Integrated Monitoring in Bird Conservation Regions (IMBCR) for Playa Lakes Joint Venture (PLJV): 2016 - 2017 Conservation Reserve Program Report

September 2018

Connecting People, Birds and Land

Bird Conservancy of the Rockies
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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

Bird Conservancy of the Rockies (Bird Conservancy), in conjunction with its partners, conducted landbird monitoring for the tenth year in a row for the Integrated Monitoring in Bird Conservation Regions (IMBCR) program. The IMBCR for Playa Lakes Joint Venture (PLJV) program is a collaborative partnership for evaluating and implementing wildlife conservation in the Shortgrass Prairie and Central Mixed grass Prairie Bird Conservation Regions. The partnership was designed to address management and conservation needs of a wide range of stakeholders including private landowners, conservation initiatives, federal agencies and state wildlife agencies. 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 Bird Conservation Regions (BCR) or states, facilitating conservation at local and national levels. The sampling design allows analysts to estimate species densities, population sizes, and occupancy rates for individual strata or biologically meaningful combinations of strata. The IMBCR design provides a spatially consistent and flexible framework for understanding the status and annual changes of bird populations. Collaboration across organizations and spatial scales increases sample sizes and improves the accuracy and precision of population estimates. Analyzing the data collectively allows us to estimate detection probabilities for species that would otherwise have insufficient numbers of detections at local scales.

The IMBCR program is well-positioned to address the conservation and management needs of a wide range of stakeholders due to the hierarchical design and IMBCR partnership. Population monitoring within BCRs can be implemented 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 throughout a species' geographic range. By focusing on scales relevant to management and conservation, information obtained from monitoring in BCRs can be integrated into research and management at various scales applicable to land managers. Post-stratifying IMBCR data by vegetation types and conservation practices provides a framework for effectiveness monitoring to learn about the success of management actions. The Conservation Reserve Program (CRP) is a voluntary program for agricultural producers administered by Farm Service Agency providing incentives to landowners to take cropland out of production and plant it back into grassland. The objectives of this report are to 1) evaluate avian population density on CRP lands relative to agricultural lands and native grassland, and 2) estimate the contributions of CRP lands to bird populations in the PLJV region.

This report summarizes the results of the 2016 and 2017 field seasons for the PLJV region, including the post-stratification analysis to estimate avian population density on CRP lands, agricultural lands and native grassland. 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 (Rocky Mountain Avian Data Center, www.rmbo.org/v3/avian/ExploretheData.aspx, accessed 6 Jun 2018). Instructions for using the Avian Data Center are included in Appendix A of this report and are available on the Avian Data Center itself. Each stratum or combination of strata presented in this report's Results section contains a web link that leads directly to the Avian Data Center with the appropriate queries already populated. Please note that not every stratum or conceivable combination of strata are summarized in this report. All individual strata and all biologically meaningful combinations of strata, or "superstrata", can be found on the Avian Data Center.

The control-impact comparison of population density on CRP lands relative to agricultural lands indicated large positive treatment effects for the Cassin's sparrow (*Peucaea cassinii*), grasshopper sparrow (*Ammodramus savannarum*), lark bunting (*Calamospiza melanocorys*) and mourning dove (*Zenaida macroura*). We observed large negative treatment effects for densities of the brown-headed cowbird (*Molothrus ater*), horned lark (*Eremophila alpestris*) and red-winged blackbird (*Agelaius*

phoeniceus), and these species were less abundant on CRP lands than agricultural lands. The comparison of population density on CRP lands relative to native grassland suggested CRP may provide suitable habitat for several grassland bird species. There was some indication of lower habitat suitability for CRP lands relative to native grassland for the ash-throated flycatcher (*Myiarchus cinerascens*), lark bunting, lark sparrow (*Chondestes grammacus*), turkey vulture (*Cathartes aura*) and western meadowlark (*Sturnella neglecta*). Population density was greater on CRP lands than native grassland for the dickcissel (*Spiza americana*), long-billed curlew (*Numenius americanus*), mourning dove and northern bobwhite (*Colinus virginianus*). We found lack of treatment effects and similar population densities on CRP lands relative to native grassland for the brown-headed cowbird, Cassin's sparrow, eastern meadowlark (*S. magna*), grasshopper sparrow, horned lark, loggerhead shrike (*Lanius ludovicianus*), scaled quail (*Callipepla squamata*) and Swainson's hawk (*Buteo swainsoni*). Overall, restoring cropland by planting CRP is expected to be an effective conservation strategy to provide suitable habitat and increase the abundance of several grassland bird species that are declining in the Great Plains.

Avian population sizes on CRP lands suggested large contributions to regional populations of the Chihuahuan raven (*Corvus cryptoleucus*), dickcissel, grasshopper sparrow, lark bunting, long-billed curlew, ring-necked pheasant (*Phasianus colchicus*) and Swainson's hawk. Land enrolled in the CRP program provided breeding habitat ~3 million grasshopper sparrows in 2016 and ~2 million grasshopper sparrows in 2017, and the 9% contribution to the regional population was proportionally greater than the 5% availability of CRP in the region. In addition, the CRP program contributed to the regional populations of several grassland species in proportion to the availability of CRP in the PLJV region, including the Cassin's sparrow, common nighthawk (*Chordeiles minor*), eastern meadowlark, killdeer (*Charadrius vociferus*), mourning dove, red-winged blackbird, scaled quail, western kingbird (*Tyrannus verticalis*) and western meadowlark. Overall, the population estimates suggested changes to land enrolled in CRP over time may have important population consequences for declining grassland bird species in the southern Great Plains.

Acknowledgements

We thank Playa Lakes Joint Venture for building a collaborative partnership and acquiring funding across the states within their boundary to allow for the addition of IMBCR for PLJV. Funding for surveys in the PLJV region was provided by Colorado Parks & Wildlife; Kansas Department of Wildlife, Parks & Tourism; Nebraska Game & Parks Commission; New Mexico Department of Game & Fish; Oklahoma Department of Wildlife Conservation; Texas Parks & Wildlife Department; US Department of Agriculture, Farm Service Agency (grant # AG-3151-C-16-0017); US Forest Service; Great Plains Landscape Conservation Cooperative; and US Fish and Wildlife Service, Region 2 - Southwest Region, Migratory Bird Office. Thank you to Rich Iovanna from the Farm Service for advice, collaboration and the development of research questions. Bird Conservancy of the Rockies' landowner liaison, Jenny Berven, with help from Tiffany Peeken, contacted county assessors to determine land ownership of survey locations. We thank Paul Lukacs of the University of Montana who wrote code in program R to automate data analysis for density estimation. The report benefited from thoughtful reviews by Anne Bartuszevige and Rich Iovanna. We also thank the many field technicians who collected avian and vegetation point count data and contacted private landowners to obtain access to survey locations and establish working relationships for the future. Without the efforts of these technicians and the cooperation of numerous private landowners, IMBCR partners would have been unable to conduct avian monitoring on private lands. Finally, this report benefited greatly from review by Bird Conservancy staff and IMBCR partners.

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Introduction

Monitoring is an essential component of wildlife management and conservation science (Witmer 2005, Marsh and Trenham 2008). Common goals of population monitoring are to estimate the population status of target species and to detect changes in populations over time (Thompson et al. 1998, Sauer and Knutson 2008). In addition to providing basic information on species distributions, effective monitoring programs can identify species that are at-risk due to small or declining populations (Dreitz et al. 2006); provide an understanding of how management actions affect populations (Lyons et al. 2008); and evaluate population responses to landscape alteration and climate change (Baron et al. 2008, Lindenmayer and Likens 2009).

While monitoring at local scales remains critical, there is an increasing need to monitor the consequences of environmental change over large spatial and temporal scales and address questions much larger than those that can be answered within individual management units (Jones 2011, Pavlacky et al. 2017). Reconciling disparities between the geographic scale of management actions and the scale of ecological and species-specific responses is a persistent challenge for natural resource management agencies (Conroy et al. 2012). Population monitoring of eco-regional landscapes provides an important context for evaluating population change at local and regional scales, with the potential to identify causal factors and management actions for species recovery (Manley et al. 2005, Sauer and Knutson 2008).

Before monitoring can be used by land managers to guide conservation efforts, sound program designs and analytic methods are necessary to produce unbiased population estimates (Sauer and Knutson 2008, Lindenmayer and Likens 2010). At the most fundamental level, reliable knowledge about the status of avian populations requires accounting for spatial variation and incomplete detection of the target species (Pollock et al. 2002, Rosenstock et al. 2002, Thompson 2002). Addressing spatial variation entails the use of probabilistic sampling designs, which allow population estimates to be extended over the entire area of interest (Thompson et al. 1998). Accounting for incomplete detection involves the use of appropriate sampling and analytic methods to address the fact that few, if any, species are so conspicuous that they are detected with certainty when present during a survey. Accounting for these two sources of variation ensures observed trends reflect true population changes rather than artifacts of the sampling and observation processes (Pollock et al. 2002, Thompson 2002).

The apparent large-scale declines of avian populations and the loss, fragmentation and degradation of native habitats highlight the need for extensive and rigorous landbird monitoring programs (Rich et al. 2004, US NABCI Monitoring Subcommittee 2007). The US North American Bird Conservation Initiative’s (NABCI) “Opportunities for Improving Avian Monitoring” (US NABCI Monitoring Subcommittee 2007) provided goals for avian monitoring programs, including:

Goal 1: Fully integrate monitoring into bird management and conservation practices and ensure that monitoring is aligned with management and conservation priorities.

Goal 2: Coordinate monitoring programs among organizations and integrate them across spatial scales to solve conservation or management problems effectively.

Goal 3: Increase the value of monitoring information by improving statistical design.

Goal 4: Maintain bird population monitoring data in modern data management systems. Recognize legal, institutional, proprietary, and other constraints while still providing greater availability of raw data, associated metadata, and summary data for bird monitoring programs.

With the US NABCI Monitoring Subcommittee (2007) guidelines in mind, Bird Conservancy of the Rockies and its partners initiated a broad-scale bird monitoring program in 2008, entitled “Integrated Monitoring in Bird Conservation Regions” (IMBCR, Blakesley and Hanni 2009, Pavlacky et al. 2017). See Appendix B: IMBCR Program and Stratification History for a complete history of this program. The monitoring objectives of the IMBCR partnership are to:

1. Provide robust density, population and occupancy estimates that account for incomplete detection and are comparable at different geographic extents;
2. Provide long-term status and trend data for all regularly occurring breeding landbird species throughout the study area;
3. Provide a design framework to spatially integrate existing bird monitoring efforts in the region to provide better information on distribution and abundance of breeding landbirds, especially for high priority species;
4. Provide basic habitat association data for most bird species to address habitat management issues;
5. Maintain a high-quality database that is accessible to all of our collaborators as well as to the public over the internet, in the form of raw and summarized data; and
6. Generate decision support tools that help guide conservation efforts and provide a better measure of conservation success.

The IMBCR design uses Bird Conservation Regions (BCRs) as sampling frames (Fig. 1), stratified by land ownership inside each BCR (US NABCI Monitoring Subcommittee 2007). BCRs provide a spatially consistent framework for bird conservation in North America. Each BCR represents a distinct ecological region with similar bird communities, vegetation types and resource management interests (NABCI, 2000). Population monitoring within BCRs can be implemented 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 throughout a species’ geographic range. By focusing on scales relevant to management and conservation, information obtained from monitoring in BCRs can be integrated into research and management at various scales applicable to land managers (Conroy et al. 2012, Pavlacky et al. 2017). The spatially balanced design of the IMBCR program samples vegetation types in proportion to their availability within strata, and post-stratification can be used to estimate population density for specific vegetation types (Thomas et al. 2010, Pavlacky et al. 2017). Post-stratification often increases the precision of the density estimates (Fewster et al. 2009), and population estimates for specific vegetation types may play a role in informing vegetation management activities. In addition, post-stratifying by specific conservation practices provides a framework for effectiveness monitoring to learn about the success of management actions (Lyons et al. 2008).

