Four Forest Restoration Initiative Bird Surveys:

2015 Field Season Report

May 2016

Bird Conservancy of the Rockies
14500 Lark Bunting Lane
Brighton, CO 80603
303-659-4348
www.birdconservancy.org
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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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Contact Information:
Chris White
chris.white@birdconservancy.org
Bird Conservancy
14500 Lark Bunting Lane
Brighton, CO 80603
303-659-4348

Executive Summary

In 2015, Bird Conservancy of the Rockies, under contract with the US Forest Service Four Forest Restoration Initiative (4FRI), conducted landbird monitoring within three Task Orders (Hart Prairie, Wing Mountain, and Clint's Well) in Coconino National Forest to monitor avian response to Ponderosa Pine thinning on Coconino National Forest. The data collected under this agreement will serve to establish baseline estimates for songbirds in these Task Orders prior to treatment. Once treatments have been done in these Task Orders, we will revisit these sites and collect post-treatment data, allowing us to compare pre- and post-treatment density and occupancy estimates.

Under the 2015 agreement with 4FRI, Bird Conservancy completed all 30 target samples within the three Task Orders. Technicians conducted 419 point counts within the 30 surveyed sampling units between 30 May and 21 June, 2015. Technicians detected 5,536 individual birds representing 60 species, as well as 68 Abert's Squirrels and 17 Red Squirrels (Table 1). Three of the species recorded are Coconino National Forest Management Indicator Species (MIS): Hairy Woodpecker, Pygmy Nuthatch, and Wild Turkey.

Bird Conservancy estimated densities and population sizes for 55 species (Table 2), including the three MIS detected. The data yielded robust density estimates (percent coefficient of variation (% CV) < 50) for 36 of these species. We also estimated density for Abert's and Red Squirrels.

Bird Conservancy estimated the proportion of 1 km^2 grid cells occupied (Psi) throughout the Task Orders for 55 species (Table 3), including 2 of the MIS species detected (Hairy Woodpecker and Pygmy Nuthatch). The data yielded robust occupancy estimates (% CV < 50) for 32 of these species. We also estimated occupancy for Abert's and Red Squirrels.

This monitoring effort is done in conjunction with larger national efforts of the Integrated Monitoring in Bird Conservation Regions program (IMBCR). IMBCR uses a spatially balanced sampling design which allows inferences to avian species occurrence and population sizes at various scales, facilitating conservation at local and national levels. The sampling design allows for the estimation of density, population size and occupancy for individual strata or combinations of strata. The collaboration across organizations and spatial scales allows for increased sample sizes and improves the accuracy and precision of the population estimates. Auxiliary (or "overlay") projects, such as this 4FRI project, are a growing component of IMBCR that improve efficiency and is tailored to address specific management questions. Auxiliary projects utilize the IMBCR sampling design and field methods but are not integrated into the nested stratification. These projects benefit by incorporating detection data from relevant IMBCR surveys in analyses. Had this been a stand-alone project, we would likely have been able generate densities for only 21 species rather than 57, based on the minimum 80 detections needed for Distance analyses. Likewise, we would have been able to estimate occupancy for 40 species rather than 57, based on the requirement that a species be detected on at least ten points to estimate occupancy. Utilizing the IMBCR design also allows the resulting population estimates to be placed in a regional context. In this way the collaborative efficiency of the IMBCR program is extended to auxiliary projects, and vice versa, by improving the accuracy and precision of population estimates, and allowing population estimates for infrequently detected species.

The IMBCR program is well positioned to address conservation and management needs for 4FRI. By focusing on multiple scales from local management units to BCRs, IMBCR can easily be integrated within an interdisciplinary approach to bird conservation that combines monitoring, research and management. Recently developed habitat analyses and species distribution maps can be used as the basis of decision support tools for avian conservation.

Acknowledgements

We thank Dan Kipervaser and Jessica Gist with the US Forest Service Four Forest Restoration Initiative for funding this project and providing the spatial information needed for the project. We thank Gary White, professor emeritus of Colorado State University, who wrote the initial SAS code and implemented the multi-scale occupancy model in program MARK and Paul Lukacs of the University of Montana who wrote code in program R to automate data analysis for density and occupancy estimates. We thank Jeff Laake for implementing the multi-scale occupancy model in the RMark package which aided in the automation of the analyses. We also thank the field technicians who collected avian and vegetation point count data. Finally, this report benefited greatly from review by Bird Conservancy and 4FRI staff.

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Introduction

There is a major effort underway in the Southwest to restore ponderosa pine (*Pinus ponderosa*) forests to a more historically natural landscape through a combination of mechanical thinning and prescribed burns. In Arizona, this effort is being led by the Four Forest Restoration Initiative (4FRI), a collaboration between four large national forests in Arizona along with several other partners. In 2015, 4FRI contracted with Bird Conservancy of the Rockies to monitor avian response to Ponderosa Pine thinning on Coconino National Forest. This report summarized pre-treatment data collected on three Task Orders in Coconino National Forest (Hart Prairie, Wing Mountain, and Clint's Well). The data collected under this agreement will serve to establish baseline estimates for songbirds in these Task Orders prior to treatment. Once treatments have been done in these Task Orders, we will revisit these sites and collect post-treatment data, allowing us to compare pre- and post-treatment density and occupancy estimates. IMBCR has already been implemented on Coconino National Forest since 2009, meaning the 4FRI project can leverage their dataset against the forest-wide monitoring effort, leading to greater efficiencies for the project.

