Breeding Bird Monitoring in Custer State Park, South Dakota

March 1, 2019

Bird Conservancy of the Rockies
Connecting People, Birds and Land

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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

Custer State Park is the largest state park in South Dakota and contains diverse habitat types at a wide range of elevations. Because of its size and habitat diversity, Custer State Park hosts a diverse assemblage of breeding bird species that likely are important to regional bird populations. Major habitat changes have occurred in the park over the past 10 years as a result of mountain pine beetle infestations, timber harvest and salvage logging, and large fires.

To examine the current state of bird populations in Custer State Park, we conducted breeding bird surveys in summer 2018 using the same sampling design and field protocols as the Integrated Monitoring of Bird Conservation Regions (IMBCR) program. IMBCR uses a spatially balanced sampling design which allows inferences to avian species occurrence and population sizes at various scales, from small management units such as individual parks to entire Bird Conservation Regions (BCRs) or states, facilitating conservation from local to national levels. The sampling design allows for the estimation of density, population size and occupancy for individual strata or biologically meaningful combinations of strata. Because of this, we not only can obtain Custer State Park breeding bird density and population size estimates, but can compare these estimates to larger regions to gain insights into breeding bird dynamics in the park. In addition, these estimates can serve as a baseline to understand bird responses to recent deforestation and the Legion Lake fire as the habitat recovers over the next several years.

We selected sampling units (1 km^2 grid cells) in Custer State Park using generalized random-tessellation stratification (GRTS), a spatially-balanced sampling algorithm. Point count technicians surveyed for landbirds at each of 16 points spaced 250 m apart within each selected grid cell. During each six-minute count, conducted within five hours of sunrise, technicians recorded all birds heard and seen. The point count data then were used to estimate density and population size for each species. First, we estimated the detection probability using distance analysis. The detection probability is used to adjust the count of birds to account for birds that were present but undetected. We fit a detection function to the distribution of recorded distances and then used Watanabe-Akaike's Information Criterion and model selection theory to select the most parsimonious detection function for each species.

Field technicians gathered data in Custer State Park between 21 June and 8 July, 2018, and surveyed 56 points in five grid cells. They detected 821 individuals of 71 species in five general habitat types. Comparing these results to other regional results, 21 species were detected in the Black Hills National Forest in 2018 that were not detected in Custer State Park, while seven species were detected in Custer Park that were not detected in Black Hills National Forest. Thirty-four species were recorded during surveys in the park in 2004-2006 that were not recorded in 2018. In contrast, Cassin's Finch was the only species recorded in 2018 that was not detected during the earlier survey.

Bird Conservancy estimated densities and population sizes for 61 species, with robust density estimates (CV < 50%) for 21 of these. Species with densities greater than 9 birds/km^2 included American Robin, Spotted Towhee, Western Tanager, Western Meadowlark, Black-capped Chickadee, Red Crossbill, Brewer's Blackbird, Brown-headed Cowbird and Chipping Sparrow. A comparison of bird densities to those in all of the Black Hills National Forest and to those in a 2004-2006 park survey suggests that forest habitats in Custer State Park in 2018 are much different than those of the surrounding forest or of historical habitats and currently are less suitable for forest birds. In contrast, grassland and edge-associated species had higher densites in Custer State Park in 2018, suggesting that the park historically and currently has larger

grasslands than the Forest. These results give managers useful information for prioritizing management actions at both local and regional scales.

To view interactive maps illustrating survey and detection locations, species counts, and density, population and occupancy results, please visit Bird Conservancy's Rocky Mountain Avian Data Center at http://rmbo.org/v3/avian/ExploretheData.aspx. Instructions for using the Data Center are available on the Center's website.

The advantages of the IMBCR sampling design and survey protocol utilized in the Custer State Park surveys are as follows:

- The GRTS sampling design and point count monitoring protocol allow for more precise estimates to be generated using detection probability.
- The GRTS approach has the flexibility to generate valid population estimates at scales relevant to land management agencies, as well as support conservation efforts at both local and regional scales.
- Incorporating data collected at small scales to estimate parameters at larger scales allows this design to address the need for large-scale monitoring and research, which has been emphasized in bird conservation initiatives. The region-wide population estimates generated from this data can better assist managers in understanding trends in landbird populations.
- By analyzing data across both the Custer State Park and the BCR 17 sampling frames we can estimate common detection probabilities for species that would have otherwise had an insufficient number of detections for analyses.
- All sample units in the sampling frame are ordered, such that any set of consecutively numbered units is a spatially well-balanced sample. In the case of fluctuating budgets, monitoring partners can adjust the sampling effort among years within each stratum while still preserving a random, spatially-balanced sampling design.
- The IMBCR design allows sampling of all habitats, allowing managers to relate changes in bird populations to landscape changes over time.

The IMBCR program is well positioned to address conservation and management needs for a wide range of stakeholders, landowners and government entities at various spatial scales. By focusing on multiple scales from local management units to BCRs, IMBCR can easily be integrated within an interdisciplinary approach to bird conservation that combines monitoring, research and management. Recently developed habitat analyses and species distribution maps can be used as the basis of decision support tools for avian conservation.

Acknowledgements

Funding for the Custer State Park surveys came from the SDGFP's Wildlife Diversity small grant program. Many individuals helped make the 2018 field season a success. We thank Gary White, professor emeritus of Colorado State University, who wrote the initial SAS code and implemented the multi-scale occupancy model in program MARK and Paul Lukacs of the University of Montana who wrote code in program R to automate data analysis for density and occupancy estimates. We thank Jeff Laake for implementing the multi-scale occupancy model in the RMark package which aided in the automation of the analyses. The Nature Conservancy provided excellent training facilities at the Whitney Preserve in South Dakota for the northern survey team. We also thank the many field technicians who collected avian and vegetation point count data. Finally, this report benefited greatly from review by Matt Smith of Bird Conservancy.