Important properties of the IMBCR design are:

- All areas are available for sampling including all vegetation types;
- Strata are based on fixed attributes, which allows us to relate changes in bird populations to changes on the landscape through time;
- Each state’s portion of a BCR can be stratified differently, depending upon local needs and areas to which one wants to make inferences;
- Aggregation of strata-wide estimates to BCR- or state-wide estimates is built into the design;
- Local population trends are directly comparable to regional trends; and
- Coordination among partners reduces the costs and/or increases efficiencies of monitoring per partner.

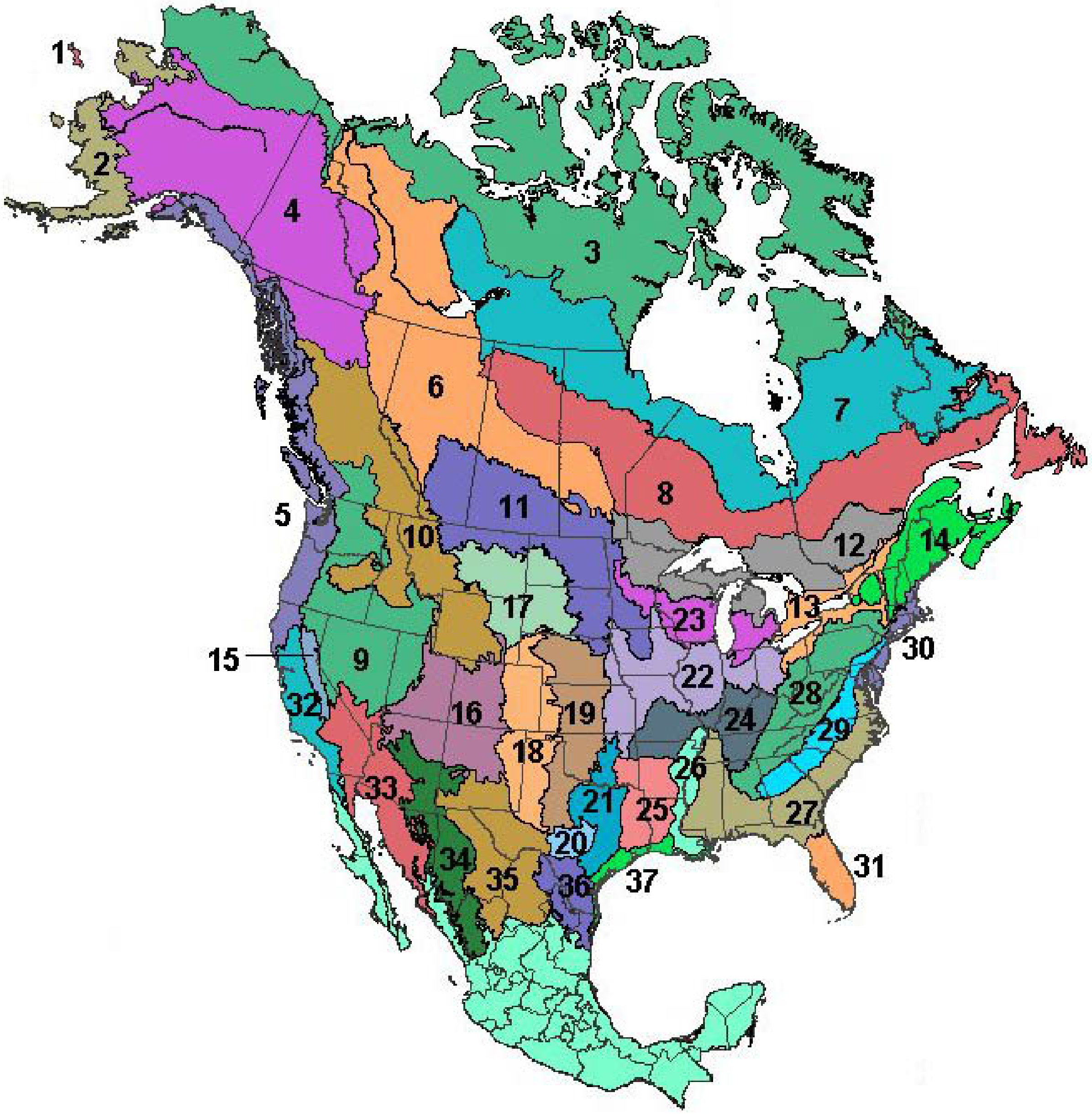

Figure 1. Bird Conservation Regions in North America, excluding Hawaii and Mexico (US North American Bird Conservation Initiative, www.nabci-us.org/resources/bird-conservation-regions-map, accessed 5 Jun 2018.

The Playa Lakes Joint Venture (PLJV) is a collaborative partnership for evaluating and implementing wildlife conservation in the Shortgrass Prairie and Central Mixed Grass Prairie BCRs (US NABCI Committee 2000b;a). The partnership was designed to address management and conservation needs of a wide range of stakeholders including private landowners, initiatives such as Partner's in Flight (Carter et al. 2000), federal agencies such as the Bureau of Land Management, Farm Service Agency, Natural Resources Conservation Service, Forest Service, Department of Defense, and the state wildlife agencies of Colorado, Nebraska, New Mexico, Oklahoma and Texas. Because a large percentage of the Great Plains are privately owned, the recovery of grassland bird species depends on conservation initiatives with strong partnerships between private landowners and resource professionals (Brennan and Kuvlesky 2005). The Conservation Reserve Program (CRP) is a voluntary program for agricultural producers administered by Farm Service Agency providing incentives to landowners to take cropland out of production and plant it back into grassland (Vandever and Allen 2015). The program was designed to address a number of economic and environmental issues affiliated with agricultural land, and although the recovery of wildlife populations associated with agro-ecosystems was not a primary goal of the CRP, the program has become an important tool for managing grassland birds (Vandever and Allen 2015), including species of conservation concern such as the lesser prairie-chicken (*Tympanuchus pallidicinctus*, Van Pelt et al. 2013). Effectiveness monitoring (Lyons et al. 2008) to determine the ability of the CRP for increasing populations of grassland birds may ultimately be useful for evaluating the success of Farm Bill practices toward a program of evidence-based conservation (Briske et al. 2017).

The objectives of this report are to 1) evaluate avian population density on CRP lands relative to agricultural lands and native grassland, and 2) estimate the contributions of CRP lands to bird populations in the PLJV region. We predict the population density of grassland bird species will be greater on CRP lands than agricultural lands. Effect sizes for differences between population density on CRP lands and agricultural lands may provide predictions for avian responses to the CRP restoration of agricultural lands. We predict the population density of grassland birds will be greater on native grassland than CRP lands. Effect sizes for differences between population density on CRP lands and native grassland may provide an evaluation of habitat suitability of CRP relative to native grassland for grassland bird species. Understanding the contribution of CRP to regional bird populations provides the information to evaluate the success of the program for meeting conservation objectives in the PLJV region.

Methods

Study Area

In 2016, IMBCR encompassed three entire states (Colorado, Montana and Wyoming) and portions of 10 additional states (Arizona, Idaho, Kansas, North Dakota, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Utah); two entire USFS Regions (Regions 1 and 2) and portions of Regions 3 and 4; all of the Badlands and Prairies BCR and almost all of the Shortgrass Prairie BCR and portions of seven additional BCRs (Great Basin, Northern Rockies, Prairie Potholes, Southern Rockies/Colorado Plateau, Central Mixed-grass Prairie, Sonoran and Mohave Deserts, and Sierra Madre Occidental; Fig. 2).

In 2017, the IMBCR program's area of inference encompassed three entire states (Colorado, Utah, and Wyoming) and portions of 12 additional states (Arizona, California, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, and Texas). We surveyed across US Forest Service (USFS) Regions 1, 2, and 4 and in portions of Region 3; all of the Badlands and Prairies BCR (BCR 17), all of the Shortgrass Prairie BCR (BCR 18), and portions of eight other BCRs: Great Basin (BCR 9), Northern Rockies (BCR 10), Prairie Potholes (BCR 11), Sierra Nevada (BCR 15), Southern Rockies/Colorado Plateau (BCR 16), Central Mixed-grass Prairie (BCR 19), Sonoran and Mohave Deserts (BCR 33), and Sierra Madre Occidental (BCR 34, Fig. 2).

For a map and complete descriptions of the Bird Conservation Regions, see the NABCI website (US North American Bird Conservation Initiative, www.nabci-us.org/resources/bird-conservation-regions-map, accessed 5 Jun 2018).

BCR 18: Shortgrass Prairie

The Shortgrass Prairie Bird Conservation Region is characterized by unique shortgrass prairie. What was once contiguous prairie is now fragmented by agriculture and the remnant grasslands are now exposed to new grazing regimes (PLJV 2007). Numerous playa lakes dot the region and wetlands occur along major river corridors that drain the Rocky Mountains. Because of a change in the hydrology of these rivers, more shrubs and trees have encroached upon the wetlands (US NABCI Committee 2000b;a). BCR 18 stretches north-south in the rain shadow of the Rocky Mountains and covers portions of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming.

This was the ninth year we implemented IMBCR within BCR 18. In BCR 18, Bird Conservancy conducted surveys throughout Colorado, Kansas, Nebraska, New Mexico, Oklahoma, Texas, and Wyoming. The only portion of BCR 18 not surveyed in 2016 was the small area within South Dakota. The effort in BCR 18 comprised 37 strata covering 381,286 km².

BCR 19: Central Mixed-grass Prairie

The Central Mixed-grass Prairie Bird Conservation Region lies between shortgrass prairie to the west and tallgrass prairie to the east (US NABCI Committee 2000b;a). This region consists of a mixture of shortgrass and tallgrass prairie habitats, with some native and hand-planted Ponderosa Pine forests in northwestern Nebraska. BCR 19 runs north-south from the southern border of South Dakota through Nebraska, Kansas, Oklahoma, and north-central Texas.

This was the sixth year we implemented IMBCR within BCR 19. In BCR 19, Bird Conservancy conducted surveys throughout Kansas, Oklahoma, and Texas; and within USFS lands in BCR 19 in Nebraska. The effort in BCR 19 comprised 11 strata covering 274,583 km².

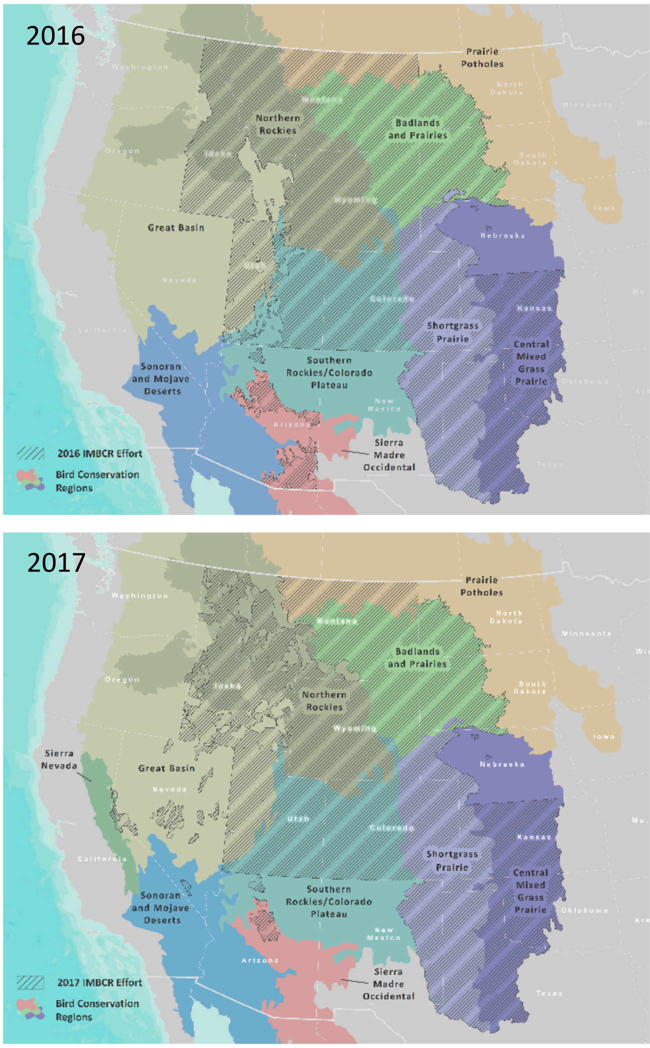

Figure 2. The spatial extent of sampled Bird Conservation Regions (BCR) using the Integrated Monitoring in Bird Conservation Regions (IMBCR) design, 2016 - 2017. The colored regions represent the BCRs and the hatched regions represent the area of inference for the IMBCR program.