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 (Alexander et al. 2008, Lyons et al. 2008); and evaluate population responses to landscape alteration and climate change (Baron et al. 2008, Lindenmayer and Likens 2009); as well as provide basic information on species distributions..

Bird Conservation Regions (BCRs) provide a spatially consistent framework for bird conservation in North America. The BCRs represent distinct ecological regions with similar bird communities, vegetation types and resource management interests (US North American Bird Conservation Initiative 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 (Ruth et al. 2003).

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). 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 that 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 (Pollock et al. 2002, Thompson 2002). 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 US North American Bird Conservation Initiative's (NABCI) "Opportunities for Improving Avian Monitoring" (US North American Bird Conservation Initiative 2007) provided goals for avian monitoring programs:

> 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 NABCI Monitoring Subcommittee (2007) guidelines in mind, the IMBCR partners designed a broad-scale monitoring program entitled "Integrated Monitoring in Bird Conservation Regions" (IMBCR) (Blakesley and Hanni 2009). Important properties of the IMBCR design are:

- All areas are available for sampling including all vegetation types.
- Strata are based on fixed attributes; this will allow 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 can be directly compared to regional trends.
- Coordination among partners can reduce the costs and/or increase efficiencies of monitoring per partner.

Using the IMBCR design, the IMBCR partnership monitoring objectives 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 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.

Methods

Study Area

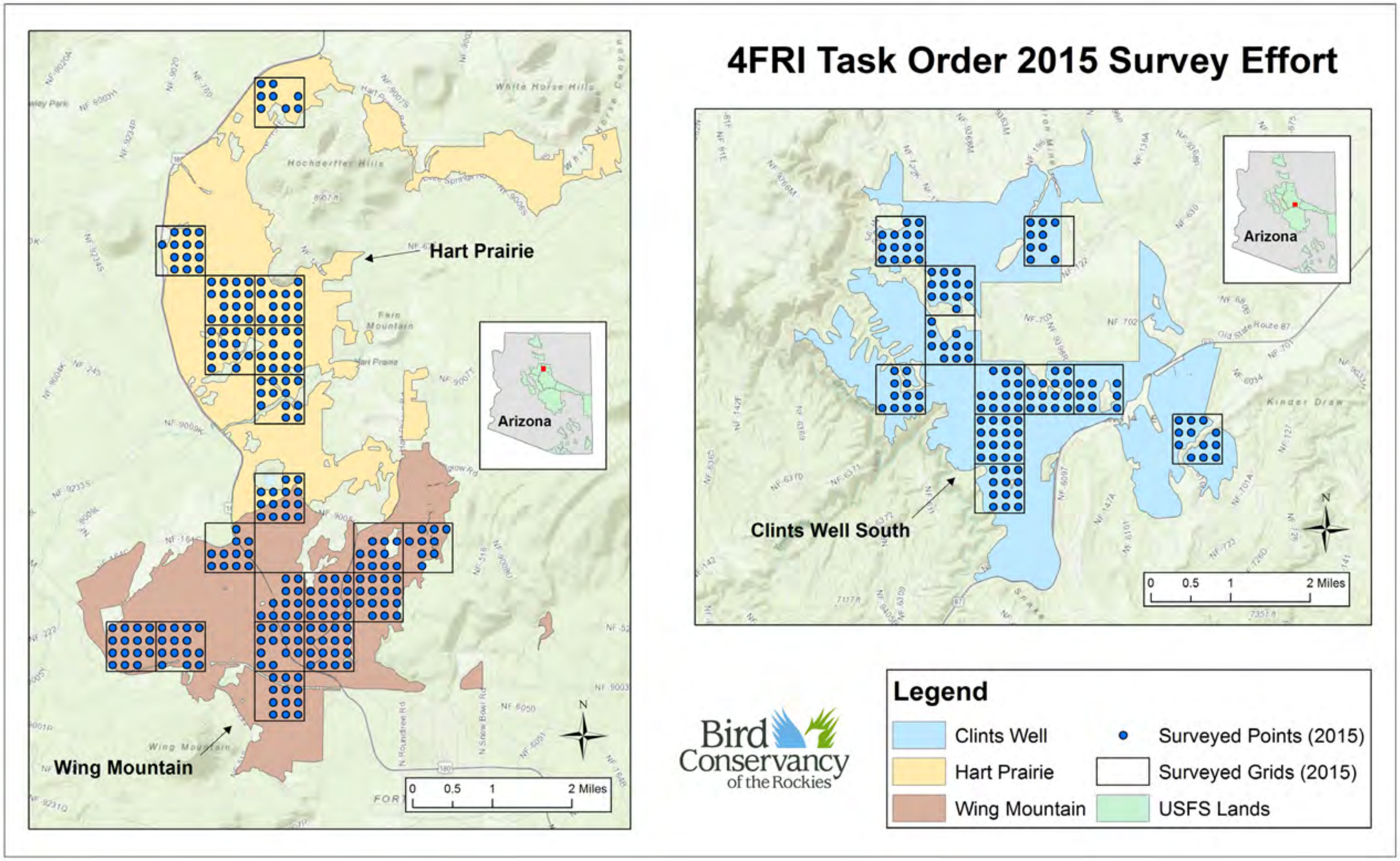

Figure 1. Spatial extent of sampling for the Four Forest Restoration Initiative, 2015.