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Introduction

At 71,000 acres, Custer State Park is the largest state park in South Dakota and contains diverse habitat types at a wide range of elevations. Because of its size and habitat diversity, Custer State Park hosts a diverse assemblage of breeding bird species that likely are important to overall bird populations in the region. In the past 20 years, two research groups have conducted bird surveys and estimated bird densities in the park. Schickel (2007) documented 117 breeding bird species in the park from 2004 to 2006 while Panning and colleagues surveyed birds during 2009 – 2011 as part of a timber harvest study (Panning et al. 2013).

Since these surveys were published, major habitat changes have occurred in the park as a result of timber harvest, salvage logging, fires, and mountain pine beetle infestations, especially in the northern and central portions. In December 2017 the Legion Lake fire burned a little more than half of the park, mostly in the south portion (Gabbert 2017). With such widespread forest alteration events, it is likely that bird populations within the park have been affected, some positively and some negatively, which could impact regional bird populations.

To examine the current state of bird populations in Custer State Park, we conducted breeding bird surveys in summer 2018 using the same sampling design and field protocols as the Integrated Monitoring of Bird Conservation Regions (IMBCR) program. We also collected bird data in other parts of the Black Hills, including Wind Cave National Park, Black Hills National Forest, and throughout Bird Conservation Region (BCR) 17 in summer 2018 as part of the IMBCR program. This enables us to not only compare the state park 2018 data to previous park surveys, but also to compare these data to a wider region in the same year.

The objectives of this study were to:

1) Conduct bird surveys and use these data to estimate current densities and population sizes of breeding bird species in Custer State Park.

2) Compare Custer State Park estimates to those of other strata in the region.

3) Establish a baseline for future comparisons that may try to document and understand bird responses to recent deforestation and the Legion Lake fire as the habitat recovers over the next several years.

Methods

Survey grid selection.

Survey grid selection and field protocols used those of the Integrated Monitoring of Bird Conservation Regions (IMBCR) program (Pavlacky et al. 2017). IMBCR uses a spatially balanced sampling design which allows inferences to avian species occurrence and population sizes at various scales, from local management units to entire states or Bird Conservation Regions. The hierarchical (nested) stratification allows for the estimation of density, population size and occupancy for individual strata or biologically meaningful combinations of strata. In this case, we created a stratum for Custer State Park separate from other strata in the state and BCR 17, for which we also collected data in 2018 under the main IMBCR program and funded from other sources.

We developed a grid of potential sampling units (1 km² cells) by superimposing a uniform grid of cells over Custer State Park. We used the United States National Grid (USNG), a nonproprietary alphanumeric referencing system derived from the Military Grid Reference System that was created by the Federal Geographic Data Committee. We then selected ten sampling units using generalized random-tessellation stratification (GRTS), a spatially balanced sampling algorithm (Stevens and Olsen 2004) (Figure 1). Each sampling unit contained 16 evenly-spaced sample points, 250 meters apart (Figure 2).

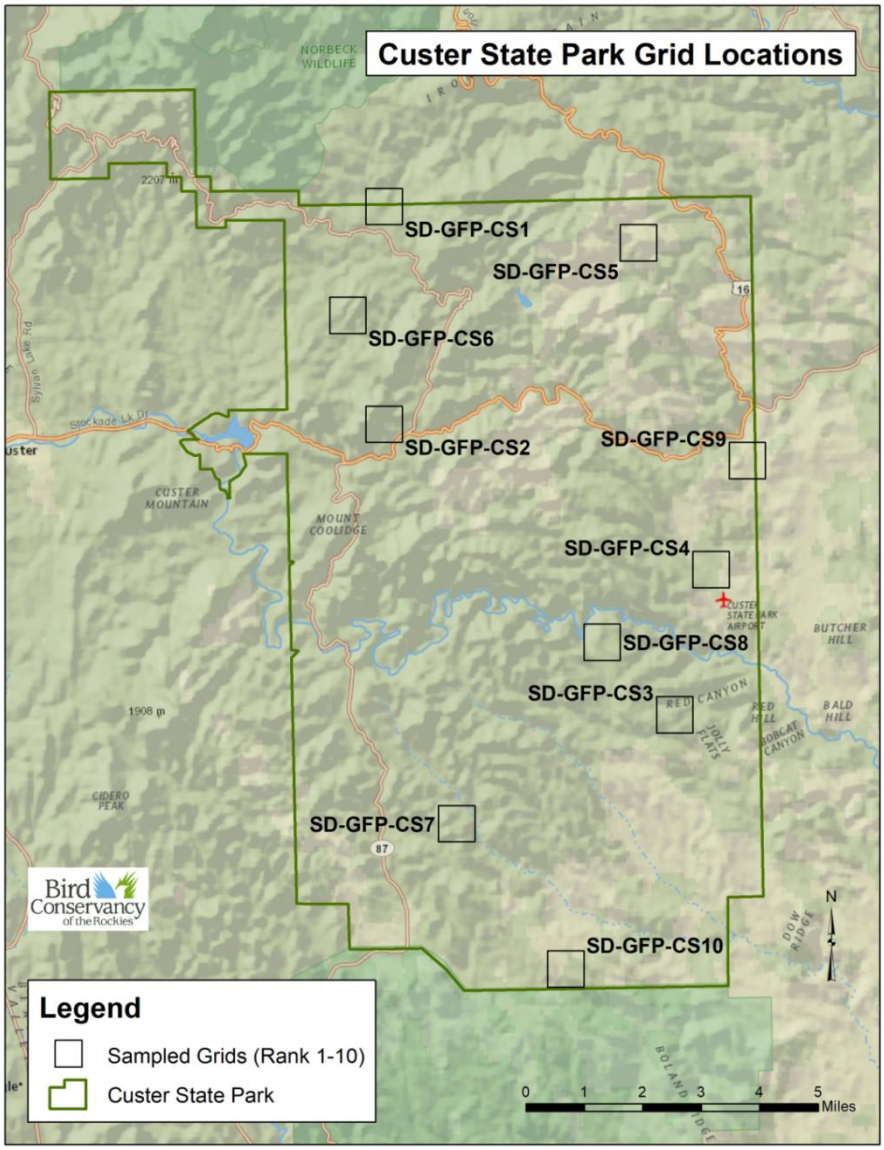

Figure 1. Grids selected for survey in Custer State Park.
Field technicians surveyed birds in grids CS1 through CS5.