Sampling Design

Sampling Frame and Stratification

A key component of the IMBCR design is the ability to infer across spatial scales, from small management units, such as individual national forests or BLM field offices, to entire states and BCRs (Pavlacky et al. 2017). This is accomplished through hierarchical (nested) stratification, which allows data from smaller-order strata to be combined to make inferences about higher-order strata. For example, data from each individual national forest stratum in USFS Region 2 are combined to produce Region-wide avian population estimates; data from each individual stratum in Montana are combined to produce state-wide estimates; data from each individual stratum in BCR 17 are combined to produce BCR-wide estimates.

We defined strata based on areas to which IMBCR partners wanted to make inferences. We defined the largest sampling frame by the intersection of state and BCR boundaries (e.g., Wyoming BCR 10). We based the strata within the state-BCRs frame on fixed attributes such as land ownership boundaries, elevation zones, major river systems and wilderness/roadless designations.

Sampling Units

The IMBCR design defines sampling units as 1 km² grid cells, each containing 16 evenly spaced sample points, 250 meters apart (Fig. 3). We define potential sampling units by superimposing a uniform grid of cells over each state in the study area. We then assign each grid cell to a stratum using ArcGIS version 10.X and higher (ArcGIS Version 10, Environmental Systems Research Institute, Redlands, CA). For all stratifications developed after 2012, we used the United States National Grid, a nonproprietary alphanumeric referencing system derived from the Military Grid Reference System that was created by the Federal Geographic Data Committee.

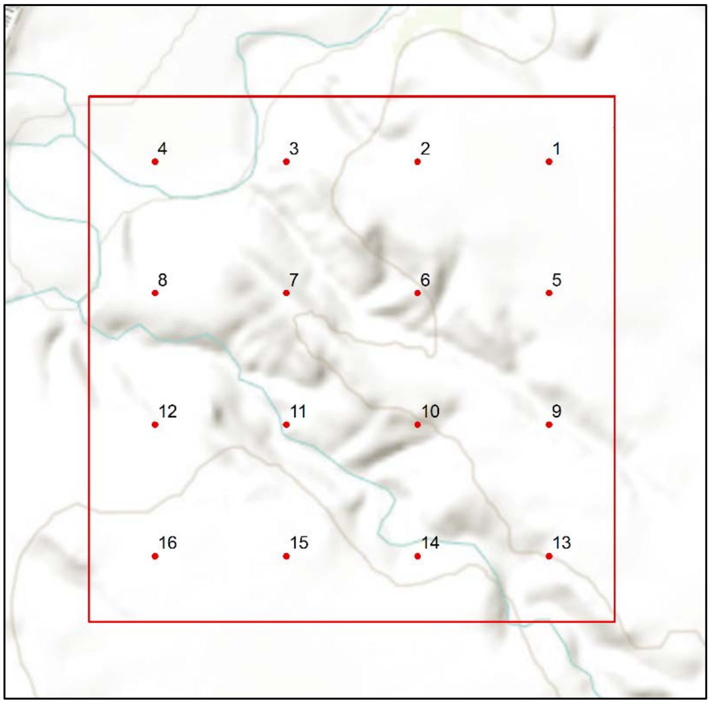

Figure 3. Example 1 km² sampling unit using the Integrated Monitoring in Bird Conservation Regions design.

Sample Selection

Within each stratum, the IMBCR design used generalized random-tessellation stratification (GRTS), a spatially balanced sampling algorithm, to select sample units (Stevens and Olsen 2004). The GRTS design has some appealing properties with respect to long-term monitoring of birds at large spatial scales:

- Spatially balanced sampling is generally 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; and
- All sample units in the sampling frame are ordered, such that any set of consecutively numbered units is a spatially well-balanced sample (Stevens and Olsen 2004). In the case of fluctuating budgets, IMBCR partners can adjust the sampling effort among years within each stratum while still preserving a random, spatially balanced sampling design. In addition, the spatially-balanced property of the sample is maintained when access to sampling units are not possible, such as when private landowners deny access permission or dangerous terrain exists.

A minimum of two sampling units within each stratum are required to estimate the variances of population parameters. However, reliable stratum-level occupancy estimates require larger samples sizes, with a minimum of approximately 10 samples per stratum. Furthermore, additional samples may be required for strata comprising large geographic areas. Because we estimate regional density and occupancy using an area-weighted mean, adding more samples to a particular stratum does not bias the overall estimate, it simply increases the precision. After the initial two sampling units were selected, the remaining allocation of sampling effort among strata was based on the priorities of the funding partners.

Sampling Methods

IMBCR surveyors (also referred to as field technician, technician or observer in this report), with excellent aural and visual bird identification skills, conducted field work in 2016 and 2017. 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.

Field technicians conducted point counts (Buckland 2006) following protocols established by IMBCR partners (Hanni et al. 2018). 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. 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. 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 vegetation 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.

The comparison of avian population density on CRP lands relative to agricultural lands represents a control-impact design (Morrison et al. 2008) for estimating the effect of restoring agricultural lands to CRP lands. The control-impact design for the comparison of avian population density on CRP lands and native grassland provides a way to evaluate habitat suitability of the CRP for various bird species. To evaluate the influence of CRP lands on bird populations in the PLJV region, we post-stratified (Thomas et al. 2010) the point count plots by three vegetation types, including agricultural lands, native grassland and CRP lands (Table 1). We used the primary vegetation type collected in the field through the IMBCR program to classify the land cover of each point count plot according to agricultural land and native grassland. We defined agricultural lands as agricultural or rural land planted for food production or ornamental purposes in sparsely developed areas (Hanni et al. 2016). We defined native grassland as grassland, sagebrush shrub-land, shrub-land, and desert or semi-desert shrub-land vegetation types (Hanni et al. 2016). We defined CRP lands by the Common Land Unit (CLU) geospatial dataset (USDA 2014) depicting the spatial distribution of lands enrolled in the CRP. We attributed point count locations falling inside the boundary of the CRP polygons within a Geographic Information System environment (ArcGIS Version 10.1, Environmental Systems Research Institute, Redlands, CA). We attributed the 2015 CRP data to the 2016 IMBCR data, and attributed the 2016 CRP data to the 2017 IMBCR data. For both years, we calculated the area of CRP (km^2) within the 43 strata in the PLJV region (Fig. 5). Overall, the area of the PLJV region was 642,782 km^2. Using the 2015 CLU data, CRP comprised 5.0% of the PLJV region in 2016 (32,404.63 km^2), and using the 2016 CLU data, CRP comprised 4.9% of the PLJV region in 2017 (31,248.10 km^2). We estimated the area of agricultural land and native grassland in the 43 strata of the PLJV region by multiplying the strata areas by the proportion of point counts containing agricultural land and native grassland, respectively.

Table 1. The sample sizes for the numbers of grid cells and point count plots for the post-stratification of the Playa Lakes Joint Venture region, 2016 and 2017.

Post-stratification	2016		2017	
	Grid cells	Point count plots	Grid cells	Point count plots
Agricultural lands	107	587	106	547
Native grassland	227	1,618	245	1,895
Conservation Reserve Program lands	28	143	28	131

We calculated weighted means and Standard Deviations (SD) of ground and shrub cover variables for the vegetation types across years according to the area of the vegetation types in each of the PLJV strata (Table 2). We tested for differences between the vegetation variable means *i* by calculating effect sizes ($\hat{\theta}_i$) using the difference $\hat{\theta}_i = \hat{x}_{\mathrm{CRP}_i} - \hat{x}_{\mathrm{Ref}_i}$, where $\hat{x}_{\mathrm{CRP}_i}$ is the mean of vegetation variable *i* for CRP lands and $\hat{x}_{\mathrm{Ref}_i}$ is the mean of vegetation variable *i* for the reference category. We calculated the SD and 90% Confidence Intervals (CI) for the effect size using the delta method (Powell 2007) to evaluate statistical support for the effect sizes. We found that live grass ground cover [$\hat{\theta}$ = -5.87; SD = 2.45; CI = -9.91, -1.83] and shrub canopy cover [$\hat{\theta}$ = -0.89; SD = 0.53; CI = -1.77, -0.01] were lower on CRP lands than native grasslands, whereas live grass height [$\hat{\theta}$ = 5.46; SD = 2.78; CI = 0.88, 10.04] and residual grass height [$\hat{\theta}$ = 14.86; SD = 5.93; CI = 5.10, 24.62] were greater on CRP lands than native grasslands (Table 2). Bare-litter ground cover [$\hat{\theta}$ = -11.88; SD = 4.74; CI = -19.69, -4.07] was lower on CRP lands than agricultural lands, whereas live grass height [$\hat{\theta}$ = 12.25; SD = 5.33; CI = 3.48, 21.03], residual grass ground cover [$\hat{\theta}$ = 3.74; SD = 1.84; CI = 0.71, 6.78] and residual grass height [$\hat{\theta}$ = 23.52; SD = 9.11; CI = 8.54, 38.51] were greater on CRP lands than agricultural reference lands (Table 2). The remaining comparisons between vegetation variables on CRP lands and reference lands were not considerably different (Table 2).

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 (Rocky Mountain Avian Data Center, www.rmbo.org/v3/avian/ExploretheData.aspx, accessed 5 Jun 2018). There you will find links to past and current protocols and data sheets.

Table 2. The means and Standard Deviations (SD) of ground and shrub cover variables for point count plots classified as agricultural lands, native grasslands and Conservation Reserve Program (CRP) lands, Playa Lakes Joint Venture (PLJV) region, 2016 and 2017.