Sampling Design

Sampling Frame and Stratification

IMBCR sampling occurred forest-wide throughout Coconino National Forest in 2015. For this project, sampling occurred within three Task Orders in Coconino National Forest Wing Mountain, Hart Prairie, and Clint's Well. Given the level of sampling identified for this project, all three Task Orders were combined into a single stratum to maximize efficiency and improving the accuracy of results.

Sampling Units

The IMBCR design defined sampling units as 1 km² cells, each containing 16 evenly-spaced sample points, 250 meters apart (Figure 3). We define potential sampling units by superimposing a uniform grid of cells over each state in the study area, then we assign each cell to a stratum using ArcGIS version 10.X and higher (Environmental Systems Research Institute 2006). We only visited points within the sampling grid that fell specifically within treatment areas.

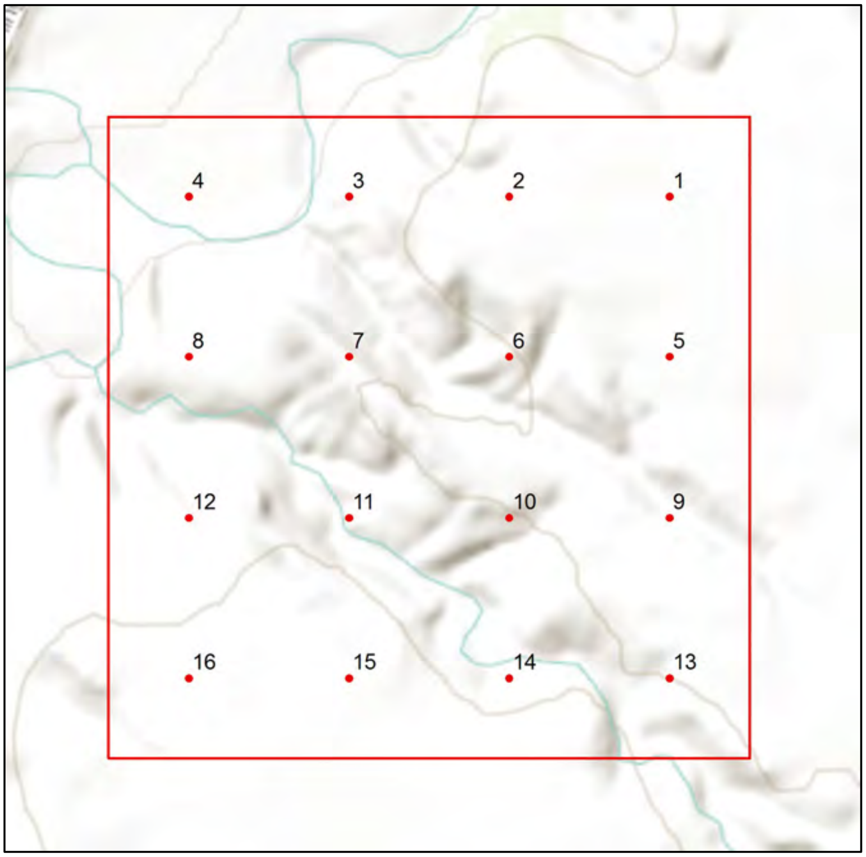

Figure 2. Example 1 km² sampling unit using the IMBCR design.

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 several 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;

- 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.

Sampling Methods

IMBCR surveyors with excellent aural and visual bird-identification skills conducted field work in 2015. 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 (also referred to as technician, or observer in this report) conducted point counts (Buckland et al. 2001) following protocols established by IMBCR partners (Hanni et al. 2015). 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 or not 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 to measure the distance to a bird, observers estimated the distance by measuring to some object near the bird. In addition to recording all bird species detected in the area during point counts, observers recorded birds flying over but not using the immediate surrounding landscape. Observers also recorded Abert’s squirrel (*Sciurus aberti*) and American red squirrel (*Tamiasciurus hudsonicus*). While observers traveled between points within a sampling unit they recorded the presence of any species not recorded during a point count. The opportunistic detections of these species are used for distribution mapping purposes only.

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

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

For more detailed information about survey methods and vegetation data collection protocols, refer to Bird Conservancy’s Field Protocol for Spatially Balanced Sampling of Landbird Populations on our Avian Data Center website at http://rmbo/v3/avian/DataCollection.aspx. There you will find links to past and current protocols and data sheets.