Field Methods

Field technicians with excellent aural and visual bird-identification skills conducted point counts at surveyed points within each selected grid cell, following protocols established by IMBCR

partners (Buckland et al. 2001, Hanni et al. 2016). Prior to conducting surveys, technicians completed an intensive training program to ensure full understanding of the field protocol; review bird and plant identification; and practice distance estimation in a variety of habitats. Many field technicians attended a second, shorter mid-season training to review protocol and practice bird and plant identification at high-elevation sites that were surveyed later in the season.

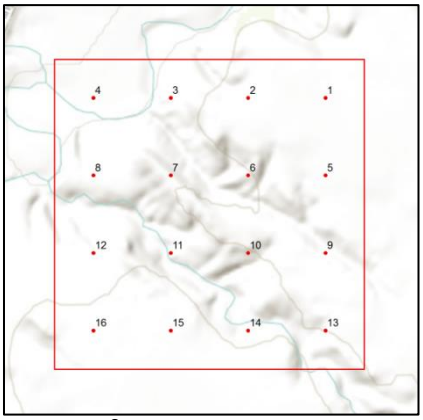

Figure 2. Example 1 km^2 sampling unit using the IMBCR design

Observers conducted surveys in the morning, beginning one-half hour before sunrise and concluding no later than five hours after sunrise. Technicians recorded the start time for every point count conducted. During each six-minute count, technicians recorded all birds heard and seen. For every bird detected during the six-minute period, observers recorded species; sex; horizontal distance from the observer (measured with a laser rangefinder); minute of first detection; 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 detected bird. While observers traveled between points within the sample grid, they recorded the presence of any species not recorded during a point count. The opportunistic detections of these species are used for distribution mapping purposes only. Technicians 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. Technicians 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 and relative abundance; percent cover and mean height of trees and shrubs by species; as well as grass height and ground cover types. Technicians 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 Bird Conservancy’s Field Protocol for Spatially Balanced Sampling of Landbird Populations on our Avian Data Center website at http://rmbo/v3/avian/DataCollection.aspx. There you will find links to past and current protocols and data sheets.

Data Analysis

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. Application of distance theory requires that five critical assumptions be met: 1) all birds at and near the sampling location (distance = 0) are detected; 2) distances to birds are measured accurately; 3) birds do not move in response to the observer's presence (Buckland et al., 2001; Thomas et al., 2010); 4) cluster sizes are recorded without error; and 5) the sampling units are representative of the entire survey region (Buckland, Marsden, & Green, 2008).

Analysis of distance data includes fitting a detection function to the distribution of recorded distances (Buckland et al., 2001). The distribution of distances can be a function of characteristics of the object (e.g., for birds, size and color, movement, volume of song or call and frequency of call), the surrounding environment (e.g., density of vegetation) and observer ability. Because detectability varies among species, we analyzed these data separately for each species. The development of robust density estimates typically requires 80 or more independent detections within the entire sampling area. We excluded birds flying over but not using the immediate surrounding landscape, birds detected while migrating (not breeding), juvenile birds and birds detected between points from analyses.

Data analysis was conducted by Bird Conservancy personnel experienced in distance sampling and occupancy modeling to obtain density, occupancy rates, and trend estimates. All estimators were calculated for each species within each stratum or individual park, and then "rolled-up" to produce regional estimates (Pavlacky et al. 2017). All analyses were completed using free software available online, mainly program R (R Core Team 2018) and JAGS (Plummer 2003).

We used a zero-inflated *N*-mixture model (Royle et al. 2004, Sillett et al. 2012) to estimate density and abundance for all strata, such as individual parks, across all species with sufficient data. The true occupancy state of point count location *k* in grid *j*, stratum *i*, and year *t* is distributed as:

$$z_{ijkt} \sim Bern(\psi_i).$$

The number of independent clusters of individuals, *N*, of a given species at point count location *k* in grid *j*, stratum *i*, and year *t* come from a Poisson distribution:

$$N_{ijkt} \sim Poisson(\lambda_{ijt} \times z_{ijkt}),$$

with mean λ_{ijt}. Abundances at all points within a grid come from a distribution with the same mean to account for the lack of independence between points.

We estimated stratum-level trends on grid-level mean abundance using a link function:

$$\log(\lambda_{ijt}) = \alpha_i + r_i(t-1) + \varepsilon_j,$$

where ε_j is a grid-level random effect.

Zero-inflation parameters and random effects come from hyperdistributions:

$$logit(\psi_i) \sim Normal(\mu_{\psi_i}, \sigma_{\psi}^2),$$

and

$$\boldsymbol{\varepsilon} \sim Normal(0, \sigma_{\varepsilon}^2),$$

where μ_{ψ_i} is the proportion of grids on which the species was detected. We were required to constrain the hyperdistribution on ψ in this way so as to not overestimate abundance in strata with few detections. Likewise, for strata in which the species is never detected, we fixed $\psi_i = 0$. This parameterization allowed us to estimate density with uncertainty even when the species was not detected in a stratum or park, such as with low-density species.

We derived density, *D*, at the point count location as:

$$D_{ijkt} = \frac{N_{ijkt} \times s}{A_c},$$

where A_c is the area of the point count circle and *s* is the cluster size. We derived stratum-level density estimates by averaging all point-level density estimates within each stratum, and we took the area-weighted average of strata estimates to obtain regional estimates.

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 4 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)), and chose the most parsimonious detection function structure using Watanabe-Akaike Information Criterion (WAIC; Watanabe 2010, Hooten and Hobbs 2015).

We modeled the number of detections in each distance class at each point count location in year *t* as:

$$y_{ijkt} \sim Binomial(p_t, N_{ijkt}),$$

where p_t is the overall detection probability based on the chosen detection function.