Vegetation variables	CRP lands		Native grasslands		Agricultural lands	
	Mean	SD	Mean	SD	Mean	SD
Live grass ground cover (%)	9.22	1.14	15.09	2.17	9.75	4.35
Live grass height (cm)	25.04	1.79	19.58	2.13	12.79	5.02
Residual grass ground cover (%)	6.27	1.16	5.38	1.07	2.53	1.43
Residual grass height (cm)	44.29	5.14	29.44	2.96	20.77	7.52
Herbaceous ground cover (%)	5.82	2.10	3.71	0.89	3.30	1.46
Bare-litter ground cover (%)	71.68	1.99	74.41	2.44	83.56	4.31
Shrub canopy cover (%)	0.47	0.27	1.36	0.46	0.14	0.12
Shrub height (m)	0.26	0.27	0.35	0.44	0.15	0.12

Data Analysis

Distance 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, Thomas et al. 2010). The detection probability is used to adjust the count of birds to account for birds that were present but undetected (Fig. 4). The detection function model [*g*(*y*)] for the *y* distance data is of the general form $g(y) = \frac{k(y)[1+s(y)]}{k(0)[1+s(0)]}$, where *k*(*y*) is a parametric key function and *s*(*y*) is a series expansion that may be used to improve the fit of the function if necessary (Buckland et al. 2001, Marques et al. 2007). The denominator ensures detection probability is one at distance zero [*g*(0) = 1]. We considered two key functions to model the detection data including the half-normal $[k(y) = \exp(-y^2/2\sigma^2)]$ and hazard-rate $\{k(y) = 1 - \exp[-(y/\sigma)^{-b}]\}$ key functions. Both functions have a scale parameter, σ, which determines the rate at which the function decreases with increasing *y*, and the hazard-rate function has an additional shape parameter *b* (Buckland et al. 2001, Marques et al. 2007). The simple functional forms of the key functions may not adequately describe *g*(*y*). Therefore, the shape of *g*(*y*) can be adjusted by one or more series expansion terms and we considered the cosine term adjustment $\left[s(y) = \sum_{j=2}^{m} a_j \cos(j\pi y_s)\right]$, where *m* is the number of the *j* expansion terms and y_s are scaled values of the distance data *y* (Buckland et al. 2001, Marques et al. 2007). Application of distance sampling 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; 4) cluster sizes are recorded without error; and 5) the sampling units are representative of the entire survey region (Buckland et al. 2008).

Analysis of distance data includes fitting a detection function to the distribution of recorded distances (Buckland et al. 2001, Thomas et al. 2010). 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.

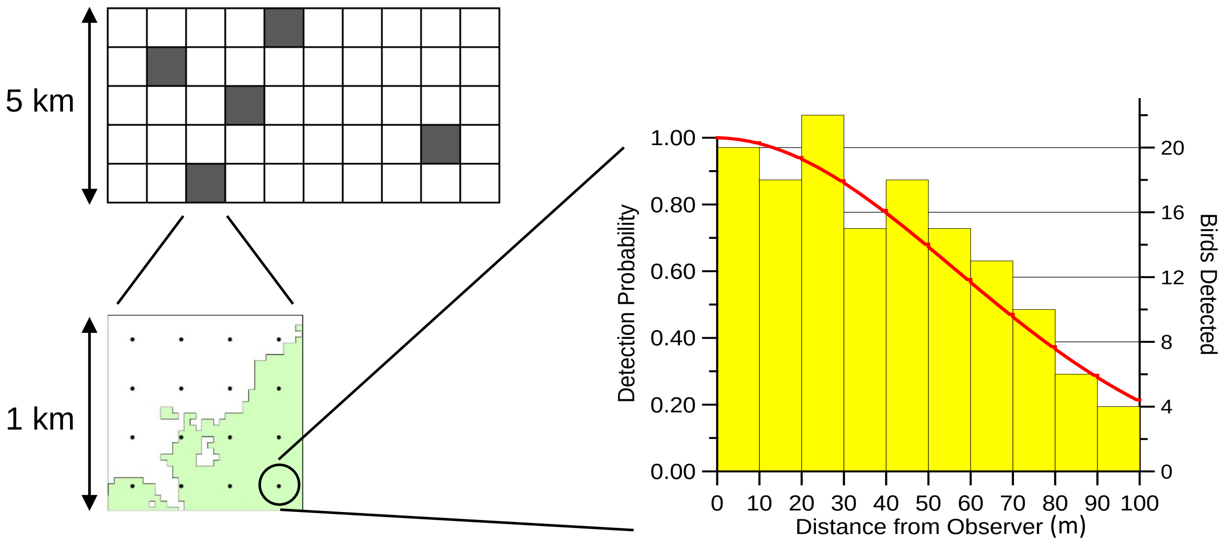

Figure 4. Distance sampling from the Integrated Monitoring in Bird Conservation Regions program, with grid cells nested within strata, point count plots nested within grid cells and distances nested within point count plots. The detection probability on the *y*-axis of the graph corresponds to the red-colored line for the detection function and birds detected on the *z*-axis corresponds to the histogram of the frequency of detections represented by the filled bars.

We estimated density for each species using a sequential framework where 1) year-specific detection functions were applied to species with greater than or equal to 80 detections per year ($n \geq 80$), 2) global detection functions were applied to species with less than 80 detections per year ($n < 80$) and greater than or equal to 80 detections over the life of the project ($n \geq 80$), and 3) remedial measures were used for species with moderate departures from the assumptions of distance sampling (Buckland et al. 2001).

We fit continuous models with no series expansions to all species and using the recommended 10% truncation for point transects. Truncating the largest 10% of the distance data shortened the tail and simplified the shape of the distributions, and this reduced the need to fit series expansions to accommodate distributions with long tails and complex shapes. For the year-specific detection functions, we fit Conventional Distance Sampling models using the half-normal and hazard-rate key functions with no series expansions (Thomas et al. 2010). For the global detection functions, in addition to the above models, we fit Multiple Covariate Distance Sampling models using half-normal and hazard-rate key function models with a categorical year covariate and no series expansions (Thomas et al. 2010). We selected the best detection function for each species using Akaike's Information Criterion adjusted for sample size (AIC_c, Burnham and Anderson 2002, Thomas et al. 2010) and considered the most parsimonious model as the estimation model. We estimated population size ($\widehat{N}$) for each stratum as $\widehat{N} = \widehat{D}*A$, where $\widehat{D}$ was the estimated population density and A was the number of 1 km^2 sampling units in each stratum. We calculated Satterthwaite 90% CIs for the estimates of density and population size for each stratum (Buckland et al., 2001). In addition, we combined the stratum-level density estimates at various spatial scales, such as management entity, State and BCR, using an area-weighted mean. For the combined density estimates, we estimated the variance for detection, cluster size and density using the delta method (Powell 2007) and the design-based estimator of Fewster et al. (2009).

We reviewed the highest ranking detection function for each species to check the shape criteria, evaluate the fit of the model and identify species with moderate departure from the assumptions of distance sampling (Buckland et al. 2001). First, we checked the shape criteria of the histogram to make sure the detection data exhibited a "shoulder" that fell away at increasing distances from the point. Second, we evaluated the fit of the model using the Kolmogorov-Smirnov goodness-of-fit test. Finally, we visually inspected the detection histograms to identify species that demonstrated evasive movement and/ or measurement errors. We looked for a type of measurement error involving the heaping of detections at certain distances that occurs when observers round detection distances. We also looked for histograms with detections that were highly skewed to the right, which may indicate a pattern of evasive movement (Buckland et al. 2001).

For species with moderate departures from the assumptions and shape criteria, we used two sequential remedial measures. First, we truncated the data to the point where detection probability was approximately 0.1 $[g(y) \sim 0.1]$ and second order cosine series-expansion terms $[s(y)]$ were applied to the half-normal and hazard-rate key function $[k(y)]$ models $\{k(y) \times [1 + s(y)]\}$ to accommodate additional wiggle in the distance distributions (Buckland et al. 2001). We did not include detection function models with a single cosine expansion term because the half-normal and hazard-rate models require the order of the terms are > 1 (Buckland et al. 2001). Second, when the goodness-of-fit test and/ or inspection of the detection histogram continued to suggest evasive movement and/or measurement errors, we grouped the distance data into four to eight bins and applied custom truncation and second order expansion terms to the half-normal and hazard rate models. These remedial measures can ameliorate problems associated with moderate levels of evasive movement and/or distance measurement errors (Buckland et al. 2001).

In addition to the general analysis above, we estimated the densities and population sizes for all species occurring in the PLJV Region in 2016 and 2017 by post-stratifying the point-count data into three mutually exclusive vegetation types (Thomas et al. 2010): agricultural lands, CRP lands and native grassland. We estimated density and population size for each of the 43 strata within the PLJV region, and aggregated the estimates for each post-stratification at the level of the PLJV region using an area-weighted mean and the delta method (Powell 2007, Pavlacky et al. 2017). We estimated effect sizes $(\hat{\Delta})$ for differences in mean population density between CRP and reference lands using $\hat{\Delta} = \hat{d}_{\text{CRP}} - \hat{d}_{\text{Ref}}$, where $\hat{d}_{\text{CRP}}$ is the estimated population density (km^{-2}) for CRP in the PLJV region and $\hat{d}_{\text{Ref}}$ is the estimated population density (km^{-2}) for agricultural lands or native grassland in the PLJV region. We evaluated statistical support for the effect sizes by evaluating 90% CIs for the difference in the means relative to zero. We estimated the CRP percent contribution to the regional bird population in the PLJV region $(\hat{\delta})$ using $\hat{\delta} = (\hat{N}_{\text{CRP}}/\hat{N}_{\text{PLJV}}) \times 100$, where $\hat{N}_{\text{CRP}}$ is the estimated population size on CRP lands in the PLJV region and $\hat{N}_{\text{PLJV}}$ is the estimated population size in the PLJV region from the IMBCR program. We estimated the standard errors for the effect sizes and percent contribution using the delta method (Powell 2007, Pavlacky et al. 2017). We presented symmetric 90% CIs for the effect sizes and asymmetric $\log_e$ CIs for the percent contribution to the population sizes. We considered the contribution to population size to be in proportion to the availability of CRP when the CI included the percentage of CRP implemented in the PLJV region.

Automated Analysis

We estimated population density using point transect distance sampling within a modified version of the R package RIMBCR (R Version 3.4.3, www.r-project.org, accessed 5 April 2018). The RIMBCR package called the raw data from the IMBCR Structured Query Language Server database and incorporated the R code created in previous years. We allowed the input of all data collected in a manner consistent with the IMBCR design to increase the number of detections available for estimating global detection rates for population density and site occupancy. The RIMBCR package used the R package mrds (Thomas et al. 2010) to fit the point transect distance sampling model. The hierarchical design of the IMBCR program allowed stratum-level estimates to be aggregated-up at multiple scales (Pavlacky et al. 2017), and the RIMBCR package provided an automated framework for combining strata-level estimates of population density at multiple spatial scales, as well as approximating the standard errors and CIs for the combined estimates.

