. Blakesley, G. C. White, D. J. Hanni, and P. M. Lukacs. 2012. Hierarchical multi-scale occupancy estimation for monitoring wildlife populations. Journal of Wildlife Management 76:154–162.

Pavlacky, D. C., B. B. Woiderski, R. A. Sparks, A. van Boer, and A. W. Green. 2019. Effectiveness Monitoring of the Lesser Prairie-Chicken Initiative and Conservation Reserve Program for Managing the Biodiversity and Population Size of Grassland Birds. <www.birdconservancy.org>.

Pollock, K. H. 1982. A capture-recapture design robust to unequal probability of capture. Journal of Wildlife Management 46:752–757.

Rosenberg K.V., A.M. Dokter, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J.C. Stanton, A.O. Panjabi, L. Helft, M. Parr, and P.P. Marra. 2019. Decline of the North American Avifauna. Science 366:120-124. DOI: 10.1126/science.aaw1313

Royle, J. A., D. K. Dawson, and S. Bates. 2004. Modeling abundance effects in distance sampling. Ecology 85:1591–1597.

Sillet, T. S., R. B. Chandler, J. A. Royle, M. Kéry, and S. A. Morrison. 2012. HIerarchical distance-sampling models to estimate population size and habitat-specific abundance of an island endemic. Ecological Applications 22:1997–2006.

South Dakota Game, F. and P. 2014. South Dakota Wildlife Action Plan.

Stevens, D. L., and A. R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. Journal of the American Statistical Association 99:262–278.

Watanabe, S. 2010. Asymptotic equivalence of Bayes cross validation and widely applicable information criterion in singular learning theory. Journal of Machine Learning Research 2010:3571–3594.

Appendix A: Area Searches of Game Production Areas

In addition to the breeding bird surveys, we also conducted area searches on 16 Region 1 GPAs between 2019 and 2020 using a protocol based on the South Dakota Breeding Bird Atlas II (SDBBA2) (Drilling et al. 2016). This involved surveying all habitats within the GPA for bird presence and evidence of breeding between mid-April and mid-July. Each GPA was surveyed at least twice over two breeding seasons, and receive a minimum effort of 10 hours per GPA. During each visit, technicians documented all breeding birds observed, categorizing each observation as *Possible* breeding, *Probable* breeding, or *Confirmed* breeding, based upon a series of standardized breeding behavior criteria developed during the SDBBA2 (Drilling et al. 2016).

Area search results

GPA	County	Visits	Visit Dates	Number of Species	Number Confirmed Breeding	Number Probable or Possible Breeding
Cooper	Custer	1	7/11/2020	32	3	29
Coxes Lake	Lawrence	1	7/10/2020	44	7	32
Little White River	Bennett	1	6/13/2019	16	1	14
Mallula	Harding	1	7/2/2019	32	9	22
Mirror Lakes	Lawrence	2	7/10/2019, 7/11/2019	55	11	35
Newell Lake	Butte	1	6/5/2019	33	0	28
Oral	Fall River	1	6/12/2019	28	5	22
Orman Dam	Butte	2	6/5/2019, 6/17/2019	28	4	20
Owen Lake	Perkins	2	6/1/2019, 7/1/2019	41	4	33
Pleasant Valley	Custer	1	6/26/2019	13	5	6
Scherbarth	Fall River	1	2/4/1900	35	8	25
Shadehill	Perkins	4	6/2/2019, 6/10/2019, 6/16/2019, 6/17/2019	67	12	47
Sorum Dam	Perkins	3	6/1/2019, 6/10/2019, 7/6/2019	40	5	31
Spring Creek	Pennington	1	6/22/2019	26	1	24
Spring Valley	Custer	2	6/25/2019, 6/26/2019	34	11	23
Todd	Bennett	1	6/13/2019	38	4	33

Appendix B: Density Estimates

Density estimates (D; birds/km^2) and %CV (percent coefficient of variation) for 118 bird species detected within the Black Hills GPAs. An asterisk indicates a SOGCN.