Results

Field technicians conducted point counts between 21 June and 8 July 2018, and surveyed 56 points in five grids (Table 1). They detected 821 individuals of 71 species (Appendix A) in five general habitat types (Table 2).

During 2018 IMBCR surveys, 21 species were detected on the Black Hills National Forest that were not reported in Custer State Park (Table 3). About half of these species should be expected in the park, while others are extremely rare, possibly no longer in the park, or in habitats not surveyed in 2018. In contrast, seven species were detected in Custer State Park in 2018 that were not detected in Black Hills National Forest (Brown Thrasher, Canyon Wren, Dickcissel, Gray Catbird, Lark Bunting, Northern Pintail and Upland Sandpiper). All seven of these species were detected in very low numbers in the park (Appendix A).

Table 1. 2018 Survey dates and number of completed point counts by grid in Custer State Park

Grid Number	Survey Date	Number of Points	Number of Species	Number of Detections
SD-GFP-CS1	6/28/2018	13	32	182
SD-GFP-CS2	6/27/2018	8	20	110
SD-GFP-CS3	7/8/2018	13	32	165
SD-GFP-CS4	6/21/2018	13	43	237
SD-GFP-CS5	6/22/2018	9	35	141
Total	**----**	**56**	**71**	**821**

Table 2. Distribution and results of surveys among major habitat types

	Number of Points	Number of Species	Number of Birds
Burn	9	28	111
Cliff/Rock	3	21	43
Grassland	12	43	223
Pine Forest	22	43	312
Riparian	10	39	131

Table 3. Species detected in Black Hills National Forest but not in Custer State Park during 2018 surveys

Species	Notes
American Redstart Black-and-white Warbler Ruffed Grouse	No longer in park??
Golden-crowned Kinglet Horned Lark N. Rough-winged Swallow Orchard Oriole Pygmy Nuthatch White-throated Swift Willow Flycatcher	Rare
Black-billed Magpie Bullock's Oriole Plumbeous Vireo Townsend's Solitaire	Should be present
Am. Three-toed Woodpecker Black-backed Woodpecker Clark's Nutcracker Say's Phoebe	Should be present, low density
Lazuli Bunting MacGillivray's Warbler	Shrub/deciduous
Field Sparrow	Shrub/juniper

Excluding waterbirds and nocturnal species, 34 species were recorded during surveys in the park in 2004-2006 (Schickel 2007) that were not recorded in 2018 (Table 4). In contrast, Cassin's Finch was the only species recorded in 2018 that was not detected during the earlier survey.

Table 4. Species recorded during Custer State Park surveys in 2004-2006 but not during 2018 surveys.

Species	Notes
American Redstart Black-and-white Warbler Ruffed Grouse	No longer in park??
Black-billed Cuckoo Burrowing Owl Golden Eagle Golden-crowned Kinglet Horned Lark N. Rough-winged Swallow Northern Goshawk Orchard Oriole Pinyon Jay Prairie Falcon Pygmy Nuthatch Rose-breasted Grosbeak Savannah Sparrow Sharp-shinned Hawk White-throated Swift Willow Flycatcher	Rare
Black-billed Magpie Bullock's Oriole House Finch Plumbeous Vireo Sharp-tailed Grouse Townsend's Solitaire	Should be present
Black-backed Woodpecker Clark's Nutcracker Lewis' Woodpecker Say's Phoebe	Should be present, low-density
Lazuli Bunting MacGillivray's Warbler	Shrub/deciduous
Blue Grosbeak Field Sparrow Yellow-breasted Chat	Shrub/juniper

Bird Conservancy estimated densities and population sizes for 61species in Custer State Park, with robust density estimates (CV < 50%) for 21 of these (Appendix B). Of those species with CV < 50%, six had densities above 9 birds/km^2 – in decreasing order, American Robin, Spotted Towhee, Western Tanager, Western Meadowlark, Black-capped Chickadee and Chipping Sparrow. High-density species with less precise estimates (CV > 50%) included Red Crossbill (57 birds/kms^2), Brown-headed Cowbird (19 birds/kms^2) and Brewer's Blackbird (16 birds/kms^2) (Appendix B).

Compared to bird densities in all of the Black Hills National Forest, grassland and edge-associated species had higher densites in Custer State Park (Table 5). In contrast, several pine forest species had lower densities in the park compared to those in the rest of the National Forest. Several forest species with less precise estimates showed the same trend; densities of White-breasted and Red-breasted nuthatches, Pine Siskin, Red-breasted Sapsucker, Ovenbird, Warbling Vireo and Dark-eyed Junco all were at least 3 times higher in the National Forest than in the state park (Appendix B).

Table 5. Comparison of estimated 2018 bird densities (birds/km^2) in Custer State Park (CSP) versus those in the Black Hills National Forest (BHNF).

Species*	Density CSP	Density BHNF	Difference
Spotted Towhee	15.6	3.9	11.7
Western Meadowlark	10.3	4.4	5.8
Grasshopper Sparrow	7.6	2.5	5.1
Eastern Bluebird	5.8	0.8	5.0
Western Tanager	12.0	7.4	4.6
Black-headed Grosbeak	5.4	2.1	3.3
Song Sparrow	4.0	1.0	3.0
Northern Flicker	6.8	4.7	2.2
House Wren	6.8	9.8	-3.0
Vesper Sparrow	1.2	4.5	-3.3
Western Wood-Pewee	4.7	12.9	-8.2
American Robin	21.4	32.1	-10.8
Yellow-rumped Warbler	6.4	22.9	-16.6
Black-capped Chickadee	10.1	32.5	-22.3
Chipping Sparrow	9.5	46.9	-37.4

*Table only includes species with density CV < 50%.

In comparison with all of western South Dakota, densities of woodland species were higher in Custer State Park, while densities of some grassland species were lower (Table 6).