Results

Playa Lakes Joint Venture

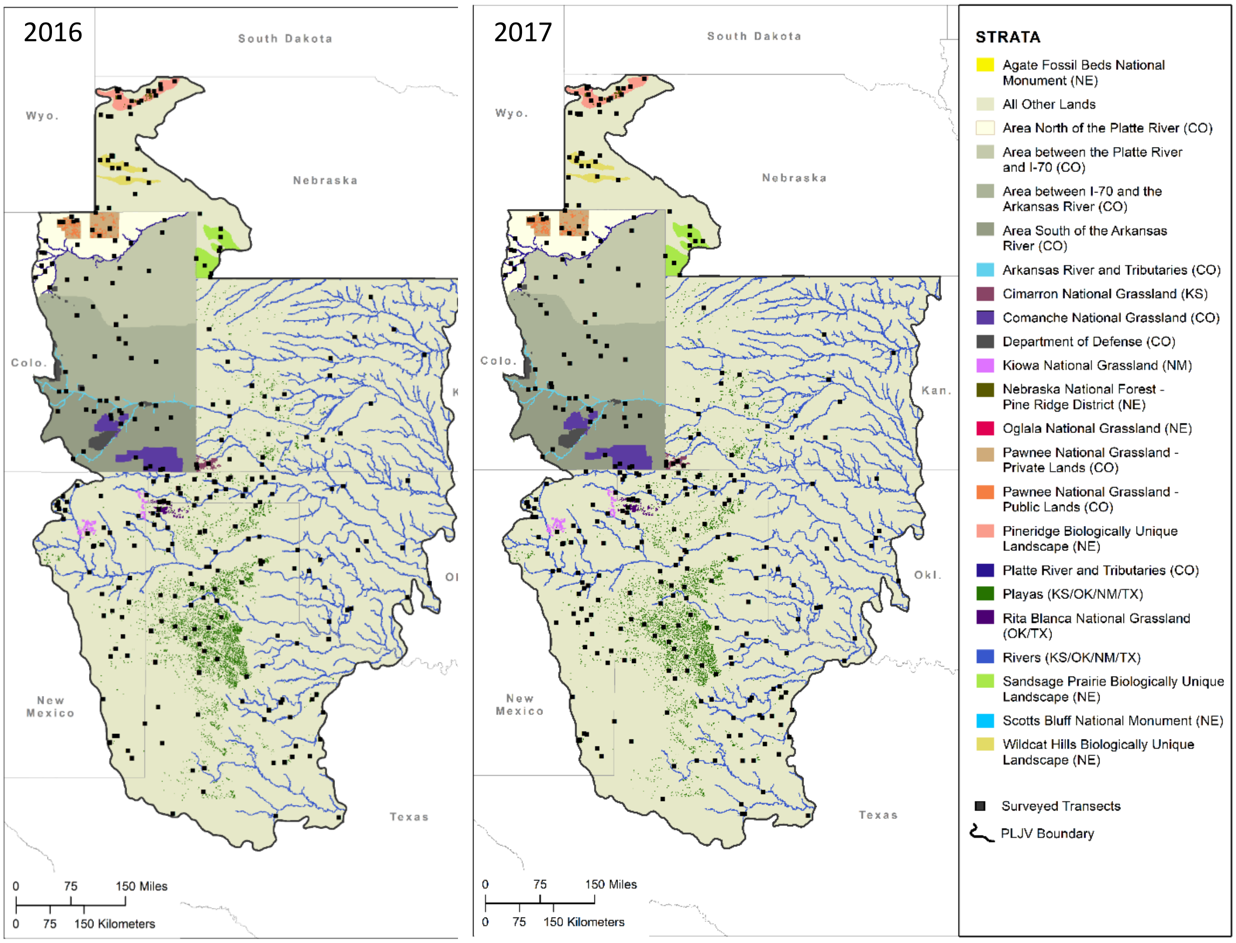

Figure 5. Survey locations and strata in the Playa Lakes Joint Venture (PLJV) region during 2016 and 2017. The black square symbols represent the survey locations and the color coded regions represent the strata.

Playa Lakes Joint Venture Total

In 2016, the Playa Lakes Joint Venture (PLJV) coordinated a partnership between several state wildlife agencies and Bird Conservancy to expand sampling in five of the joint venture's six states: Nebraska, Kansas, New Mexico, Oklahoma, and Texas. PLJV's sixth state, Colorado, was already included in the IMBCR program starting in 2008. This expansion now provides the program with nearly complete coverage of two BCRs that were only sparsely covered in past years: Shortgrass Prairie (BCR 18) and Central Mixed Grass Prairie (BCR 19). The BCR 18 and 19 portions of these 5 states were divided into several strata, including, playas, rivers, biologically unique landscapes in Nebraska, and all other lands.

With the expansion of IMBCR throughout the PLJV region, several existing strata needed to be fit to the US National Grid to make them consistent with the rest of the IMBCR program in the region: Cimarron, Kiowa, and Rita Blanca National Grasslands in Kansas, Oklahoma, New Mexico, and Texas. In addition, we determined that the portion of Rita Blanca National Grassland that fell in New Mexico was actually managed by Kiowa National Grassland, so that

We obtained results for the Playa Lakes Joint Venture area by compiling and jointly analyzing data from 43 Strata in six states (Fig. 5).

Field technicians completed 300 of 330 planned surveys (90.9%) in 2016. Technicians conducted 2,847 point counts within the 300 surveyed grid cells between 26 April and 9 July. They detected 226 bird species.

Bird Conservancy estimated densities and population sizes for 156 species during 2016. The data yielded robust density estimates (CV < 50%) for 65 of these species.

Field technicians completed all 330 planned surveys (100%) in 2017. Technicians conducted 3169 point counts within the 330 surveyed grid cells between April 24 and July 11. They detected 220 bird species.

We estimated densities and population sizes for 156 species during 2017. The data yielded robust density estimates (CV < 50%) for 75 of these species.

To view a map of survey locations, density results and species counts within the Playa Lakes Joint Venture area across all years of the project follow the web link below and hit the “Run Query” button highlighted in red located near the top of the page. If you want to limit results to 2016 or 2017, after you click on the link below select “Year” from the Filter drop down box on the top left of the screen. Hit the “Add” button, select the year, hit “Add Filter”, then “Run Query”.

Playa Lakes Joint Venture Results

Avian Density in CRP relative to Agricultural Lands and Native Grassland

We estimated avian population densities for CRP lands, agricultural lands and native grassland within the PLJV region in 2016 and 2017 (Fig. 5, Table 1S, available in Supporting Information). We presented the effect sizes for the comparison of avian population density in CRP lands relative to agricultural lands in Table 3, and CRP lands relative native grassland in Table 4, respectively. We presented the results for grassland obligate and facultative species (Vickery and Herkert 1999) in the text below, but presented the results for all 53 bird species observed on CRP lands in the tables.

Avian population densities on CRP lands were greater than agricultural lands in both 2016 and 2017 for the Cassin’s sparrow (*Peucaea cassinii*), grasshopper sparrow (*Ammodramus savannarum*), lark bunting (*Calamospiza melanocorys*) and mourning dove (*Zenaida macroura*, Table 3, Table 1S, available in Supporting Information). In contrast, the brown-headed cowbird (*Molothrus ater*), horned lark (*Eremophila alpestris*) and red-winged blackbird (*Agelaius phoeniceus*) showed lower population densities on CRP lands than agricultural lands in both 2016 and 2017 (Table 3, Table 1S, available in Supporting Information). The population density of the American kestrel (*Falco sparverius*), Chihuahuan raven (*Corvus cryptoleucus*), common nighthawk (*Chordeiles minor*), dickcissel (*Spiza americana*), ring-necked pheasant (*Phasianus colchicus*), scaled quail (*Callipepla squamata*), Swainson’s hawk (*Buteo swainsoni*), turkey vulture (*Cathartes aura*) and western meadowlark (*Sturnella neglecta*) showed similar population densities on CRP lands and agricultural lands in both years (Table 3, Table 1S, available in Supporting Information).

Table 3. The effect sizes for differences in avian population density between Conservation Reserve Program (CRP) and agricultural lands within the Playa Lakes Joint Venture Region, 2016 and 2017. The effects represent population density of bird species on CRP lands (km^{-2}) minus population density (km^{-2}) on agricultural lands, and the Standard Error (SE), and Lower (LCL) and Upper (UCL) 90% Confidence Limits, respectively represent the precision of the effect sizes. The bold values represent measureable effect sizes with 90% Confidence Intervals excluding zero.

Species	2016				2017			
	Effect	SE	LCL	UCL	Effect	SE	LCL	UCL
American Kestrel	-0.24	0.11	-0.42	-0.06	0.34	0.36	-0.26	0.95
Ash-throated Flycatcher	-	-	-	-	**0.34**	**0.02**	**0.31**	**0.37**
Barn Swallow	**-8.69**	**2.85**	**-13.38**	**-4.00**	-8.46	5.87	-18.12	1.21
Bell's Vireo	-	-	-	-	-2.19	1.38	-4.47	0.08
Brown-headed Cowbird	**-8.71**	**4.21**	**-15.65**	**-1.78**	**-28.54**	**6.46**	**-39.17**	**-17.92**
Blue Grosbeak	-0.01	0.02	-0.04	0.02	0.09	0.94	-1.45	1.64
Blue Jay	-	-	-	-	-0.99	1.02	-2.67	0.69
Brewer's Sparrow	0.33	0.25	-0.10	0.75	-	-	-	-
Brown Thrasher	-0.17	0.21	-0.53	0.18	-	-	-	-
Bullock's Oriole	1.03	0.99	-0.61	2.67	**-0.33**	**0.14**	**-0.57**	**-0.10**
Blue-winged Teal	-	-	-	-	-0.02	0.03	-0.07	0.03
Cassin's Sparrow	**18.70**	**4.76**	**10.87**	**26.53**	**21.01**	**8.70**	**6.70**	**35.32**
Curve-billed Thrasher	-	-	-	-	-	-	-	-
Chihuahuan Raven	0.27	0.35	-0.32	0.85	0.04	0.10	-0.14	0.21
Cliff Swallow	**-1.37**	**0.65**	**-2.45**	**-0.30**	**73.37**	**14.85**	**48.94**	**97.80**
Common Grackle	**-1.21**	**1.75**	**-4.10**	**1.67**	-16.00	11.36	-34.69	2.69
Common Nighthawk	-1.33	0.98	-2.95	0.30	-0.17	0.44	-0.90	0.56
Common Raven	<0.01	<0.01	-0.01	0.01	-	-	-	-
Dickcissel	2.46	7.47	-9.84	14.76	8.79	6.46	-1.84	19.41
Eastern Meadowlark	-1.39	2.63	-5.72	2.94	**3.96**	**0.96**	**2.39**	**5.54**
Eurasian Collared-Dove	0.61	0.52	-0.24	1.47	**-2.46**	**0.70**	**-3.61**	**-1.31**
European Starling	-	-	-	-	**-0.98**	**0.47**	**-1.75**	**-0.21**
Great Blue Heron	0.17	0.15	-0.09	0.43	-	-	-	-
Golden-fronted Woodpecker	-	-	-	-	-0.13	0.14	-0.36	0.10
Great Horned Owl	-0.08	0.96	-1.66	1.49	-	-	-	-
Grasshopper Sparrow	**74.56**	**17.27**	**46.14**	**102.98**	**69.03**	**14.68**	**44.87**	**93.19**
Great-tailed Grackle	0.13	1.43	-2.23	2.48	-	-	-	-
Horned Lark	**-39.60**	**13.89**	**-62.46**	**-16.74**	**-21.63**	**8.41**	**-35.46**	**-7.80**
House Sparrow	**9.73**	**5.19**	**1.19**	**18.27**	-1.66	10.18	-18.42	15.10
Killdeer	**-2.00**	**1.05**	**-3.73**	**-0.27**	-2.89	2.07	-6.31	0.52
Lark Bunting	**11.89**	**4.21**	**4.95**	**18.82**	**8.98**	**1.84**	**5.95**	**12.01**
Lark Sparrow	**-2.59**	**1.25**	**-4.66**	**-0.52**	1.95	4.44	-5.35	9.25
Long-billed Curlew	0.28	0.34	-0.29	0.84	**0.15**	**0.06**	**0.05**	**0.25**
Lesser Prairie-Chicken	**0.20**	**0.05**	**0.11**	**0.30**	-	-	-	-
Loggerhead Shrike	<0.01	<0.01	-0.02	0.01	-	-	-	-
Mallard	-	-	-	-	-0.10	0.09	-0.25	0.04
Mourning Dove	**7.69**	**3.77**	**1.48**	**13.90**	**6.60**	**2.49**	**2.49**	**10.70**
Northern Bobwhite	**3.74**	**1.25**	**1.67**	**5.80**	-0.02	0.88	-1.47	1.43
Northern Cardinal	-	-	-	-	**-2.87**	**1.26**	**-4.96**	**-0.79**
Northern Mockingbird	**-1.02**	**0.45**	**-1.76**	**-0.29**	**-3.26**	**1.45**	**-5.65**	**-0.87**

Species	2016				2017			
	Effect	SE	LCL	UCL	Effect	SE	LCL	UCL
Orchard Oriole	0.40	0.59	-0.58	1.39	-	-	-	-
Ring-necked Pheasant	-0.28	0.99	-1.91	1.36	0.41	0.99	-1.23	2.04
Rock Pigeon	**0.57**	**0.20**	**0.25**	**0.90**	-	-	-	-
Red-tailed Hawk	-	-	-	-	-0.71	0.47	-1.48	0.07
Red-winged Blackbird	**-11.42**	**5.91**	**-21.16**	**-1.69**	**-14.06**	**7.31**	**-26.09**	**-2.04**
Scaled Quail	1.02	0.74	-0.21	2.25	0.54	0.65	-0.55	1.62
Scissor-tailed Flycatcher	-0.85	0.74	-2.07	0.36	-	-	-	-
Swainson's Hawk	0.02	0.33	-0.54	0.57	0.35	0.29	-0.13	0.82
Turkey Vulture	0.01	0.01	-0.01	0.03	-0.29	0.22	-0.65	0.08
Western Kingbird	**8.99**	**5.32**	**0.24**	**17.74**	10.73	8.58	-3.39	24.85
Western Meadowlark	3.69	3.70	-2.40	9.78	4.29	3.38	-1.27	9.85
Yellow-billed Cuckoo	-	-	-	-	-1.13	0.83	-2.51	0.24
Yellow-headed Blackbird	-0.11	0.45	-0.86	0.64	-	-	-	-

Population density was greater on CRP lands than native grasslands for the dickcissel, long-billed curlew (*Numenius americanus*), mourning dove and northern bobwhite in both 2016 and 2017 (Table 4, Table 1S, available in Supporting Information). Population density of the brown-headed cowbird, Cassin's sparrow, eastern meadowlark (*S. magna*), grasshopper sparrow, horned lark, loggerhead shrike (*Lanius ludovicianus*), scaled quail and Swainson's hawk was similar in CRP lands and native grassland in both years (Table 4, Table 1S, available in Supporting Information).