Species	Timber Control				Timber Treatment				Grazing Control				Grazing Treatment			
	2019		2020		2019		2020		2019		2020		2019		2020	
	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV
American Crow	1.32	48	0.81	51	1.02	47	1.31	48	0.14	66	0.20	45	0.28	45	0.66	45
American Goldfinch	23.21	53	14.40	60	14.82	48	10.48	55	30.52	50	20.64	49	10.88	49	9.00	49
American Kestrel	0.27	91	0.50	64	0.00	283	0.18	91	0.30	53	0.47	40	0.65	39	0.34	51
American Redstart	6.51	59	3.08	66	21.04	41	3.78	60	0.00	430	0.25	81	0.00	357	0.35	93
American Robin	26.65	21	22.72	22	31.46	19	22.79	24	6.53	23	10.15	19	5.27	22	9.23	22
American White Pelican*	-	-	-	-	-	-	-	-	0.00	462	0.02	210	-	-	-	-
Baltimore Oriole	-	-	-	-	-	-	-	-	0.37	88	0.00	208	-	-	-	-
Bank Swallow	-	-	-	-	-	-	-	-	0.70	188	0.00	435	-	-	-	-
Barn Swallow	0.00	247	1.56	162	-	-	-	-	-	-	-	-	0.00	306	0.53	161
Black-and-white Warbler	0.40	131	5.78	42	2.52	52	3.90	44	-	-	-	-	-	-	-	-
Black-backed Woodpecker*	1.15	84	0.00	360	-	-	-	-	-	-	-	-	-	-	-	-
Black-billed Magpie	1.15	73	1.22	55	0.27	70	0.18	78	1.56	53	1.81	54	2.03	50	1.40	49
Black-capped Chickadee	28.26	20	58.74	19	31.46	22	63.49	20	14.97	22	25.04	22	11.15	21	19.98	23
Black-headed Grosbeak	16.34	17	21.64	18	23.15	16	14.35	22	2.07	27	2.31	25	1.31	29	0.77	42
Blue Grosbeak	-	-	-	-	-	-	-	-	0.00	431	0.08	86	0.00	516	0.11	95
Blue Jay	4.39	49	8.71	54	4.83	49	5.69	54	1.05	63	1.29	53	0.09	127	0.22	73
Blue-gray Gnatcatcher	-	-	-	-	-	-	-	-	16.35	29	7.01	29	2.57	50	1.03	65
Bobolink	0.00	472	0.46	91	-	-	-	-	0.00	605	0.11	88	-	-	-	-
Brewer's Blackbird	1.04	146	0.00	421	-	-	-	-	0.20	172	1.79	104	0.85	115	0.86	90
Brown Creeper	-	-	-	-	0.00	369	3.15	79	4.62	46	0.00	154	1.44	65	6.65	40
Brown Thrasher	-	-	-	-	-	-	-	-	0.74	44	0.52	47	1.14	36	0.41	54
Brown-headed Cowbird	43.11	75	26.48	78	46.75	75	26.50	77	39.10	74	15.39	75	17.50	77	10.27	70
Bullock's Oriole	-	-	-	-	-	-	-	-	10.62	34	10.03	35	-	-	-	-
Canada Goose	-	-	-	-	-	-	-	-	0.55	168	0.25	166	0.00	459	0.02	286
Canada Jay	-	-	-	-	-	-	-	-	-	-	-	-	0.00	305	0.39	105
Canyon Wren	0.13	91	0.00	362	0.00	385	0.14	85	0.29	42	0.72	24	0.27	39	0.34	36

Species	Timber Control 2019 D	%CV	2020 D	%CV	Timber Treatment 2019 D	%CV	2020 D	%CV	Grazing Control 2019 D	%CV	2020 D	%CV	Grazing Treatment 2019 D	%CV	2020 D	%CV
Cedar Waxwing	13.30	147	15.47	131	18.75	143	15.62	135	21.76	149	7.99	143	14.67	142	6.98	141
Chipping Sparrow	54.35	25	27.04	28	86.96	24	35.12	30	18.40	27	17.90	26	28.58	24	18.66	27
Clay-colored Sparrow	-	-	-	-	-	-	-	-	0.00	484	0.18	88	-	-	-	-
Cliff Swallow	-	-	-	-	0.00	352	1.38	398	0.00	398	0.32	260	-	-	-	-
Common Grackle	14.43	118	10.74	122	4.09	126	4.82	122	4.58	116	3.98	112	4.10	122	1.48	149
Common Nighthawk	0.41	63	0.00	228	0.80	44	0.35	66	4.06	19	1.18	24	2.68	24	1.62	24
Common Poorwill	0.12	101	0.00	200	-	-	-	-	0.07	69	0.08	68	0.05	75	0.06	77
Common Yellowthroat	0.70	63	2.15	46	0.31	96	0.00	394	0.08	138	0.82	35	-	-	-	-
Cooper's Hawk	0.00	248	0.75	100	0.08	236	1.58	92	0.32	117	0.00	282	0.27	83	0.32	87
Cordilleran Flycatcher	7.29	30	15.67	22	13.02	22	10.98	25	0.66	66	2.70	25	3.23	25	4.59	23
Dark-eyed Junco	1.91	75	1.96	85	9.69	45	50.15	28	0.58	90	0.00	298	0.42	100	0.00	364
Dickcissel	0.22	123	4.55	30	-	-	-	-	0.00	439	0.11	78	2.77	27	19.26	11
Downy Woodpecker	-	-	-	-	1.27	83	1.15	84	0.00	223	0.26	88	0.00	199	0.37	93
Dusky Flycatcher	2.68	51	2.74	53	0.00	204	4.03	45	-	-	-	-	1.93	41	0.00	181
Eastern Bluebird	2.93	52	3.64	45	0.75	66	1.35	49	1.89	38	2.69	37	0.69	46	0.88	45
Eastern Kingbird	2.64	51	0.00	175	1.14	72	0.00	236	13.53	37	3.77	39	0.46	61	0.49	60
Eastern Phoebe	-	-	-	-	-	-	-	-	0.00	273	0.25	66	-	-	-	-
Eurasian Collared-Dove	0.33	118	0.00	228	-	-	-	-	1.22	92	1.67	76	0.20	92	1.17	83
European Starling	2.31	184	1.98	284	-	-	-	-	1.60	198	0.70	209	0.16	752	2.48	263
Field Sparrow	1.29	43	0.00	271	0.23	83	0.00	455	2.15	21	3.14	16	3.50	19	5.12	16
Golden-crowned Kinglet	0.00	350	3.79	87	-	-	-	-	-	-	-	-	-	-	-	-
Grasshopper Sparrow	0.00	160	27.80	15	-	-	-	-	27.11	10	23.37	9	59.36	6	57.57	6
Gray Catbird	3.11	64	1.77	80	1.24	100	0.00	236	0.63	84	0.43	85	-	-	-	-
Great Blue Heron	-	-	-	-	-	-	-	-	0.00	522	0.03	149	-	-	-	-
Great Crested Flycatcher	-	-	-	-	-	-	-	-	0.00	278	0.11	83	-	-	-	-
Great Horned Owl	-	-	-	-	-	-	-	-	0.01	156	0.06	68	0.03	85	0.00	225
Hairy Woodpecker	2.05	58	1.40	74	1.22	83	9.19	32	0.77	65	1.77	35	1.46	46	0.60	67
House Finch	0.00	372	1.03	155	-	-	-	-	2.59	63	3.16	73	0.00	372	0.35	102
House Wren	4.92	37	20.83	18	6.74	26	6.36	32	15.70	14	14.10	11	26.69	10	17.57	12