In the park, nine species with precise estimates, primarily forest species, had lower densities in 2018 compared to the 2004-2006 (Schickel 2007) survey results (Table 7). In addition, densities of another nine forest species with less precise estimates were at least 3 times lower during the current survey: Mountain Bluebird, Hairy Woodpecker, Red-naped Sapsucker, Cordilleran Flycatcher, White-breasted and Red-breasted nuthatches, Ruby-crowned Kinglet, Warbling Vireo and Dark-eyed Junco. In contrast, far fewer species had higher densities in 2018; besides those listed in Table 7, densities of Red Crossbill, Brewer's Blackbird, Cedar Waxwing, Brown-headed Cowbird and Common Grackle were at least 3 times higher in 2018.

Table 6. Comparison of estimated 2018 bird densities (birds/km^2) in Custer State Park (CSP) versus those in all of West River South Dakota (W.SD).

Species*	Density CSP	Density W.SD	Difference
American Robin	21.4	2.9	18.5
Western Tanager	12.0	0.4	11.6
Spotted Towhee	15.6	4.1	11.4
Black-capped Chickadee	10.1	2.1	8.0
Northern Flicker	6.8	0.3	6.5
Black-headed Grosbeak	5.4	0.1	5.3
Eastern Bluebird	5.8	0.5	5.3
Yellow-rumped Warbler	6.4	1.1	5.3
Downy Woodpecker	5.5	0.6	4.9
House Wren	6.8	2.6	4.2
Chipping Sparrow	9.5	5.3	4.2
Song Sparrow	4.0	0.1	3.9
Mountain Bluebird	4.7	1.0	3.7
Western Wood-Pewee	4.7	1.7	3.0
Red-headed Woodpecker	2.5	0.1	2.5
Rock Wren	2.1	0.2	1.9
Vesper Sparrow	1.2	6.2	-5.0
Western Meadowlark	10.3	42.4	-32.1
Grasshopper Sparrow	7.6	110.4	-102.8

*Table only includes species with density CV < 50%.

Table 7. Comparison of estimated Custer State Park bird densities (birds/km^2) during 2018 surveys versus those during 2004-2006 surveys.

Species*	Density 2018	Density 2004-2006	Difference
Spotted Towhee	15.6	8.2	7.3
Eastern Bluebird	5.8	1.6	4.2
Northern Flicker	6.8	3.6	3.2
Mountain Bluebird	4.7	9.8	-5.1
Vesper Sparrow	1.2	6.7	-5.5
Western Tanager	12.0	17.6	-5.6
Song Sparrow	4.0	9.6	-5.6
Western Meadowlark	10.3	16.2	-5.9
Black-capped Chickadee	10.1	17.1	-7.0
American Robin	21.4	35.0	-13.6
Yellow-rumped Warbler	6.4	32.6	-26.2
Chipping Sparrow	9.5	61.2	-51.7

*Table only includes species with density CV < 50%.

To view interactive maps illustrating survey and detection locations, species counts, and density, population and occupancy results for Custer State Park, please visit Bird Conservancy's Rocky Mountain Avian Data Center at http://rmbo.org/v3/avian/ExploretheData.aspx. Instructions for using the Avian Data Center are available on the Center's website. Results from

all strata and biologically meaningful combinations of strata, termed “super strata”, can also be queried on the Rocky Mountain Avian Data Center.

Discussion

The summer 2018 point count surveys documented 71 bird species in Custer State Park. This is fewer than the 90 non-aquatic species detected in the Black Hills National Forest in 2018 and 109 species document in the park in 2004-2006 (Schickel 2007). Many of the species missing on the park 2018 list are rare or occur in low densities (Tables 3 and 4). Others occur in shrubland, a rare habitat in the park. Five grids were surveyed in the park in 2018; this is adequate to estimate densities and population sizes but will miss many rare species. Many more surveys were conducted in the National Forest in 2018 (28 grids) and in the park during 2004-2006 (45 grids) and this expanded coverage increased the likelihood of detecting rare species. There were however several species that we would expect to have been recorded during the 2018 park surveys. In particular, Plumbeous Vireo and Townsend’s Solitaire were quite abundant in the park during the earlier surveys (13 birds/km^2 and 9 birds/km^2 respectively). Both of these species occur in coniferous forests with a strong shrub or tree understory. That they were not detected at all in 2018 suggests that park forests have lost the necessary understory to support these species.

A key component of the IMBCR design is the ability to derive inferences across spatial scales, from small management units such as a state park to entire states and BCRs. Because of this, we were not only able to obtain park-level density and population estimates but were able to compare these to those of larger regions and to historical data to gain further insights into the results. The comparisons show Custer State Park in 2018 had lower densities of many forest species compared to densities in the Black Hills National Forest in 2018 as well as historical densities in the park. Several species, such as Chipping Sparrow, Yellow-rumped Warbler and Western Wood-pewee, are forest generalists and are found in all types of timber management (Dykstra 1996, Mills et al. 2000). Primary (woodpeckers and sapsuckers) and secondary-cavity (nuthatches) species also occurred in much lower densities in the park in 2018. This suggests that forest habitats in Custer State Park in 2018 are much different than those of the surrounding forest or of historical habitats and currently are less suitable for forest birds. In contrast, species with higher densities in the park in 2018 tended to be edge (Cedar Waxwing, Spotted Towhee, Black-headed Grosbeak, Song Sparrow) or rangeland-associated (Brewer’s Blackbird, Mourning Dove, Common Grackle) species. This indicates a shift towards more fragmented and smaller forest patches with an increase in grassland. Bison and other grazing animal herds in the park may also be impacting bird populations. Densities of two grassland species, Grasshopper Sparrow and Western Meadowlark, did not change within the park between the two surveys but were higher than those in the surrounding National Forest, suggesting that the park historically and currently has larger, higher-quality grasslands than the Forest. These results give managers useful information for prioritizing management actions at both local and regional scales.