Table 4. The effect sizes for differences in avian population density between Conservation Reserve Program (CRP) and native grassland within the Playa Lakes Join Venture Region, 2016 and 2017. The effects represent population density of bird species on CRP lands (km^{-2}) minus population density (km^{-2}) on native grasslands, and the Standard Error (SE), and Lower (LCL) and Upper (UCL) 90% Confidence Limits, respectively represent the precision of the effect sizes. The bold values represent measureable effect sizes with 90% Confidence Intervals excluding zero.

Species	2016				2017			
	Effect	SE	LCL	UCL	Effect	SE	LCL	UCL
American Kestrel	**-0.14**	**0.05**	**-0.22**	**-0.05**	0.32	0.36	-0.28	0.92
Ash-throated Flycatcher	-	-	-	-	-0.12	0.31	-0.63	0.40
Barn Swallow	**-10.30**	**3.30**	**-15.73**	**-4.88**	**-15.34**	**4.83**	**-23.30**	**-7.39**
Bell's Vireo	-	-	-	-	-0.22	0.14	-0.46	0.03
Brown-headed Cowbird	-4.51	2.98	-9.43	0.40	-2.44	1.67	-5.20	0.32
Blue Grosbeak	**-0.25**	**0.11**	**-0.43**	**-0.07**	0.57	0.83	-0.80	1.95
Blue Jay	-	-	-	-	**0.58**	**0.23**	**0.19**	**0.96**
Brewer's Sparrow	-0.17	0.49	-0.99	0.64	-	-	-	-
Brown Thrasher	-0.23	0.26	-0.66	0.21	-	-	-	-
Bullock's Oriole	1.03	0.99	-0.60	2.65	**-0.39**	**0.17**	**-0.67**	**-0.11**
Blue-winged Teal	-	-	-	-	-0.18	0.18	-0.49	0.12
Cassin's Sparrow	2.27	6.05	-7.69	12.23	3.73	8.98	-11.05	18.52
Curve-billed Thrasher	-0.07	0.06	-0.17	0.04	-	-	-	-
Chihuahuan Raven	**0.62**	**0.23**	**0.23**	**1.00**	-0.12	0.13	-0.35	0.10
Cliff Swallow	**-2.50**	**0.91**	**-4.00**	**-1.00**	**84.73**	**13.38**	**62.71**	**106.74**
Common Grackle	0.04	1.58	-2.57	2.65	-0.81	1.68	-3.58	1.96
Common Nighthawk	**0.41**	**0.14**	**0.17**	**0.65**	-0.19	0.16	-0.46	0.08
Common Raven	**-0.16**	**0.10**	**-0.32**	**0.00**	-	-	-	-
Dickcissel	**14.72**	**5.87**	**5.07**	**24.37**	**23.11**	**3.72**	**16.99**	**29.23**
Eastern Meadowlark	0.81	2.89	-3.95	5.56	-1.48	1.40	-3.79	0.82
Eurasian Collared-Dove	**1.11**	**0.47**	**0.34**	**1.89**	**-0.93**	**0.30**	**-1.43**	**-0.44**
European Starling	-	-	-	-	**-1.60**	**0.65**	**-2.68**	**-0.52**
Great Blue Heron	0.18	0.15	-0.08	0.44	-	-	-	-
Golden-fronted Woodpecker	-	-	-	-	-0.26	0.18	-0.56	0.04
Great Horned Owl	0.58	0.75	-0.67	1.82	-	-	-	-
Grasshopper Sparrow	17.54	17.82	-11.78	46.87	21.50	14.42	-2.23	45.22
Great-tailed Grackle	0.56	0.83	-0.80	1.93	-	-	-	-
Horned Lark	-12.73	13.69	-35.26	9.80	-0.77	5.35	-9.57	8.03
House Sparrow	**13.87**	**4.36**	**6.69**	**21.05**	**13.18**	**5.66**	**3.86**	**22.50**
Killdeer	**1.54**	**0.82**	**0.19**	**2.89**	0.52	1.68	-2.26	3.30
Lark Bunting	-2.46	3.85	-8.80	3.88	**-9.70**	**3.89**	**-16.10**	**-3.30**
Lark Sparrow	**-8.13**	**2.37**	**-12.05**	**-4.22**	-1.37	4.38	-8.58	5.84
Long-billed Curlew	**0.54**	**0.13**	**0.32**	**0.77**	**0.13**	**0.06**	**0.02**	**0.24**
Lesser Prairie-Chicken	-0.34	0.32	-0.87	0.19	-	-	-	-
Loggerhead Shrike	-0.12	0.08	-0.27	0.02	-0.07	0.11	-0.26	0.13
Mallard	-	-	-	-	-0.17	0.17	-0.45	0.11
Mourning Dove	**6.78**	**3.84**	**0.46**	**13.11**	**10.79**	**2.41**	**6.82**	**14.77**
Northern Bobwhite	**3.91**	**1.25**	**1.84**	**5.98**	**1.99**	**0.56**	**1.06**	**2.91**
Northern Cardinal	-	-	-	-	**-0.75**	**0.29**	**-1.22**	**-0.27**
Northern Mockingbird	**-1.71**	**0.42**	**-2.40**	**-1.02**	**-1.49**	**0.33**	**-2.04**	**-0.94**

Species	2016				2017			
	Effect	SE	LCL	UCL	Effect	SE	LCL	UCL
Orchard Oriole	0.49	0.34	-0.08	1.06	-	-	-	-
Ring-necked Pheasant	1.34	0.97	-0.26	2.94	**2.98**	**0.90**	**1.50**	**4.46**
Rock Pigeon	**0.64**	**0.15**	**0.39**	**0.88**	-	-	-	-
Red-tailed Hawk	-	-	-	-	-0.04	0.04	-0.11	0.03
Red-winged Blackbird	4.91	4.96	-3.25	13.07	**10.52**	**4.36**	**3.34**	**17.71**
Scaled Quail	0.14	1.11	-1.70	1.98	0.03	0.69	-1.11	1.17
Scissor-tailed Flycatcher	-0.92	0.75	-2.16	0.32	-	-	-	-
Swainson's Hawk	0.29	0.28	-0.18	0.77	0.31	0.29	-0.17	0.78
Turkey Vulture	**-0.28**	**0.16**	**-0.55**	**-0.01**	-0.30	0.19	-0.61	0.02
Western Kingbird	**9.82**	**5.32**	**1.07**	**18.58**	12.68	8.33	-1.03	26.39
Western Meadowlark	**-7.84**	**4.41**	**-15.10**	**-0.58**	-2.03	2.68	-6.44	2.38
Yellow-billed Cuckoo	-	-	-	-	**0.18**	**0.05**	**0.09**	**0.27**
Yellow-headed Blackbird	0.30	0.37	-0.32	0.91	-	-	-	-

Contributions to Regional Population Sizes

The land enrolled in the CRP program accounted for 5.0% of the PLJV region in 2016 and 4.9% of the PLJV region in 2017. We present grassland bird species (Vickery and Herkert 1999) with CRP contributions to population sizes in 2016 and 2017 that were proportional to the the area of CRP implemented in the PLJV region and species with contributions greater than the percentages of CRP implemented in the region. Population contributions with confidence intervals including the area of CRP in the region were considered proportional to the area of CRP.

The CRP program accounted for less than 5.0% ($\hat{\delta}$ < 0.1%, CI = 0.0 - 0.1) of the American kestrel population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information). In 2017, the CRP program conserved 18.0% (CI = 3.7 - 86.3) of the American kestrel population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 9,952, CI = 1,114 - 88,841) was in proportion to availability of CRP within the region.

Land enrolled in the CRP program accounted for 7.1% (CI = 4.7 - 10.8) of the Cassin's sparrow population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 651,286, CI = 375,655 - 1,129,156) was in proportion to availability of CRP within the region. In 2017, the CRP program conserved 6.4% (CI = 3.5 - 11.7) of the Cassin's sparrow population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 599,657, CI = 235,106 - 1,529,471) was in proportion to availability of CRP within the region.

Land enrolled in the CRP program conserved 15.5% (CI = 5.4 - 44.0) of the Chihuahuan raven population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), corresponding to a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 18,534, CI = 10,144 - 33,860). In 2017, the CRP program conserved 2.7% (CI = 0.8 - 8.4) of the Chihuahuan raven population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 3,164, CI = 900 - 11,121) was in proportion to availability of CRP in the region.

The CRP program conserved 3.5% (CI = 1.5 - 7.8) of the common nighthawk population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 17,745, CI = 12,318 - 25,563) was in proportion to availability of CRP in the region. In 2017, the CRP program accounted for 2.7% (CI = 1.4 - 5.1) of the common nighthawk population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 7,588, CI = 6,930 - 8,308) was in proportion to availability of CRP in the region.

Land enrolled in CRP program accounted for 7.4% (CI = 4.5 - 12.2) of the dickcissel population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 697,052, CI = 479,913 - 1,012,436) was in proportion to availability of CRP in the region. In 2017, the CRP program conserved 8.2% (CI = 6.0 - 11.2) of the dickcissel population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), corresponding to a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 857,390, CI = 790,427 - 930,026).

The CRP program accounted for 4.8% (CI = 2.5 - 9.0) of the eastern meadowlark population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 199,855, CI = 108,734 - 367,337) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 4.8% (CI = 3.2 - 7.2) of the eastern meadowlark population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 137,896, CI = 82,504 - 230,477) was in proportion to availability of CRP in the region.

The CRP program conserved 8.9% (CI = 6.5 - 12.1) of the grasshopper sparrow population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), representing a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 3,130,846, CI = 2,306,728 - 4,249,392). In 2017, the CRP program contributed to 8.8% (CI = 6.4 - 12.0) of the grasshopper sparrow population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), corresponding to a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 2,128,493, CI = 1,406,965 - 3,220,037).

Land enrolled in CRP program accounted for 4.0% (CI = 2.7 - 6.0) of the horned lark population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 1,399,777, CI = 500,846 - 3,912,130) was in proportion to availability of CRP in the region. In 2017, the CRP program accounted for less than 4.9% ($\hat{\delta}$ < 3.8%, CI = 3.1 - 4.7) of the horned lark population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information).