Species	Timber Control				Timber Treatment				Grazing Control				Grazing Treatment			
	2019		2020		2019		2020		2019		2020		2019		2020	
	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV
Indigo Bunting	0.00	145	0.89	59	0.00	181	2.57	43	-	-	-	-	1.71	27	0.23	87
Killdeer	-	-	-	-	-	-	-	-	0.12	78	0.33	58	-	-	-	-
Lark Bunting*	-	-	-	-	-	-	-	-	0.00	328	0.19	291	-	-	-	-
Lark Sparrow	1.46	72	8.69	51	0.79	115	7.87	51	56.12	43	39.30	40	24.67	42	8.57	43
Lazuli Bunting	0.00	419	0.64	74	-	-	-	-	9.14	22	11.46	20	3.88	29	9.59	18
Least Flycatcher	-	-	-	-	0.80	90	0.00	443	1.34	48	0.37	77	0.29	96	0.00	351
Lesser Goldfinch	-	-	-	-	-	-	-	-	-	-	-	-	0.00	426	0.50	105
MacGillivray's Warbler	1.21	87	0.00	441	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	0.28	167	0.00	406	-	-	-	-	0.03	244	0.34	113	-	-	-	-
Mountain Bluebird	0.00	260	1.26	68	0.00	433	0.56	88	0.12	155	1.17	55	3.96	50	1.09	62
Mourning Dove	6.64	40	4.22	43	4.26	37	4.98	36	16.63	33	10.71	34	9.59	35	6.36	35
Northern Cardinal	-	-	-	-	0.00	325	0.36	74	-	-	-	-	-	-	-	-
Northern Flicker	1.56	36	3.28	24	0.62	57	0.84	50	2.81	21	2.33	18	1.99	21	1.45	24
Northern Rough-winged Swallow	-	-	-	-	-	-	-	-	0.87	238	0.57	295	0.76	227	1.49	166
Olive-sided Flycatcher	-	-	-	-	-	-	-	-	0.00	463	0.06	86	-	-	-	-
Orchard Oriole	0.93	104	0.00	240	-	-	-	-	6.21	39	6.73	31	0.31	100	0.00	206
Osprey*	-	-	-	-	-	-	-	-	0.00	409	0.03	100	-	-	-	-
Ovenbird	24.97	12	28.95	12	28.19	11	27.60	14	0.00	547	0.11	80	0.93	33	2.15	26
Pine Siskin	3.64	106	5.97	128	13.16	112	13.28	124	2.31	119	1.62	106	1.91	116	2.62	120
Plumbeous Vireo	2.02	56	13.65	17	4.69	29	8.26	23	3.47	23	1.70	23	1.99	26	2.69	23
Prairie Falcon	-	-	-	-	-	-	-	-	-	-	-	-	0.06	109	0.00	218
Pygmy Nuthatch	-	-	-	-	-	-	-	-	1.24	76	3.28	53	4.48	53	6.09	52
Red Crossbill	6.10	176	28.49	165	11.12	152	39.89	150	4.18	157	11.51	148	17.35	153	14.85	146
Red-breasted Nuthatch	24.63	22	42.59	22	22.83	21	56.52	21	3.31	28	9.33	22	5.62	26	10.65	22
Red-eyed Vireo	2.45	45	6.02	29	7.00	30	5.01	30	0.00	428	0.12	79	2.09	30	1.03	37
Red-headed Woodpecker	0.24	72	0.25	81	0.43	63	0.00	162	1.10	30	1.18	25	0.24	53	0.06	112
Red-naped Sapsucker	-	-	-	-	0.00	304	2.23	62	-	-	-	-	-	-	-	-
Red-tailed Hawk	0.32	62	1.11	41	-	-	-	-	1.20	32	0.90	33	0.10	67	0.10	62
Red-winged Blackbird	0.27	98	0.00	358	-	-	-	-	5.02	80	4.27	80	0.63	83	2.78	75