These surveys were an auxiliary, or "overlay”, project, which are a growing component of the IMBCR program. They are designed to address specific management questions. Overlay projects utilize the IMBCR sampling design and field methods but are not integrated into the nested stratification of the IMBCR program. These projects benefit from the IMBCR program by incorporating detection data from relevant IMBCR surveys in their analyses. Utilizing the IMBCR

design also allows the resulting project-specific population estimates to be placed in a regional context. In this way, the collaborative efficiency of the IMBCR program is extended to overlay projects by improving the accuracy and precision of population estimates for infrequently detected species and allowing those estimates to be compared to larger, regional populations.

The IMBCR sampling design and survey protocol utilized in the Custer Park surveys have additional advantages to those mentioned above:

- The GRTS sampling design and point count survey protocol allows for more precise population and occupancy estimates to be generated using detection probability. Spatially-balanced sampling generally is more efficient than simple random sampling of natural resources (Stevens and Olsen 2004). Incorporating information about spatial autocorrelation in the data can increase precision in density estimates.
- The IMBCR approach has the flexibility to generate valid population estimates at scales relevant to land management agencies, as well as support conservation efforts at both local and regional scales. Comparing the Custer State Park 2018 data to the same-year regional data as well as historical information resulted in an ability to interpret bird populations at both scales, with just one year of data collection. This allows researchers and managers to generate and test hypotheses on the reasons for these observations, which then allows managers to implement adaptive management to conserve bird populations.
- Population size estimates presented in this report were produced from density estimates that accounted for spatial variation and incomplete detection, which allowed the population estimates to be extended over the state park (Pollock et al. 2002, Thompson 2002, Nichols et al. 2009).
- Incorporating data collected at small scales to estimate parameters at larger scales allows this design to address the need for large-scale monitoring and research, which has been emphasized in bird conservation initiatives (Ruth et al. 2003). The region-wide population estimates generated from this data can better assist managers in understanding trends in landbird populations (US North American Bird Conservation Initiative 2009).
- By analyzing data across both the individual state park and its respective BCR sampling frames we can estimate common detection probabilities for species that would have otherwise had an insufficient number of detections.
- The IMBCR design allows sampling of all habitats, allowing managers to relate point count results to habitat. Because all vegetation classes are available for sampling and samples are spatially balanced, rare habitats are sampled less frequently than others. Sampling of these rare habitats does appear to be proportional to land cover classifications. Further explorations of sampled habitat types can be done through post-stratification of the data by vegetation cover type and primary habitat to determine if some species and habitats are under-sampled. Additional analyses of avian-habitat relationships using the vegetation data collected during the point count can help guide future conservation and management.

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Appendix A. List of bird species detected in Custer State Park in 2018

Common Name	Scientific Name	Number of Detections
American Crow	*Corvus brachyrhynchos*	32
American Goldfinch	*Spinus tristis*	8
American Kestrel	*Falco sparverius*	4
American Robin	*Turdus migratorius*	73
Barn Swallow	*Hirundo rustica*	1
Black-capped Chickadee	*Poecile atricapillus*	32
Black-headed Grosbeak	*Pheucticus melancocephalus*	17
Blue Jay	*Cyanocitta cristata*	1
Bobolink	*Dolichonyx oryzivorus*	1
Brewer's Blackbird	*Euphagus cyanocephalus*	32
Brown Creeper	*Certhia americana*	1
Brown Thrasher	*Toxostoma rufum*	1
Brown-headed Cowbird	*Molothrus ater*	25
Canada Jay	*Perisoreus canadensis*	2
Canyon Wren	*Catherpes mexicanus*	1
Cassin's Finch	*Haemorhous cassinii*	1
Cedar Waxwing	*Bombycilla cedrorum*	2
Chipping Sparrow	*Spizella passerina*	19
Cliff Swallow	*Petrochelidon pyrrhonota*	1
Common Grackle	*Quiscalus quiscula*	5
Common Nighthawk	*Chordeiles minor*	12
Common Yellowthroat	*Geothlypis trichas*	5
Cooper's Hawk	*Accipiter cooperii*	1
Cordilleran Flycatcher	*Empidonax occidentalis*	2
Dark-eyed Junco	*Junco hyemalis aikeni*	20
Dickcissel	*Spiza americana*	1
Downy Woodpecker	*Dryobbates pubescens*	5
Dusky Flycatcher	*Empidonax oberholseri*	2
Eastern Bluebird	*Sialia sialia*	21
Eastern Kingbird	*Tyrannus tyrannus*	3
European Starling	*Sturnus vulgaris*	1
Grasshopper Sparrow	*Ammodramus savannarum*	7
Gray Catbird	*Dumetella carolinensis*	1
Hairy Woodpecker	*Dryobates villosus*	3
House Wren	*Troglodytes aedon*	12

Common Name	Scientific Name	Number of Detections
Lark Bunting	*Calamospiza melanocorys*	1
Lark Sparrow	*Chondestes grammacus*	1
Least Flycatcher	*Empidonax minimus*	2
Mountain Bluebird	*Sialia currucoides*	11
Mourning Dove	*Zenaida macroura*	28
Northern Flicker	*Colaptes auratus*	41
Northern Pintail	*Anas acuta*	2
Ovenbird	*Seiurus aurocapilla*	11
Pine Siskin	*Spinus pinus*	5
Red Crossbill	*Loxia curvirostra*	42
Red-breasted Nuthatch	*Sitta canadensis*	30
Red-eyed Vireo	*Vireo olivaceus*	3
Red-headed Woodpecker	*Melanerpes erythrocephalus*	11
Red-naped Sapsucker	*Sphyrapicus nuchalis*	2
Red-tailed Hawk	*Buteo jamaicensis*	1
Red-winged Blackbird	*Agelaius phoeniceus*	15
Rock Pigeon	*Columba livia*	2
Rock Wren	*Salpinctes obsoletus*	11
Ruby-crowned Kinglet	*Regulus calendula*	6
Song Sparrow	*Melospiza melodia*	8
Spotted Towhee	*Pipilo maculatus*	28
Swainson's Thrush	*Catharus ustulatus*	4
Tree Swallow	*Tachycineta bicolor*	1
Turkey Vulture	*Cathartes aura*	2
Upland Sandpiper	*Bartramia longicauda*	4
Vesper Sparrow	*Pooecetes gramineus*	5
Violet-green Swallow	*Tachycineta thalassina*	5
Warbling Vireo	*Vireo gilvus*	2
Western Kingbird	*Tyrannus verticalis*	3
Western Meadowlark	*Sturnella neglecta*	78
Western Tanager	*Piranga ludoviciana*	35
Western Wood-Pewee	*Contopus sordidulus*	23
White-breasted Nuthatch	*Sitta carolinensis*	10
Wild Turkey	*Meleagris gallopavo*	1
Yellow Warbler	*Setophaga petechia*	2
Yellow-rumped Warbler	*Setophaga coronata*	30
Total		**821**