The CRP program conserved 4.9% (CI = 3.0 - 8.0) of the killdeer population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 86,249, CI = 51,002 - 145,854) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 3.1% (CI = 0.9 - 9.5) of the killdeer population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 59,658, CI = 11,201 - 317,723) was in proportion to availability of CRP in the region.

Land enrolled in CRP program accounted for 6.3% (CI = 5.0 - 7.8) of the lark bunting population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), representing a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 745,806, CI = 696,502 - 798,600). In 2017, the CRP program conserved 4.6% (CI = 3.6 - 5.9) of the lark bunting population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 356,147, CI = 297,303 - 426,638) was in proportion to availability of CRP in the region.

The CRP program accounted for less than 5.0% ($\hat{\delta}$ = 0.7%, CI = 0.2 - 2.8) of the lark sparrow (*Chondestes grammacus*) population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information). In 2017, the CRP program contributed to 4.0% (CI = 1.1 - 14.7) of the lark sparrow population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 133,751, CI = 18,406 - 971,905) was in proportion to availability of CRP in the region.

Land enrolled in CRP program accounted for less than 5.0% ($\hat{\delta}$ < 0.1%, CI = 0.0 - 0.2) of the loggerhead shrike population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information). In 2017, the CRP program contributed to 1.7% (CI = 0.1 - 17.3) of the loggerhead shrike population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 1,746, CI = 3 - 934,126) was in proportion to availability of CRP in the region.

Land enrolled in CRP program conserved 40.5% (CI = 9.3 - 176.0) of the long-billed curlew population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), corresponding to a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 16,398, CI = 11,438 - 23,507). In 2017, the CRP program accounted for 10.1% (CI = 4.1 - 24.3) of the long-billed curlew population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 4,478, CI = 968 - 20,712) was in proportion to availability of CRP in the region.

The CRP program conserved 6.8% (CI = 4.6 - 10.0) of the mourning dove population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 485,860, CI = 292,391 - 807,340) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 6.3% (CI = 4.8 - 8.2) of the mourning dove population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 409,873, CI = 224,914 - 746,934) was in proportion to availability of CRP in the region.

Land enrolled in CRP program accounted for 6.7% (CI = 4.7 - 9.3) of the northern bobwhite population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 204,962, CI = 156,943 - 267,673) was in proportion to availability of CRP in the region. In 2017, the CRP program conserved less than 4.9% ($\hat{\delta}$ = 3.2%, CI = 2.4 - 4.3) of the northern bobwhite population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information).

The CRP program conserved 3.9% (CI = 2.1 - 7.3) of the red-winged blackbird population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 356,592, CI = 173,434 - 733,173) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 3.2% (CI = 1.8 - 5.6) of the red-winged blackbird population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 356,850, CI = 176,554 - 721,260) was in proportion to availability of CRP in the region.

The CRP program conserved 7.4% (CI = 3.2 - 16.6) of the ring-necked pheasant population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 56,498, CI = 15,940 - 200,252) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 7.7% (CI = 4.9 - 12.0) of the ring-necked pheasant population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), corresponding to a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 90,085, CI = 48,414 - 167,622).

Land enrolled in CRP program accounted for 3.0% (CI = 1.3 - 6.6) of the scaled quail population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 46,440, CI = 16,411 - 131,413) was in proportion to availability of CRP in the region. In 2017, the CRP program conserved 3.0% (CI = 0.9 - 10.2) of the scaled quail population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 21,447, CI = 5,403 - 85,128) was in proportion to availability of CRP in the region.

The CRP program conserved 7.3% (CI = 1.7 - 30.0) of the Swainson's hawk population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 10,156, CI = 1,168 - 88,270) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 17.5% (CI = 4.9 - 62.4) of the Swainson's hawk population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), corresponding to a population size proportionally greater than the availability of CRP ($\widehat{N}$ = 9,791, CI = 1,678 - 57,132).

Land enrolled in CRP program accounted for 9.2% (CI = 4.6 - 18.3) of the western kingbird population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 379,687, CI = 135,666 - 1,062,627) was in proportion to availability of CRP in the region. In 2017, the CRP program conserved 8.0% (CI = 3.5 - 18.0) of the western kingbird population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 443,898, CI = 133,434 - 1,476,722) was in proportion to availability of CRP in the region.

The CRP program conserved 5.0% (CI = 3.9 - 6.4) of the western meadowlark population in the PLJV region in 2016 (Fig. 6, Table 1S, available in Supporting Information), and because the CI included the area of CRP in the region (5.0%), the contribution to population size ($\widehat{N}$ = 731,848, CI = 539,820 - 992,184) was in proportion to availability of CRP in the region. In 2017, the CRP program contributed to 4.6% (CI = 3.6 - 5.7) of the western meadowlark population in the PLJV region (Fig. 6, Table 1S, available in Supporting Information), but because the CI included the area of CRP in the region (4.9%), the contribution to population size ($\widehat{N}$ = 533,767, CI = 412,183 - 691,213) was in proportion to availability of CRP in the region.

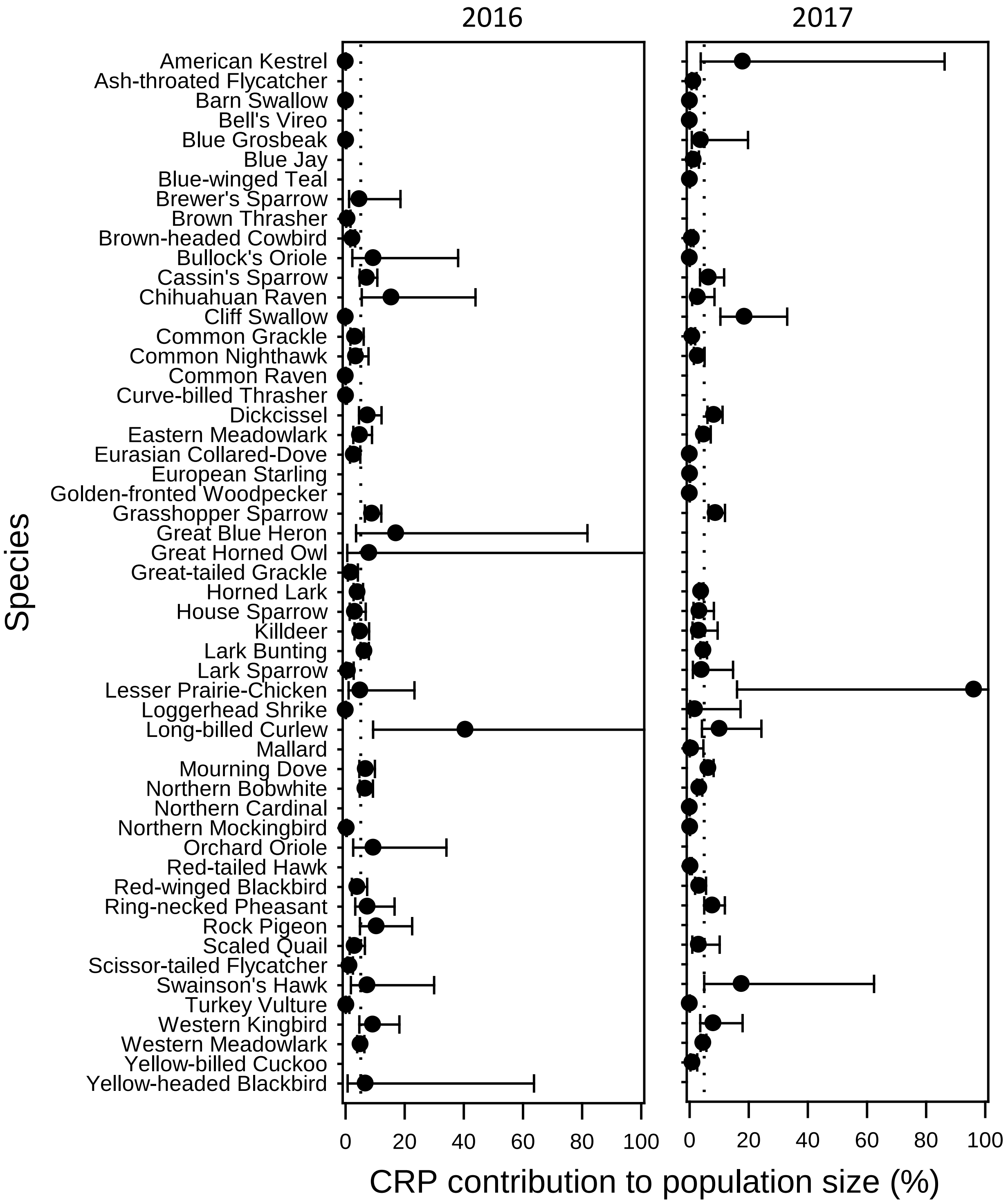

Figure 6. The contribution of the Conservation Reserve Program (CRP) to avian population sizes in the Playa Lakes Joint Venture (PLJV), 2016 and 2017. The symbols represent the percentage of the bird populations conserved by CRP in the PLJV region and the error bars are 90% Confidence Intervals for the percentage. The vertical dashed lines represent 5.0% and 4.9% of the PLJV region enrolled in CRP during 2016 and 2017, respectively.

Discussion

We developed a post-stratification framework for the IMBCR program to monitor the effectiveness of CRP for increasing the abundance of grassland birds relative to agricultural lands and native grassland. We estimated population size to evaluate contributions of CRP lands to bird populations in the PLJV region. We predicted the population density of grassland bird species would be greater on CRP lands than agricultural lands, and hypothesized that habitat suitability would be lower on CRP lands than native prairie. We found CRP increased the abundance of several obligate and generalist grassland species (Vickery and Herkert 1999) relative to agricultural lands. Although we found some evidence for lower habitat suitability on CRP lands relative to native prairie, a greater number of species showed either no difference or greater habitat suitability on CRP lands relative to native prairie. For the most part, the effects were consistent with known life history and habitat affiliations of the species (Knopf 1996). We did not expect positive effects of CRP for species that require keystone habitat features or disturbance related habitat features. For example, we did not expect positive effects of CRP for grassland obligates, such as the burrowing owl, which depends on prairie dog (*Cynomys* spp.) colonies, or the horned lark and mountain plover, that depend on grazing disturbance with short grass and bare ground conditions (Knopf 1996). Likewise, we did not expect positive effects of CRP for grassland generalists such as the field sparrow and western kingbird, that favor old fields with shrub and tree components (Knopf 1996), or killdeer and red-winged blackbird that often use grasslands adjacent to wetlands. We found large contributions of CRP to the grasshopper sparrow population in the PLJV region, and CRP contributed to regional populations in proportion to availability for a wide range of obligate and generalist grassland species. The following discussion begins with a treatment of obligate and generalist grassland species expected to benefit from CRP, and we indicate when a species did not conform to expectations. We finish by discussing the role effectiveness monitoring plays in managing CRP to meet conservation objectives for grassland birds in the southern Great Plains.

We predicted habitat suitability for grassland bird species would be greater on CRP than agricultural lands, and there was strong evidence for greater population densities of the Cassin's sparrow, grasshopper sparrow, lark bunting and mourning dove on CRP relative to agricultural lands. We did not find consistent differences across years for the remaining grassland species, which suggested the response of these species to the enrollment or expiration of CRP over time is not well understood. Several grassland species showed greater abundance on agricultural lands than expected (Table 1S, available in Supporting Information), suggesting it may be incorrect to assume agricultural lands provide no habitat for these species. However, the agricultural land designation from the IMBCR program includes both cropland and rural vegetation, and future post-stratification may be improved by a GIS exercise to separate cropland and rural vegetation. We found bare-litter ground cover was lower on CRP lands relative to agricultural lands, and an although live grass ground cover was similar, live grass height, residual grass ground cover and residual grass height was much greater on CRP lands relative to agricultural lands. The population density of the brown-headed cowbird was consistently lower on CRP lands than agricultural lands. The low density of brown-headed cowbirds may correspond to low rates of nest parasitism on CRP lands, which may improve nesting success for the dickcissel, eastern meadowlark, grasshopper sparrow, lark bunting, lark sparrow, loggerhead shrike and western meadowlark (Shaffer et al. 2004).