Species	Timber Control				Timber Treatment				Grazing Control				Grazing Treatment			
	2019		2020		2019		2020		2019		2020		2019		2020	
	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV
Ring-necked Pheasant	-	-	-	-	-	-	-	-	0.15	37	0.12	32	0.03	73	0.22	29
Rock Pigeon	2.81	176	3.07	165	0.52	214	2.02	176	0.00	315	0.16	207	-	-	-	-
Rock Wren	0.00	414	0.19	75	-	-	-	-	1.10	23	5.36	13	0.96	24	0.95	26
Ruby-crowned Kinglet	0.00	381	0.67	76	-	-	-	-	-	-	-	-	0.22	79	0.00	437
Savannah Sparrow	-	-	-	-	-	-	-	-	-	-	-	-	4.71	34	0.00	168
Say's Phoebe	-	-	-	-	-	-	-	-	0.72	63	0.35	65	0.00	427	0.07	96
Sharp-tailed Grouse	-	-	-	-	-	-	-	-	0.06	167	0.00	390	-	-	-	-
Song Sparrow	-	-	-	-	-	-	-	-	1.29	45	0.05	142	0.22	86	0.00	422
Sora	-	-	-	-	-	-	-	-	0.00	299	0.04	92	-	-	-	-
Spotted Sandpiper	-	-	-	-	-	-	-	-	0.00	277	0.11	93	-	-	-	-
Spotted Towhee	32.75	12	52.12	9	38.67	11	70.85	8	32.48	8	45.29	6	31.37	8	30.55	7
Squirrel, Red	23.17	31	16.95	33	21.89	25	27.80	29	0.00	162	0.98	66	3.04	49	3.25	40
Swainson's Thrush	0.00	360	0.58	89	0.76	69	3.95	37	0.00	512	0.14	89	-	-	-	-
Townsend's Solitaire	-	-	-	-	0.00	346	0.49	77	-	-	-	-	0.00	408	0.16	79
Tree Swallow	0.00	276	1.73	187	-	-	-	-	0.10	239	0.94	174	-	-	-	-
Turkey Vulture	0.10	167	0.00	255	0.77	151	0.36	155	0.41	118	0.92	111	0.21	132	0.06	165
Upland Sandpiper	-	-	-	-	-	-	-	-	0.11	60	0.00	231	1.18	26	0.89	25
Vesper Sparrow	6.19	21	14.45	15	0.76	47	1.37	44	0.00	546	0.11	76	0.70	32	1.04	31
Violet-green Swallow	0.00	520	1.38	225	0.00	357	1.57	223	1.22	311	2.66	172	1.33	201	1.26	260
Warbling Vireo	2.59	41	2.28	42	4.31	32	1.20	65	0.00	181	1.19	32	-	-	-	-
Western Grebe	-	-	-	-	-	-	-	-	0.00	352	0.02	147	-	-	-	-
Western Kingbird	0.00	362	0.48	106	-	-	-	-	5.18	41	3.78	39	0.15	96	0.00	434
Western Meadowlark	3.15	30	2.31	29	0.36	53	0.00	421	19.33	16	14.25	18	29.20	17	12.64	18
Western Tanager	2.73	53	20.53	23	6.43	33	22.56	23	2.47	28	2.85	28	4.98	23	7.44	20
Western Wood-Pewee	9.20	17	9.87	19	14.49	13	24.30	12	7.62	12	10.55	9	6.33	13	9.43	12
White-breasted Nuthatch	4.71	43	12.46	36	5.96	43	11.83	32	3.31	38	2.81	37	1.93	41	2.12	43
White-throated Swift	0.00	492	0.57	197	1.00	148	0.00	487	-	-	-	-	0.15	212	0.00	666
Wild Turkey	1.01	152	0.00	233	0.33	143	0.00	269	0.42	121	0.15	114	0.17	142	0.02	233
Willow Flycatcher	-	-	-	-	-	-	-	-	-	-	-	-	0.68	69	0.00	222