Appendix B. Estimated bird densities and population sizes from surveys conducted in Custer State Park in 2018, Black Hills National Forest in 2018, West River South Dakota in 2018, and Custer State Park in 2004-2006 (Table 7 in Schickel 2007). Table includes estimated densities per km^2 (Dens), population size (N), percent coefficient of variation of density estimates (% CV), and sample sizes (n) of breeding birds used in analyses. Dashes indicate the sample size was insufficient for estimating density while blanks indicate the species was not detected during that year at that location. Schickel (2007) did not estimate population sizes.

	Custer SP 2018				Black Hills Nat. Forest 2018				West River SD 2018				Custer SP '04-'06		
Species	**Dens**	**N**	**% CV**	***n***	**Dens**	**N**	**% CV**	***n***	**Dens**	**N**	**% CV**	***n***	**Dens**	**% CV**	***n***
American Crow	0.47	138	53	32	0.59	3799	47	99	0.28	11471	40	278	----	----	----
American Goldfinch	7.56	2223	59	8	11.63	75275	50	66	5.73	339775	57	175	11.78	24	110
American Kestrel	0.69	203	49	4	0.17	1069	43	0	0.01	313	47	16	----	----	----
American Redstart				0	13.23	85618	14	77	0.75	11863	15	80	----	----	----
American Robin	21.38	6286	16	73	32.14	207973	14	564	2.94	62543	21	728	35.00	12	472
A. Three-toed Woodpecker				0	0.20	1319	84	5	0.01	1112	84	5	----	----	----
Barn Swallow	2.01	590	201	1	2.26	14596	132	10	0.40	57652	140	46	2.04	55	28
Black-backed Woodpecker				0	1.96	12707	40	7	0.12	5072	40	10	----	----	----
Black-billed Magpie				0	0.32	2081	48	8	0.47	22787	47	90	----	----	----
Black-capped Chickadee	10.10	2970	34	32	32.45	209926	23	275	2.12	57013	26	399	17.10	14	292
Black-headed Grosbeak	5.43	1595	26	17	2.13	13754	17	13	0.09	2044	23	23	7.07	39	49
Blue Jay	0.23	67	85	1	1.22	7921	33	24	0.09	7178	81	27	----	----	----
Bobolink	0.47	138	77	1	0.21	1373	69	9	1.05	46551	43	208	----	----	----
Brewer's Blackbird	16.52	4856	90	32	0.58	3737	140	2	2.79	247547	86	95	6.91	72	37
Brown Creeper	----	----	----	1	2.81	18157	42	4	0.12	6779	53	6	3.09	39	39
Brown Thrasher	0.40	119	86	1	0.01	36	381	0	0.52	31307	58	12	----	----	----
Brown-headed Cowbird	18.55	5455	99	25	23.81	154062	93	120	54.21	4871783	87	1176	12.81	20	126
Bullock's Oriole				0	0.18	1135	80.5	3	0.29	24584	81	14	----	----	----
Canada Jay	1.34	394	90	2	1.71	11066	63	10	0.06	4335	76	10	----	----	----
Canyon Wren	0.15	45	79	1	0.01	35	284	0	0.00	100	144	9	----	----	----
Cassin's Finch	0.78	231	76	1	0.05	309	156	1	0.00	474	165	1			0
Cedar Waxwing	7.26	2133	202	2	6.91	44686	158	35	2.37	448857	183	40	----	----	----
Chipping Sparrow	9.50	2793	36	19	46.94	303710	27	363	5.34	181266	33	506	61.18	13	371
Clark's Nutcracker				0	0.17	1130	119	2	0.01	762	101	21	----	----	----
Cliff Swallow	----	----	----	1	21.90	141666	433	28	15.63	8156635	505	154	----	----	----