We hypothesized grassland birds would exhibit lower habitat suitability on CRP lands than on native grassland, and found some evidence for lower densities of the ash-throated flycatcher, lark bunting, lark sparrow, turkey vulture and western meadowlark on CRP lands relative to native grassland. Otherwise we were unable to find consistent evidence across years for lower avian population densities on CRP lands relative to native grassland. In contrast to our predictions, we found consistent evidence across years for greater population densities on CRP lands relative to native prairie for the dickcissel, long-billed curlew, mourning dove and northern bobwhite. We found live grass ground cover and shrub canopy cover was lower on CRP lands relative to native grasslands, whereas live grass height and residual grass height were greater on CRP lands relative to native grasslands. The positive treatment effects suggested CRP provided highly suitable breeding habitat for these species. In addition, we found lack of treatment effects and similar population densities on CRP lands relative to native grassland for the brown-headed cowbird, Cassin's sparrow, eastern meadowlark, grasshopper sparrow, horned lark, loggerhead shrike, scaled quail and Swainson's hawk. The lack of treatment effects for these species suggested CRP provides suitable breeding habitat for these species. However, we caution the treatment effects or lack of effects on abundance may not translate to habitat quality resulting in higher survival and reproduction of the species (Van Horne 1983).

We estimated population sizes for all observed species on CRP lands relative to population sizes for the entire PLJV region to determine the contribution of CRP to regional bird populations. We found consistent evidence across years for large contributions of CRP to the grasshopper sparrow population in the PLJV region. Land enrolled in the CRP program accounted for ~3 million grasshopper sparrows in 2016 and ~2 million grasshopper sparrows in 2017, and the 9% contribution was proportionally greater than the 5% availability of CRP in the region. In addition, we found some evidence for contributions to avian population size above and beyond the 5% availability of CRP in the PLJV region for the Chihuahuan raven (16%), dickcissel (8%), lark bunting (6%), long-billed curlew (41%), ring-necked pheasant (8%) and Swainson's hawk (18%). We found consistent evidence across years for CRP contributions in proportion to availability in the PLJV region for the Cassin's sparrow, common nighthawk, eastern meadowlark, mourning dove, scaled quail and western meadowlark. The CRP practice has the potential to address long-term population declines in the Great Plains for species such as the common nighthawk, eastern meadowlark, grasshopper sparrow, lark bunting, mourning dove and western meadowlark (Sauer et al. 2017).

One difficulty making inference from the study is that abundance over time often shows high annual variation due to stochastic processes unrelated to the treatment effect of interest (Joseph et al. 2006, Pollock 2006). For example, several species of grassland birds are known to be nomadic in response to annual variability in weather patterns (George et al. 1992, Niemuth et al. 2008), and this is one source of annual variation unrelated to the CRP treatment effect. Monitoring grassland birds over large spatial and temporal scales may be necessary to evaluate population responses to management treatments (Pavlacky et al. 2017), and while the spatial extent of the PLJV region is likely large enough to subsume regional movements, estimates of abundance in each year may not have sufficient power to evaluate treatment effects given the observed annual variation. Monitoring over several years and analyses to evaluate treatment effects across years may be necessary to achieve robust treatment effects for some species. Alternately, because site occupancy often exhibits lower annual variation than abundance, site occupancy may show greater power to detect treatment effects over short time frames than abundance (Joseph et al. 2006, Pollock 2006).

The IMBCR (Pavlacky et al. 2017) and North American Breeding Bird Survey (BBS, Robbins and Van Velzen 1967, Sauer et al. 2003) programs represent contrasting approaches to estimating avian population sizes. In terms of spatial and temporal applicability, the IMBCR program covers portions of 13 western US states from 2010 to present, whereas the BBS program covers the continental US from 1966 to present. In addition to differences in spatial and temporal coverage, the IMBCR and BBS programs use different analytical approaches related to the study designs. Study designs accounting for geographic variation and detection error are known to produce reliable knowledge about wildlife populations (Pollock et al. 2002, Nichols et al. 2009), whereas study design relying on convenience sampling and population indices that fail to account for detection error run the risk erroneous conclusions (Anderson 2001). The IMBCR program uses a probabilistic design to select a representative sample of 1 km^2 units from a sampling frame, which is important for achieving unbiased population estimates, valid estimates of precision and strong inference to un-sampled units in the monitoring region (Pavlacky et al. 2017). The BBS program uses a probabilistic design to select 1 degree blocks of latitude and longitude from a sampling frame limited to roaded areas, and uses convenience sampling to monitor bird populations only along roadways within the blocks (Robbins and Van Velzen 1967, Bystrak 1981). Consequently, population estimation from the BBS often proceeds by assuming bird populations along unrepresentative roadways are identical to bird populations within un-sampled roadless areas (Link et al. 1994, Sauer et al. 2003). In addition to the representativeness of the monitoring data, the IMBCR and BBS differ in their ability to adjust the count data for detection error and estimate un-biased population sizes (Pollock et al. 2002, Nichols et al. 2009). The IMBCR program employs data collection protocols to account for detection error, allowing direct estimates of density and population size (Pavlacky et al. 2017). Because the design of the BBS does not include data collection protocols to account for detection error, and except for a few notable exceptions (e.g., Hostetler and Chandler 2015), the resulting estimates are either population indices that merely account for variation in detection (Link et al. 1994, Link and Sauer 1997) or population indices adjusted by a series of correction factors based on arbitrary assumptions (Thogmartin et al. 2006, Thogmartin 2010). Finally, the design-based framework of the IMBCR program allows robust population estimation using standard methods, such as distance sampling (Thomas et al. 2010), that are accessible to a wide range wildlife biologists and land managers, whereas population estimation from the BBS requires model-based approaches accessible to the highest levels of quantitative expertise (Pavlacky et al. 2017).

Although the IMBCR point count protocols are well suited for detecting many breeding landbird species, the protocols are not well-suited for estimating the abundance of water bird and grouse species, or highly mobile species. Although IMBCR generally samples vegetation types in proportion to availability, many wetlands are too rare to be captured by current levels of sampling. In addition, passive point count surveys are generally unable to survey secretive or cryptic species that do not provide vocalization cues during the timeframes suitable for surveying landbirds when they singing and actively defending territories. Several grouse species, such as the lesser prairie-chicken, as well as several water bird families, are relatively silent and nearly invisible to passive point count methodology during the timeframe suitable for surveying landbirds. In addition, the IMBCR point count protocols do not effectively survey the abundance of highly mobile species, such as birds of prey, with home ranges orders of magnitude larger than the 1 km^2 sampling units. Finally, mobile species commonly detected on the wing, such as hummingbirds and swallows, may violate the distance sampling assumption that distances to birds are measured accurately prior to movement (Buckland et al. 2001). However, if flying birds are detected moving away from the observer just as often as they are detected moving toward the observer, then the density estimates are expected to be un-biased.

Management Implications

Monitoring is integral to the management and conservation of wildlife populations (Marsh and Trenham 2008, Jones 2011), and is a key part of decision making and adaptive management, providing the means for assessing the impacts of management changes and improving system understanding (Nichols and Williams 2006, Lyons et al. 2008). The hierarchical design of the IMBCR program provides a framework for determining species responses to conservation practices and understanding how local conservation efforts scale-up to influence regional bird populations (Pavlacky et al. 2017). We used post-stratification (Thomas et al. 2010) within a control-impact design (Morrison et al. 2008) to evaluate the effectiveness of CRP relative to agricultural lands and native grassland. The PLJV partnership to collect seamless monitoring data over large regions composed of public, tribal and private land ownership was important for estimating avian population sizes for CRP relative to population sizes in the region.

Effectiveness monitoring is useful for learning about the success of management actions, and also plays important roles in decision making and adaptive management (Lyons et al. 2008). The control-impact treatment effects (Morrison et al. 2008) for evaluating avian population densities on CRP relative to agricultural land (Table 3) provides predictions for increases in abundance expected from taking cropland out of production and planting CRP grassland. For example, enrolling agricultural land into CRP grassland is expected to increase the population density of the Cassin's sparrow by ≥397%, grasshopper sparrow by ≥196%, lark bunting by ≥80% and mourning dove by ≥65% (Table 1S, available in Supporting Information). The treatment effect for habitat suitability suggested enrolling agricultural land into CRP provided suitable habitat for the brown-headed cowbird, Cassin's sparrow, dickcissel, eastern meadowlark, grasshopper sparrow, horned lark, loggerhead shrike, long-billed curlew, mourning dove, northern bobwhite, scaled quail and Swainson's hawk. Although the before-after-control-impact design is better able to tease apart temporal and spatial variation than the control-impact design used in this study (Morrison et al. 2008), the results suggested CRP may provide suitable habitat for several grassland bird species and be an effective conservation strategy for increasing the abundance of these species in the PLJV region. The treatment effects can be used to evaluate bird conservation objectives within a decision making framework, or because of uncertainty about before-after effects, in an adaptive management framework (Lyons et al. 2008). For example, the bird conservation objectives can be evaluated along with landowner and stakeholder objectives for CRP, as well as outcomes for other management actions such as prescribed grazing, to determine the management actions that best satisfy the bird conservation and stakeholder objectives (Lyons et al. 2008). In general effectiveness monitoring of Farm Bill conservation practices provides confidence to land managers and resource professionals, as well as increases accountability for the evidence-based management of natural resources in the public trust (Briske et al. 2017).

We used the hierarchical framework of the IMBCR for PLJV program within an eco-regional context to establish the linkage between local habitat management and regional bird populations (Pavlacky et al. 2017). Trend estimation from the BBS shows several grassland birds are declining in the Great Plains, including the common nighthawk, eastern meadowlark, grasshopper sparrow, lark bunting, lark sparrow, loggerhead shrike, mourning dove, northern bobwhite, northern harrier and western meadowlark (Sauer et al. 2017). Because habitat loss and fragmentation are the leading causes of the population declines, CRP restoration may be necessary to meet recovery objectives for grassland birds (Brennan and Kuvlesky 2005, Herkert 2009). We showed CRP is an effective conservation strategy for increasing population sizes of several grassland bird species. The estimates of population size for CRP lands in the PLJV region can be used to evaluate progress toward meeting conservation objectives for grassland birds (Nichols and Williams 2006). For example, the population responses can be used in population viability simulations to ask how much CRP is required to meet population targets for species of conservation need. In addition, the population responses can be used to understand the consequences of CRP enrollment and expiry on grassland birds in the PLJV region. For example, our results suggest changes in the enrollment or expiry of CRP may dramatically affect the population sizes of the Chihuahuan raven, dickcissel, grasshopper sparrow, lark bunting, long-billed curlew, ring-necked pheasant and Swainson's hawk, and many other grassland species are likely to show changes in population size in proportion to changes in CRP enrollment or expiry. Finally the population responses to CRP can be used to set conservation priorities in the region (Wilson et al. 2009) to address the "what to do" and "where to do it" questions in conservation planning (Wilson et al. 2007). For example, systematic conservation planning (McBride et al. 2010) can be used to investigate tradeoffs involved with maximizing the population size of grassland birds, maximizing crop production and minimizing costs to private landowners to arrive at optimal solutions to the conservation of Great Plains agro-ecosystems (Behrman et al. 2015).

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