Species	Timber Control				Timber Treatment				Grazing Control				Grazing Treatment			
	2019		2020		2019		2020		2019		2020		2019		2020	
	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV	D	%CV
Wood Duck	-	-	-	-	1.25	140	0.00	238	-	-	-	-	-	-	-	-
Yellow Warbler	-	-	-	-	1.40	62	0.00	254	5.26	21	6.53	17	1.48	37	1.41	43
Yellow-billed Cuckoo	-	-	-	-	-	-	-	-	0.08	95	0.25	41	-	-	-	-
Yellow-breasted Chat	0.00	183	1.26	43	0.00	375	0.24	85	6.08	15	7.31	10	3.57	15	5.10	14
Yellow-headed Blackbird	-	-	-	-	-	-	-	-	0.00	832	0.31	821	-	-	-	-
Yellow-rumped Warbler	0.64	118	11.76	26	2.28	60	13.74	23	0.86	50	0.63	48	3.98	23	8.45	18

Appendix C: Occupancy Estimates

Occupancy Analysis

Occupancy estimation is most commonly used to quantify the proportion of sample units (i.e., 1 km² cells) occupied by an organism (MacKenzie et al. 2002). The application of occupancy modeling requires multiple surveys of the sample unit in space or time to estimate a detection probability (MacKenzie et al. 2006). The detection probability adjusts the proportion of sites occupied to account for species that were present but undetected (MacKenzie et al. 2002). We used a removal design (MacKenzie et al. 2006), to estimate a detection probability for each species, in which we binned minutes one and two, minutes three and four and minutes five and six to meet the assumption of a monotonic decline in the detection rates through time. After the target species was detected at a point, we set all subsequent sampling intervals at that point to "missing data" (MacKenzie et al. 2006).

The 16 points in each sampling unit served as spatial replicates for estimating the proportion of points occupied within the sampled sampling units. We used a Bayesian, multi-scale occupancy model (Nichols et al. 2008, Mordecai et al. 2011, Green et al. 2019) to estimate 1) the probability of detecting a species given presence (p), 2) the proportion of points occupied by a species given presence within sampled sampling units (θ, Theta) and 3) the proportion of sampling units occupied by a species (ψ, Psi).

We truncated the data, using only detections <125 m from the sample points, except for Accipitriformes, Anseriformes, Falconiformes, Galliformes, Gruiformes, Pelecaniformes, Podicepidiformes, and Suliformes for which we used the maximum observed distance for each species. Truncating the data allowed us to use bird detections over a consistent plot size and ensured that the points were independent (points were spread 250 m apart), which in turn allowed us to estimate θ (the proportion of points occupied within each sampling unit) (Pavlacky et al. 2012). The interpretation of θ for species for which we used maximum distances changes from occupancy to use because point count buffers overlap, but we chose this approach to provide estimates for a larger number of species.

We expected regional differences in the behavior, habitat use, and local abundance of species would correspond to regional variation in detection and the fraction of occupied points. Therefore, we estimated the proportion of sampling units occupied (ψ) for each stratum by estimating BCR-by-year specific estimates of detection (p) and point-level occupancy (θ). We fixed p and θ to 0 for BCRs in which a particular species was never detected.

We fixed ψ to 0 for strata in which the species was never detected. The true point-level occupancy state was conditional on the grid-cell-level occupancy state (i.e., occupied or unoccupied), such that a point could only be occupied if the grid cell was occupied. Finally, we modeled the observation process conditional on the point being occupied using removal modeling.

Our application of the multi-scale model was analogous to a within-season robust design (Pollock 1982) where the two-minute intervals at each point were the secondary samples for estimating p and the points were the primary samples for estimating θ (Nichols et al. 2008, Pavlacky et al. 2012). We considered both p and θ to be nuisance variables that were important for generating unbiased estimates of ψ. θ can be considered an availability parameter or the probability a species was present and available for sampling at the points (Nichols et al. 2008, Pavlacky et al. 2012).