Data Analysis

Distance Analysis

Distance sampling theory was developed to account for the decreasing probability of detecting an object of interest (e.g., a bird) with increasing distance from the observer to the object (Buckland et al. 2001). The detection probability is used to adjust the count of birds to account for birds that were present but undetected. Application of distance theory requires that five critical assumptions be met: 1) all birds at and near the sampling location (distance = 0) are detected; 2) distances to birds are measured accurately; 3) birds do not move in response to the observer's presence (Buckland et al. 2001, Thomas et al. 2010); 4) cluster sizes are recorded without error; and 5) the sampling units are representative of the entire survey region (Buckland et al. 2008).

Analysis of distance data includes fitting a detection function to the distribution of recorded distances (Buckland et al. 2001). The distribution of distances can be a function of characteristics of the object (e.g., for birds, size and color, movement, volume of song or call and frequency of call), the surrounding environment (e.g., density of vegetation), and observer ability. Because detectability varies among species, we analyzed these data separately for each species. The development of robust density estimates typically requires 80 or more independent detections ($n \geq 80$) 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.

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).

Beginning this year, we streamlined the analysis by fitting models with no series expansions to all species using the recommended 10% truncation for point transects. 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 most parsimonious detection function for each species using Akaike's Information Criterion adjusted for sample size (AIC_c; Burnham & 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% Confidence Intervals (CI) 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 and cluster size using the delta method (Powell 2007, Thomas et al. 2010) and the variance for the encounter rate using 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 [$g(w) \sim 0.1$] and included key functions with second order cosine series-expansion terms in the candidate set of models (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. These remedial measures can ameliorate problems associated with moderate levels of evasive movement and/ or distance measurement errors (Buckland et al. 2001).

Occupancy Analysis

Occupancy estimation is most commonly used to quantify the proportion of sample units (i.e., 1 km^2 cells) occupied by an organism (MacKenzie et al. 2002). The application of occupancy modeling requires multiple surveys of the sample unit in space or time to estimate a detection probability (MacKenzie et al. 2006). The detection probability adjusts the proportion of sites occupied to account for species that were present but undetected (MacKenzie et al. 2002). We used a removal design (MacKenzie et al. 2006), to estimate a detection probability for each species, in which we binned minutes one and two, minutes three and four and minutes five and six to meet the assumption of a monotonic decline in the detection rates through time. After the target species was detected at a point, we set all subsequent sampling intervals at that point to “missing data” (MacKenzie et al. 2006).

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

We truncated the data, using only detections less than 125 m from the sample points. Truncating the data at less than 125 m allowed us to use bird detections over a consistent plot size and ensured that the points were independent (points were spread 250 m apart), which in turn allowed us to estimate Theta (the proportion of points occupied within each sampling unit) (Pavlacky et al. 2012)

We expected that regional differences in the behavior, habitat use, and local abundance of species would correspond to regional variation in detection and the fraction of occupied points. Therefore, we estimated the proportion of sampling units occupied (Psi) for each stratum by evaluating four models with different structure for detection (p) and the proportion of points occupied (Theta). Within these models, p and Theta were held constant across the BCRs and/or allowed to vary by BCR. Models are defined as follows:

Model 1: Held *p* and Theta constant;
Model 2: Held *p* constant, but allowed Theta to vary across BCRs;
Model 3: Allowed *p* to vary across BCRs, but held Theta constant;
Model 4: Allowed both *p* and Theta to vary across BCRs.

We ran model 1 for species with less than 10 point detections in each BCR or less than 10 point detections in all but one BCR. We ran models 1 through 4 for species with greater than 10 point detections in more than one BCR. For the purpose of estimating regional variation in detection (*p*) and availability (Theta), we pooled data for BCRs with fewer than 10 point detections into adjacent BCRs with sufficient numbers of detections. We used model selection and AIC corrected for small sample size (AIC_c) to weight models from which estimates of Psi were derived for each species (Burnham and Anderson 2002). We model averaged the estimates of Psi from models 1 through 4 and calculated unconditional standard errors and 90% CIs (Burnham and Anderson 2002). We combined stratum-level estimates of Psi using an area-weighted mean. The variances and standard errors for the combined estimates of Psi were estimated using the delta method (Powell 2007).

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

Automated Analysis

We estimated population density using point transect distance sampling and site occupancy using the multi-scale occupancy model within a modified version of the RIMBCR package (R Core Team 2014; Paul Lukacs, University of Montana, Missoula). The RIMBCR package streamlined the analyses by calling the raw data from the IMBCR Structured Query Language (SQL) 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 package mrds (Thomas et al. 2010, R Core Team 2014) to fit the point transect distance sampling model, and program MARK (White and Burnham 1999) and package RMark (Laake 2013, R Core Team 2014) to fit the multi-scale occupancy model. The RIMBCR package provided an automated framework for combining strata-level estimates of population density and site occupancy at multiple spatial scales, as well as approximating the standard errors and CIs for the combined estimates.