	Custer SP 2018				Black Hills Nat. Forest 2018				West River SD 2018				Custer SP '04-'06		
Species	**Dens**	**N**	**% CV**	***n***	**Dens**	**N**	**% CV**	***n***	**Dens**	**N**	**% CV**	***n***	**Dens**	**% CV**	***n***
Common Grackle	5.20	1529	102	5	1.06	6883	127	5	6.47	749040	112	52	----	----	----
Common Nighthawk	1.59	466	41	12	0.55	3545	40	10	0.48	24004	49	85	----	----	----
Common Yellowthroat	1.05	308	60	5	1.86	12023	23	21	0.13	2732	21	31	9.00	70	52
Cooper's Hawk		----	----	1	0.49	3169	49	5	0.03	1550	49	5	----	----	----
Cordilleran Flycatcher	1.21	357	70	2	2.22	14377	26.	5	0.10	3614	35	20	8.08	29	74
Dark-eyed Junco	1.75	516	80	20	47.51	307388	32	271	2.74	91063	32	294	27.21	16	328
Dickcissel	0.49	145	78	1				0	3.05	92443	29	55	----	----	----
Downy Woodpecker	5.50	1616	48	5	3.80	24555	26	19	0.59	45677	75	23	----	----	----
Dusky Flycatcher	----	----	----	2	8.87	57359	12	41	0.49	6753	13	57	3.36	55	45
Eastern Bluebird	5.81	1707	27	21	0.78	5058	32	8	0.49	26780	52	70	1.63	50	19
Eastern Kingbird	1.40	411	90	3	0.39		51	0	1.67	89316	53	49	----	----	----
European Starling	1.42	418	276	1	0.84	5414	267	23	0.84	252757	293	30	----	----	----
Golden-crowned Kinglet				0	0.85	5490	106	4	0.05	5777	106	4	----	----	----
Grasshopper Sparrow	7.57	2225	23	7	2.46	15888	23	12	110.37	582229	5	1316	7.51	50	87
Gray Catbird	----	----	----	1	0.03	201	31	0	0.01	745	113	1			0
Hairy Woodpecker	2.08	610	61	3	4.91	31745	19	31	0.28	5728	20	38	7.99	28	62
Horned Lark				0	0.20	1267	85	2	14.79	529900	35	454	----	----	----
House Wren	6.81	2002	30	12	9.82	63536	13	94	2.64	80436	30	275	----	----	----
Lark Bunting	0.52	153	169	1	0.00	19	486	0	10.38	800584	75	318	----	----	----
Lark Sparrow	----	----	----	1	2.84	18390	33	11	6.88	279250	39	157	----	----	----
Lazuli Bunting				0	0.22	1433	61	0	0.03	873	27	21	----	----	----
Least Flycatcher	2.04	600	66	2	2.79	18036	23	20	0.19	4256	21	33	----	----	----
Mountain Bluebird	4.73	1392	37	11	3.74	24182	26	53	1.05	42831	40	90	9.85	17	164
Mourning Dove	5.88	1729	275	28	2.26	14620	273	38	6.23	1574454	245	824	7.05	15	221
Northern Flicker	6.80	2000	24	41	4.66	30119	17	128	0.31	7696	24	241	3.62	24	100
Northern Pintail	----	----	----	2				0	0.01	886	118	9			
Orchard Oriole				0	1.24	8015	51	4	1.86	114679	60	15	----	----	----
Ovenbird	1.09	320	58	11	9.44	61091	9	59	0.26	3510	13	98	2.86	32	79
Pine Siskin	3.99	1173	110	5	10.23	66161	86	50	0.60	53754	87	57	2.71	62	29
Plumbeous Vireo				0	2.04	13212	14	18	0.10	1684	16	45	13.36	16	139

	Custer SP 2018				Black Hills Nat. Forest 2018				West River SD 2018				Custer SP '04-'06		
Species	**Dens**	**N**	**% CV**	***n***	**Dens**	**N**	**% CV**	***n***	**Dens**	**N**	**% CV**	***n***	**Dens**	**% CV**	***n***
Red Crossbill	56.94	16741	127	42	58.23	376749	132	199	3.47	471297	132	232	22.46	17	219
Red-breasted Nuthatch	1.10	323	58	30	19.73	127680	11	298	1.01	12021	12	383	15.25	13	366
Red-eyed Vireo	----	----	----	3	1.10	7119	29	8	0.05	1656	33	11	9.54	56	33
Red-headed Woodpecker	2.51	737	31	11	1.08	6961	26	16	0.06	1654	28	60	----	----	----
Red-naped Sapsucker	2.17	637	58	2	8.62	55791	16.	38	0.49	8359	17	43	8.25	37	75
Red-tailed Hawk	0.12	36	89	1	0.20	1280	39	9	0.02	3012	135	17	----	----	----
Red-winged Blackbird	2.78	816	99	15	3.19	20611	92	51	10.17	992934	95	902	7.90	41	88
Rock Pigeon	1.49	437	227	2				2	1.76	428351	236	52	----	----	----
Rock Wren	2.07	609	31	11	0.76	4931	20.0	13	0.16	8329	50	113	2.61	26	141
Ruby-crowned Kinglet	1.16	342	51	6	3.81	24628	11	167	0.20	2258	11	175	9.28	38	135
Say's Phoebe				0	0.19	1259	44	5	0.04	902	23	51	----	----	----
Song Sparrow	4.02	1182	38	8	0.99	6422	35	27	0.08	7364	89	31	9.62	82	36
Spotted Towhee	15.56	4574	17	28	3.90	25231	14	14	4.13	86358	20	274	8.23	26	128
Swainson's Thrush	0.63	186	84	4	1.67	10808	17	85	0.10	1759	17	94	3.48	42	56
Townsend's Solitaire				0	1.55	10036	20	10	0.06	1753	28	23	9.02	22	121
Tree Swallow	----	----	----	1	10.43	67454	115	30	2.16	390515	175	36	----	----	----
Turkey Vulture	0.13	38	154	2	0.10	634	130	18	0.01	1629	185	46	----	----	----
Upland Sandpiper	0.37	109	51	4	----	49	----	0	1.93	57690	28.9	452	----	----	----
Vesper Sparrow	1.19	348	42	5	4.47	28941	14	47	6.25	98631	15.3	156	6.68	41	113
Violet-green Swallow	8.21	2415	148	5	7.60	49145	139	19	0.59	83605	137	107	3.03	66	22
Warbling Vireo	0.70	207	80	2	13.07	84593	12	96	0.56	7994	14	109	10.11	27	110
Western Kingbird	0.62	182	100	3	0.12	768	106	0	0.02	1431	61	7			
Western Meadowlark	10.27	3019	22	78	4.42	28599	21	94	42.38	884167	20	3853	16.17	23	486
Western Tanager	12.02	3533	17	35	7.39	47788	11	90	0.38	4522	12	168	17.61	13	328
Western Wood-Pewee	4.69	1379	21	23	12.91	83520	8	286	1.66	34234	20	432	5.85	20	179
White-breasted Nuthatch	0.62	182	67	10	4.43	28687	21	53	0.64	28047	43	68	8.11	17	170
Wild Turkey	----	----	----	1	0.06	414	124	0	0.18	22891	122	46	----	----	----
Yellow Warbler	1.50	442	63	2	0.37	2373	44	6	0.86	48102	54	41	----	----	----
Yellow-rumped Warbler	6.38	1875	30	30	22.93	148384	12	321	1.11	15117	13	420	32.57	11	606