We produced occupancy estimates for a total of 115 bird species that were detected on the northern and southern Black Hills GPAs in either 2019 or 2020, and also for Red Squirrel:

Species	SD-GFP-CO				SD-GFP-GR				SD-GFP-HI				SD-GFP-LO			
	2019		2020		2019		2020		2019		2020		2019		2020	
	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV
American Crow	0.869	20	0.791	34	0.204	74	0.321	61	-	-	-	-	-	-	0.559	51
American Goldfinch	0.971	5	0.946	11	0.752	16	0.652	21	0.98	4	0.977	4	0.951	7	0.873	20
American Kestrel	0.745	39	0.772	33	0.863	18	0.801	26	0.819	24	0.813	23	-	-	0.324	85
American Redstart	0.502	38	0.326	57	-	-	0.064	96	-	-	0.062	91	0.822	16	0.32	79
American Robin	0.988	3	0.989	2	0.415	34	0.739	16	0.788	16	0.885	9	0.988	3	0.99	2
American White Pelican	-	-	-	-	-	-	-	-	-	-	0.143	90	-	-	-	-
Baltimore Oriole	-	-	-	-	-	-	-	-	0.164	112	-	-	-	-	-	-
Barn Swallow	-	-	0.228	97	-	-	0.098	97	-	-	-	-	-	-	-	-
Black-and-white Warbler	-	-	0.373	55	-	-	-	-	-	-	-	-	0.362	63	0.361	61
Black-backed Woodpecker	0.721	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black-billed Magpie	0.455	61	0.438	68	0.129	78	0.141	81	0.416	47	0.619	29	0.152	101	-	-
Black-capped Chickadee	0.984	4	0.989	2	0.851	12	0.8	14	0.989	3	0.991	2	0.99	2	0.993	2
Black-headed Grosbeak	0.976	6	0.985	3	0.498	32	0.26	53	0.624	29	0.579	29	0.989	2	0.987	3
Blue Grosbeak	-	-	-	-	-	-	-	-	-	-	0.101	95	-	-	-	-
Blue Jay	0.971	6	0.977	5	-	-	0.078	97	-	-	0.289	45	0.947	10	0.941	11
Blue-gray Gnatcatcher	-	-	-	-	0.232	53	0.267	47	0.741	23	0.526	28	-	-	-	-
Bobolink	-	-	-	-	-	-	-	-	-	-	0.053	89	-	-	-	-
Brewer's Blackbird	0.136	103	-	-	0.114	80	0.099	79	-	-	0.275	44	-	-	-	-
Brown Creeper	-	-	-	-	0.197	67	0.471	38	0.158	81	0.11	77	-	-	0.172	99
Brown Thrasher	-	-	-	-	0.288	57	0.277	59	0.375	43	0.361	44	-	-	-	-
Brown-headed Cowbird	0.978	4	0.941	10	0.939	7	0.719	16	0.936	7	0.832	11	0.992	1	0.981	5
Bullock's Oriole	-	-	-	-	-	-	-	-	0.863	17	0.907	12	-	-	-	-
Canada Goose	-	-	-	-	-	-	0.084	101	0.437	41	0.315	46	-	-	-	-
Canada Jay	-	-	-	-	-	-	0.097	101	-	-	-	-	-	-	-	-
Canyon Wren	-	-	-	-	0.69	43	0.671	44	-	-	0.866	19	-	-	-	-
Cedar Waxwing	0.817	27	0.918	12	0.93	10	0.854	21	0.684	27	0.678	28	0.897	17	0.927	12
Chipping Sparrow	0.981	3	0.951	10	0.624	21	0.579	21	0.641	23	0.612	19	0.987	2	0.979	4
Clay-colored Sparrow	-	-	-	-	-	-	-	-	-	-	0.059	94	-	-	-	-
Cliff Swallow	-	-	-	-	-	-	-	-	-	-	0.063	95	-	-	0.111	102
Common Grackle	0.942	11	0.936	13	0.407	40	0.166	70	0.469	40	0.373	38	0.507	58	0.563	52
Common Nighthawk	0.716	40	-	-	0.87	20	0.917	13	0.865	21	0.854	23	0.639	50	0.693	43
Common Poorwill	-	-	-	-	-	-	-	-	-	-	0.927	16	-	-	-	-
Common Yellowthroat	0.223	84	0.251	83	-	-	-	-	-	-	0.236	54	0.141	99	-	-
Cooper's Hawk	-	-	0.862	29	0.887	25	0.872	27	0.867	27	-	-	-	-	0.945	14
Cordilleran Flycatcher	0.838	24	0.905	14	0.397	38	0.305	44	0.205	65	0.358	36	0.963	7	0.94	12
Dark-eyed Junco	0.085	85	0.07	83	0.067	97	-	-	0.089	98	-	-	0.216	60	0.704	22
Dickcissel	-	-	0.329	44	-	-	0.655	19	-	-	0.065	91	-	-	-	-