In October 2014, we revised the RIMBCR distance sampling code to accommodate updates to package mrds 2.18. However, because we were unable to troubleshoot the complex structure of the RIMBCR code, we completely rewrote the distance sampling code between October 2014 and April 2015. The new distance sampling code retained the “roll-up” code for combining the strata-level estimates from the previous version of RIMBCR. In March 2015, we discovered a delta method (Powell 2007) error in the RIMBCR “roll-up” code (Powell 2007). We estimated the proportion of sampling units occupied (Psi) for all species that estimates the standard errors and CIs for the combined occupancy estimates. In April 2015, we revised RIMBCR to fix the error, but we were unable to troubleshoot the complex structure of the RIMBCR code. We plan to rewrite the RIMBCR occupancy code in way that allows testing, but in the mean time we developed an R “roll-up” patch that correctly estimates the standard errors and CIs for the combined occupancy estimates. We reran the "roll-up" patch for 2012-2014 to retroactively correct the standard errors and CIs for the previous combined (superstrata) occupancy estimates. We currently maintain version control of the automated analysis code in the Bird Conservancy repository (Atlassian Stash, version 3.6.1).

Results

In 2015, field technicians completed all 30 target samples within the three Task Orders (Hart Prairie, Wing Mountain, and Clint's Well). Technicians conducted 419 point counts (average 14 points/grid) within the 30 surveyed sampling units between 30 May and 21 June, 2015. Only five points within the Task Order boundaries were not sampled. Two were inaccessible due to elk exclosure fences, two were in the middle of occupied campsites, and on one point we ran out of time to survey due to decreased bird activity late in the morning.

Technicians detected 5,536 individual birds representing 60 species, as well as 68 Abert's Squirrels and 17 Red Squirrels (Table 1). Three of the species recorded are Coconino National Forest Management Indicator Species (MIS): Hairy Woodpecker, Pygmy Nuthatch, and Wild Turkey.

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Bird Conservancy estimated the proportion of 1 km^2 grid cells occupied (Psi) throughout the Task Orders for 55 species (Table 3), including 2 of the MIS species detected (Hairy Woodpecker and Pygmy Nuthatch). The data yielded robust occupancy estimates (% CV < 50) for 32 of these species. A Psi value of 1 means that a species was recorded on all surveys conducted within the study area. We were unable to generate a % CV value for species with a Psi value of 1. We also estimated occupancy for Abert's and Red Squirrels.

Click here to view a map of survey locations, density and occupancy results, and species counts for this project and hit the "Run Query" button highlighted in red located near the top of the page.

Unless otherwise specified, all bird species names listed in this report are from the American Ornithologists' Union Check-list of North and Middle American Birds, seventh edition (2007).

Table 1. Species detected on three Task Orders (Hart Prairie, Wing Mountain, and Clint's Well) within the Four Forest Restoration Initiative, along with species counts, 2015. Species for which density or occupancy was estimated are marked with an "X" in the corresponding column. Coconino National Forest Management Indicator Species are bolded.

Species	Raw Count	Density	Occupancy
Acorn Woodpecker	28	X	X
American Crow	1	X	
American Robin	190	X	X
American Three-toed Woodpecker	1		X
Band-tailed Pigeon	5	X	
Barn Swallow	1	X	X
Black-chinned Hummingbird	5		X
Black-headed Grosbeak	5	X	X

Species	**Raw Count**	**Density**	**Occupancy**
Broad-tailed Hummingbird	21	X	X
Brown Creeper	90	X	X
Brown-headed Cowbird	43	X	X
Bushtit	6	X	X
Cassin's Finch	1	X	X
Chipping Sparrow	119	X	X
Common Nighthawk	6	X	X
Common Raven	91	X	X
Cooper's Hawk	3	X	X
Cordilleran Flycatcher	117	X	X
Dark-eyed Junco	555	X	X
Downy Woodpecker	6	X	X
Evening Grosbeak	1	X	X
Grace's Warbler	343	X	X
Gray Flycatcher	36	X	X
Hairy Woodpecker	47	X	X
Hepatic Tanager	18	X	X
Hermit Thrush	122	X	X
House Wren	126	X	X
Lark Sparrow	1	X	X
Lesser Goldfinch	6	X	X
MacGillivray's Warbler	1	X	X
Mallard	1		X
Mountain Chickadee	337	X	X
Mourning Dove	90	X	X
Northern Flicker	141	X	X
Northern Rough-winged Swallow	1	X	X
Olive Warbler	60	X	X
Olive-sided Flycatcher	6	X	X
Pine Siskin	78	X	X
Plumbeous Vireo	200	X	X
Purple Martin	17	X	X
Pygmy Nuthatch	571	X	X
Red Crossbill	125	X	X
Red-breasted Nuthatch	3	X	X
Red-faced Warbler	16	X	X
Red-tailed Hawk	1		
Ruby-crowned Kinglet	2	X	X
Sharp-shinned Hawk	1		
Squirrel, Abert's	68	X	X
Squirrel, Red	17	X	X
Steller's Jay	216	X	X
Townsend's Solitaire	72	X	X

Species	**Raw Count**	**Density**	**Occupancy**
Vesper Sparrow	3	X	X
Violet-green Swallow	143	X	X
Virginia's Warbler	14	X	X
Warbling Vireo	50	X	X
Western Bluebird	146	X	X
Western Tanager	277	X	X
Western Wood-Pewee	244	X	X
White-breasted Nuthatch	256	X	X
Wild Turkey	3	X	
Williamson's Sapsucker	6	X	X
Yellow-rumped Warbler	461	X	X

Table 2. Estimated densities per km^2 (D), population sizes (N), percent coefficient of variation of estimates (% CV), and number of independent detections used in analyses (n) for breeding bird species recorded in three Task Orders (Hart Prairie, Wing Mountain, and Clint's Well) within the Four Forest Restoration Initiative, 2015. Coconino National Forest Management Indicator Species are bolded.