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Species	SD-GFP-CO				SD-GFP-GR				SD-GFP-HI				SD-GFP-LO			
	2019		2020		2019		2020		2019		2020		2019		2020	
	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV	Psi	%CV
Downy Woodpecker	-	-	-	-	-	-	0.145	99	-	-	0.126	97	0.569	57	0.595	54
Dusky Flycatcher	0.226	49	0.225	49	0.099	66	-	-	-	-	-	-	-	-	0.174	58
Eastern Bluebird	0.763	33	0.889	15	0.215	55	0.196	56	0.38	46	0.707	19	0.203	81	0.316	64
Eastern Kingbird	0.303	73	-	-	0.108	60	0.108	60	0.775	17	0.76	18	0.179	66		-
Eastern Phoebe	-	-	-	-	-	-	-	-	-	-	0.48	59	-	-	-	-
Eurasian Collared-Dove	-	-	-	-	0.555	60	0.54	62	-	-	0.555	57	-	-	-	-
European Starling	0.216	86	0.211	85	-	-	0.077	98	0.145	81	0.101	78	-	-	-	-
Field Sparrow	0.117	73	-	-	0.556	24	0.569	22	0.293	48	0.394	30	-	-	-	-
Golden-crowned Kinglet	-	-	0.343	88	-	-	-	-	-	-	-	-	-	-	-	-
Grasshopper Sparrow	-	-	0.248	36	0.664	19	0.779	13	0.64	22	0.662	17	-	-	-	-
Gray Catbird	0.26	101	-	-	-	-	-	-	0.186	81	0.131	81	0.246	97	-	-
Great Blue Heron	-	-	-	-	-	-	-	-	-	-	0.2	97	-	-	0.69	46
Great Horned Owl	-	-	-	-	0.802	33	-	-	-	-	0.771	37	-	-	-	-
Hairy Woodpecker	0.787	31	0.712	42	0.339	60	0.222	77	0.448	61	0.601	35	-	-	0.871	18
House Finch	-	-	0.345	86	-	-	0.136	103	0.387	68	0.652	34	-	-	-	-
House Wren	0.179	58	0.766	19	0.792	14	0.704	16	0.745	17	0.744	14	0.372	35	0.24	46
Indigo Bunting	-	-	0.402	67	0.206	68	-	-	-	-	-	-	-	-	0.389	68
Killdeer	-	-	-	-	-	-	-	-	-	-	0.086	95	-	-	-	-
Lark Bunting	-	-	-	-	-	-	-	-	-	-	0.056	96	-	-	-	-
Lark Sparrow	0.132	75	0.383	43	0.888	10	0.694	18	0.972	6	0.986	3	-	-	0.677	26
Lazuli Bunting	-	-	0.075	105	0.351	40	0.724	18	0.785	19	0.88	10	-	-	-	-
Least Flycatcher	-	-	-	-	0.069	92	-	-	0.121	74	0.1	70	0.081	100	-	-
Lesser Goldfinch	-	-	-	-	-	-	0.691	43	-	-	-	-	-	-	-	-
MacGillivray's Warbler	0.114	109	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallard	0.163	101	-	-	-	-	-	-	0.189	72	0.186	60	-	-	-	-
Mountain Bluebird	-	-	0.258	70	0.284	46	0.205	54	-	-	0.28	45	-	-	0.124	105
Mourning Dove	0.593	31	0.433	43	0.877	11	0.634	21	0.972	5	0.96	6	0.505	42	0.862	14
Northern Cardinal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.152	106
Northern Flicker	0.353	73	0.677	31	0.41	36	0.31	45	0.49	35	0.558	26	0.337	59	0.389	56
Northern Rough-winged Swallow	-	-	-	-	0.175	70	0.277	63	0.18	81	0.136	79	-	-	-	-
Olive-sided Flycatcher	-	-	-	-	-	-	-	-	-	-	0.088	66	-	-	-	-
Orchard Oriole	0.226	96	-	-	0.098	96	-	-	0.313	64	0.592	31	-	-	-	-
Osprey	-	-	-	-	-	-	-	-	-	-	0.211	112	-	-	-	-
Ovenbird	0.984	3	0.985	3	0.206	52	0.271	40	-	-	0.057	93	0.992	1	0.99	2
Pine Siskin	0.386	58	0.531	37	0.311	42	0.271	43	0.276	49	0.24	43	0.889	16	0.897	14
Plumbeous Vireo	0.782	37	0.958	6	0.464	36	0.381	38	0.599	32	0.436	33	0.935	12	0.951	9
Prairie Falcon	-	-	-	-	0.661	52	-	-	-	-	-	-	-	-	-	-
Pygmy Nuthatch	-	-	-	-	0.575	44	0.658	37	0.333	71	0.395	54	-	-	-	-
Red Crossbill	-	-	0.915	8	0.663	20	0.779	14	0.216	62	0.837	11	0.152	57	0.921	8
Red-breasted Nuthatch	0.986	3	0.99	2	0.523	26	0.364	32	0.202	64	0.502	24	0.986	3	0.993	1
Red-eyed Vireo	0.465	59	0.621	36	0.292	45	0.178	53	-	-	-	-	0.811	23	0.769	27
Red-headed Woodpecker	0.153	86	0.168	90	-	-	-	-	0.237	60	0.106	73	-	-	-	-