Species	**D**	**N**	**% CV**	**n**
Acorn Woodpecker	1.57	28	36	22
American Crow	0.01	0	101	1
American Robin	14.73	265	14	143
Band-tailed Pigeon	0.68	12	50	4
Barn Swallow	0.33	6	101	1
Black-headed Grosbeak	0.18	3	56	3
Broad-tailed Hummingbird	6.18	111	24	15
Brown Creeper	25.71	463	15	74
Brown-headed Cowbird	4.29	77	25	38
Bushtit	3.04	55	71	3
Cassin's Finch	0.1	2	100	1
Chipping Sparrow	22.79	410	15	91
Common Nighthawk	0.14	2	48	4
Common Raven	0.78	14	13	82
Cooper's Hawk	0.4	7	73	2
Cordilleran Flycatcher	12.02	216	14	107
Dark-eyed Junco	90.63	1,631	8	398
Downy Woodpecker	0.71	13	52	4
Evening Grosbeak	0.09	2	100	1
Grace's Warbler	34.66	624	22	295
Gray Flycatcher	5.52	99	34	33
Hairy Woodpecker	4.77	86	25	37

Species	D	N	% CV	n
Hepatic Tanager	1	18	51	15
Hermit Thrush	4.26	77	16	94
House Wren	11.91	214	28	118
Lark Sparrow	0.1	2	100	1
Lesser Goldfinch	1.21	22	46	6
MacGillivray's Warbler	0.23	4	100	1
Mountain Chickadee	56.82	1,023	7	272
Mourning Dove	2.16	39	22	78
Northern Flicker	4	72	13	118
Northern Rough-winged Swallow	0.21	4	106	1
Olive Warbler	4.19	75	21	48
Olive-sided Flycatcher	0.34	6	53	6
Pine Siskin	13.13	236	29	58
Plumbeous Vireo	13.05	235	15	173
Purple Martin	0.99	18	38	14
Pygmy Nuthatch	83.98	1,512	12	363
Red Crossbill	8.27	149	20	57
Red-breasted Nuthatch	0.4	7	74	3
Red-faced Warbler	3.67	66	52	14
Ruby-crowned Kinglet	0.13	2	101	1
Squirrel, Abert's	10.91	196	21	43
Squirrel, Red	3.78	68	70	14
Steller's Jay	11.85	213	14	175
Townsend's Solitaire	4.89	88	17	60
Vesper Sparrow	0.19	3	100	3
Violet-green Swallow	21.42	386	16	98
Virginia's Warbler	1.68	30	43	13
Warbling Vireo	5.97	107	28	39
Western Bluebird	14.27	257	13	104
Western Tanager	21.12	380	12	237
Western Wood-Pewee	12.37	223	20	231
White-breasted Nuthatch	20.94	377	9	232
Wild Turkey	0.01	0	101	1
Williamson's Sapsucker	0.5	9	71	2
Yellow-rumped Warbler	72.42	1,304	8	373

Table 3. Estimated proportion of sample units occupied (Psi), percent coefficient of variation of Psi (% CV), and number of transects with one or more detections (nTran) for breeding bird species recorded in three Task Orders (Hart Prairie, Wing Mountain, and Clint's Well) within the Four Forest Restoration Initiative, 2015. Coconino National Forest Management Indicator Species are bolded. A Psi estimate equal to 1 indicates the species was detected on all transects surveyed.

Species	Psi	% CV	nTran
Acorn Woodpecker	0.321	28	9
American Robin	0.906	6	27
American Three-toed Woodpecker	0.039	99	1
Barn Swallow	0.037	99	1
Black-chinned Hummingbird	0.078	69	2
Black-headed Grosbeak	0.17	41	5
Broad-tailed Hummingbird	0.556	18	15
Brown Creeper	0.93	6	27
Brown-headed Cowbird	0.618	16	17
Bushtit	0.107	55	3
Cassin's Finch	0.036	98	1
Chipping Sparrow	0.974	3	29
Common Nighthawk	0.378	41	6
Common Raven	0.721	16	17
Cooper's Hawk	0.408	72	3
Cordilleran Flycatcher	0.917	6	27
Dark-eyed Junco	1	0	30
Downy Woodpecker	0.863	51	6
Evening Grosbeak	0.055	99	1
Grace's Warbler	0.733	11	22
Gray Flycatcher	0.268	30	8
Hairy Woodpecker	0.756	16	18
Hepatic Tanager	0.213	37	6
Hermit Thrush	0.755	13	20
House Wren	0.501	18	15
Lark Sparrow	0.034	98	1
Lesser Goldfinch	0.187	41	5
MacGillivray's Warbler	0.034	98	1
Mallard	0.055	100	1
Mountain Chickadee	1	0	30
Mourning Dove	0.602	15	18
Northern Flicker	0.835	9	24
Northern Rough-winged Swallow	0.076	105	1
Olive Warbler	0.637	15	18
Olive-sided Flycatcher	0.132	55	3
Pine Siskin	0.646	14	19
Plumbeous Vireo	0.969	3	29
Purple Martin	0.276	30	8

Species	Psi	% CV	nTran
Pygmy Nuthatch	1	0	30
Red Crossbill	0.808	10	23
Red-breasted Nuthatch	0.072	68	2
Red-faced Warbler	0.237	33	7
Ruby-crowned Kinglet	0.068	68	2
Squirrel, Abert's	0.898	10	24
Squirrel, Red	0.1	55	3
Steller's Jay	1	0	30
Townsend's Solitaire	0.752	13	20
Vesper Sparrow	0.034	98	1
Violet-green Swallow	0.887	7	26
Virginia's Warbler	0.202	37	6
Warbling Vireo	0.409	22	12
Western Bluebird	0.946	5	28
Western Tanager	1	0	30
Western Wood-Pewee	0.903	6	27
White-breasted Nuthatch	1	0	30
Williamson's Sapsucker	0.188	51	4
Yellow-rumped Warbler	1	0	30

Discussion

Summary of Results

Auxiliary (or "overlay") projects, such as this 4FRI project, are a growing component of the larger IMBCR that improve efficiency and can be tailored to address specific management questions. Auxiliary projects utilize the IMBCR sampling design and field methods but are not integrated into the nested stratification. These projects benefit by incorporating detection data from relevant IMBCR surveys in analyses. For example, had this been a stand-alone project, we would likely have been able generate densities for only 21 species rather than 57, based on the minimum 80 detections needed for Distance analyses. Likewise, we would have been able to estimate occupancy for 40 species rather than 57, based on the requirement that a species be detected on at least ten points to estimate occupancy. Utilizing the IMBCR design also allows the resulting population estimates to be placed in a regional context. In this way the collaborative efficiency of the IMBCR program is extended to auxiliary projects, and vice versa, by improving the accuracy and precision of population estimates, and allowing population estimates for infrequently detected species.

This report summarized pre-treatment data collected on three Task Orders in Coconino National Forest (Hart Prairie, Wing Mountain, and Clint’s Well). The data collected under this agreement will serve to establish baseline estimates for songbirds in these Task Orders prior to treatment. Once treatments have been done in these Task Orders, we will revisit these sites and collect post-treatment data, allowing us to compare pre- and post-treatment density and occupancy estimates. Since this report represents only one year of pre-treatment data, we cannot yet make any inferences to what effects treatments will have on these areas.

Estimates of density or occupancy may be missing for species listed in Task Orders but present for the same species detected on national forest-wide surveys for several reasons. First, values may be missing if a species was not recorded in a Task Order or there were insufficient detections to calculate an estimate. In addition, a higher number of species were detected forest-wide because both the number of sampled units and surveyed habitats were significantly higher for the overall forest data. The habitat within the Task Orders is primarily ponderosa pine forest, while habitats within both forests included desert shrub, pinyon-juniper, ponderosa pine, mixed conifer, and others. Many of the species with estimates forest-wide (such as Curve-billed Thrasher or Ash-throated Flycatcher) simply do not occur within the Task Orders, while any species that is a ponderosa pine specialist will likely have higher density estimates within Task Orders than across the forests. It is unlikely that the differences in species detected are the result of varying observer ability since the same crew conducted surveys within the Task Orders and Coconino National Forest as a whole.

That being said, it is still possible to look at density or occupancy estimates over time to see if there is a treatment effect occurring. For example, if density estimates for Grace’s Warbler decrease in both the Task Orders and across the IMBCR program, the cause of this decline would be affecting the entire population and may not related to the treatment. However, if IMBCR-wide density estimates for Grace’s Warbler are similar pre- and post-treatment but density estimates within the WCAs appreciably increase or decrease, this would indicate a possible treatment effect. Annual estimates of density and occupancy can also be compared over time to determine if population changes are a result of population growth or decline and/or range expansion or contraction. For example, if population densities of a species declined over time, but the occupancy rates remained constant, then the population change may be the result of declining local abundance. In contrast, if both density and occupancy rates of a species declined, then population change was more likely due to range contraction.

Applications of IMBCR Data

The IMBCR program collects breeding bird information in all or portions of 12 states annually. Each year, occupancy and density estimates are calculated at a variety of spatial scales. This information can be used in the following ways to inform avian conservation:

1. Bird Population estimates can be compared in space and time. Stratum-level estimates can be compared to state and regional estimates to determine whether local populations are above or below estimates for the region.