Species	SD-GFP-CO 2019 Psi	%CV	2020 Psi	%CV	SD-GFP-GR 2019 Psi	%CV	2020 Psi	%CV	SD-GFP-HI 2019 Psi	%CV	2020 Psi	%CV	SD-GFP-LO 2019 Psi	%CV	2020 Psi	%CV
Red-naped Sapsucker	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.083	108
Red-tailed Hawk	0.84	28	0.93	12	0.316	60	0.151	73	0.71	30	0.639	29	-	-	-	-
Red-winged Blackbird	-	-	-	-	-	-	0.129	68	0.675	26	0.394	32	-	-	-	-
Ring-necked Pheasant	-	-	-	-	0.089	82	0.076	79	0.277	48	0.328	33	-	-	-	-
Rock Pigeon	0.889	20	0.891	20	-	-	-	-	-	-	0.149	100	-	-	0.655	43
Rock Wren	-	-	-	-	0.242	51	0.316	39	0.426	46	0.926	7	-	-	-	-
Ruby-crowned Kinglet	-	-	0.057	103	0.07	97	-	-	-	-	-	-	-	-	-	-
Savannah Sparrow	-	-	-	-	0.069	98	-	-	-	-	-	-	-	-	-	-
Say's Phoebe	-	-	-	-	-	-	-	-	0.411	55	0.215	73	-	-	-	-
Sharp-tailed Grouse	-	-	-	-	-	-	-	-	0.089	95	-	-	-	-	-	-
Song Sparrow	-	-	-	-	0.073	96	-	-	0.096	96	-	-	-	-	-	-
Sora	-	-	-	-	-	-	-	-	-	-	0.111	109	-	-	-	-
Spotted Sandpiper	-	-	-	-	-	-	-	-	-	-	0.24	94	-	-	-	-
Spotted Towhee	0.986	3	0.989	2	0.971	4	0.952	5	0.914	9	0.97	4	0.991	2	0.993	1
Squirrel, Red	0.486	34	0.557	34	0.193	53	0.215	46	-	-	0.116	66	0.387	37	0.697	26
Swainson's Thrush	-	-	0.132	107	-	-	-	-	-	-	0.069	87	-	-	0.345	58
Townsend's Solitaire	-	-	-	-	-	-	0.092	100	-	-	-	-	-	-	0.214	100
Tree Swallow	-	-	0.289	86	-	-	-	-	-	-	0.19	69	-	-	-	-
Turkey Vulture	0.337	85	-	-	0.556	38	-	-	0.882	19	0.923	12	0.891	17	0.813	31
Upland Sandpiper	-	-	-	-	0.318	40	0.526	23	0.091	98	-	-	-	-	-	-
Vesper Sparrow	0.772	26	0.881	14	0.18	57	0.149	57	-	-	0.058	94	0.14	62	0.151	62
Violet-green Swallow	-	-	0.228	100	0.169	71	0.235	62	0.3	65	0.581	31	-	-	0.225	101
Warbling Vireo	0.213	59	0.244	62	-	-	-	-	-	-	0.187	53	0.172	66	0.147	78
Western Grebe	-	-	-	-	-	-	-	-	-	-	0.778	38	-	-	-	-
Western Kingbird	-	-	0.244	97	0.101	96	-	-	0.88	18	0.877	17	-	-	-	-
Western Meadowlark	0.143	43	0.164	39	0.618	21	0.543	22	0.927	8	0.768	13	0.024	101	-	-
Western Tanager	0.437	75	0.921	9	0.486	31	0.316	38	0.296	48	0.341	34	0.931	15	0.982	3
Western Wood-Pewee	0.607	34	0.686	25	0.564	25	0.556	22	0.77	17	0.811	12	0.962	8	0.985	3
White-breasted Nuthatch	0.916	15	0.961	7	0.432	36	0.365	37	0.591	30	0.531	25	0.959	8	0.971	5
White-throated Swift	-	-	0.117	108	0.078	96	-	-	-	-	-	-	0.112	101	-	-
Wild Turkey	0.641	38	-	-	0.09	96	-	-	0.88	14	0.619	35	0.293	71	-	-
Willow Flycatcher	-	-	-	-	0.158	61	-	-	-	-	-	-	-	-	-	-
Wood Duck	-	-	-	-	-	-	-	-	-	-	0.479	70	0.54	65	-	-
Yellow Warbler	-	-	-	-	0.112	74	0.143	61	0.293	48	0.347	34	0.068	101	-	-
Yellow-breasted Chat	-	-	0.244	60	0.502	29	0.541	25	0.641	27	0.773	15	-	-	-	-
Yellow-headed Blackbird	-	-	-	-	-	-	-	-	-	-	0.131	98	-	-	-	-
Yellow-rumped Warbler	-	-	0.475	38	0.311	40	0.48	27	0.14	72	0.141	59	0.113	72	0.659	27