   Example: Bobolink is designated as a Common Bird in Steep Decline and a US and Canada Concern species in BCR 17 by Partners in Flight (Appendix B). We can compare any of the strata or combinations of strata within BCR 17 to the BCR-wide estimate. The density estimate for Bobolink in Knife River Indian Villages NHS is much higher than the BCR 17 estimate, indicating that Knife River may have excellent habitat for this species. On the other hand, Theodore Roosevelt National Park had a lower density estimate than BCR 17 overall. There could be a number of reasons to explain this, one being a lack of appropriate habitat for Bobolink in the Park. If land managers are interested in maintaining a healthy Bobolink population in BCR 17, they could compare stratum-level estimates and then attempt to protect areas where the species is doing very well while targeting areas with low population estimates for habitat management projects.

   Table 4. Density estimates for Bobolink in Bird Conservation Region 17, Theodore Roosevelt National Park, and Knife River Indian Villages National Historic Site, 2013. The estimated densities per km² (D), the total estimated population size of the study area (N), the percent coefficient of variation of estimates (% CV) and the number of independent detections used in analyses (n) are shown.

Stratum/Superstratum	D	N	% CV	n
BCR 17	2.15	783,522	42	334
Theodore Roosevelt National Park	1.12	328	57	9
Knife River Indian Villages NHS	51.68	258	11	155

2. Population estimates can be used to make informed management decisions about where to focus conservation efforts. For example, strata with large populations can be targeted for protection and strata with low populations can be prioritized for conservation action. A threshold could be set to trigger a management action when populations reach a predetermined level.

   Example: Brewer's Sparrow is designated as a Species of Greatest Conservation Need by Wyoming Game and Fish and a Sensitive Species by the Bureau of Land Management in Wyoming. Population estimates were generated for several BLM field offices within the state of Wyoming. Comparing Brewer's Sparrow population estimates across the various offices shows that the largest estimated population size falls within the Rawlins field office (Table 4). When comparing population sizes, it is also important to look at the size of the area involved. Rawlins is the second largest field office in Wyoming, after the Rock Springs field office. Rock Springs has the largest area and yet has a smaller population size than Rawlins. It also has the smallest density estimate compared to the other field offices and statewide BLM estimates. This may indicate the need for further investigation to determine why this may be. Perhaps the Rock Springs BLM field office naturally contains less ideal habitat for Brewer's Sparrow or there could be anthropogenic disturbances that are contributing to the lower population densities.

   Table 5. Density estimates for Brewer's Sparrow in Wyoming and on BLM Lands in Wyoming, 2013. The estimated densities per km² (D), the total estimated population size of the study area (N), the percent coefficient of variation of estimates (% CV), the number of independent detections used in analyses (n), and the total area (in km²) are shown.

Stratum/Superstratum	D	N	% CV	n	Area (km²)
WY	24.20	6,134,460	16	1235	253,467
WY-BLM	33.12	2,377,177	21	557	71,773
Buffalo Field Office	57.78	184,885	62	60	3,200
Casper Field Office	56.33	293,167	35	82	5,204
Pinedale Field Office	66.34	244,577	21	175	3,687
Rawlins Field Office	23.75	331,473	31	62	13,954
Rock Springs Field Office	19.66	297,874	39	51	15,152

3. Stratum-level population estimates of treatment areas can be compared to regional estimates to evaluate effectiveness of management actions. For example, if sagebrush habitat is treated to improve Greater Sage-grouse (GRSG) habitat, these areas can be defined as an individual stratum and sampling can take place within the stratum. If estimates for sagebrush-obligate songbirds increase within this stratum compared to regional estimates, the results would suggest that the GRSG management actions are also beneficial to sagebrush-obligate songbird species.

   Example: In 2015 we will create and survey within a new stratum encompassing the Flagstaff Watershed Project Area in Coconino National Forest. The goal of the project is to thin Mixed-Conifer habitat within the Flagstaff Watershed to reduce the potential for a catastrophic fire event. The surveys will be conducted pre- and post-thinning and the estimates generated can be compared to forest-wide estimates for Coconino National Forest.

4. Annual estimates of density and occupancy can be compared over time to determine if population changes are a result of population growth or decline and/or range expansion or contraction. For example, if population densities of a species declined over time, but the occupancy rates remained constant, then the population change was due to declines in local abundance. In contrast, if both density and occupancy rates of a species declined, then population change was due to range contraction.

   Example: Hairy Woodpecker is a Management Indicator Species in Idaho Panhandle National Forest. We've been monitoring in this forest since 2010, and if we look at estimates from 2010 through 2013 there appears to be a decline in density over time. Similarly, there appears to be a decline in occupancy from 2010 – 2013 as well. This seems to indicate that Hairy Woodpeckers may be undergoing a range contraction within Idaho Panhandle NF. These results indicate further research on Hairy Woodpecker may be warranted in the forest to determine the reason for the range contraction.

   Table 6. Density and occupancy estimates for Hairy Woodpecker in Idaho Panhandle National Forest, 2010 – 2013. The estimated densities per km² (D), the total estimated population size of the study area (N), the percent coefficient of variation of estimates on density (D %CV), the number of independent detections used in density analyses (n), estimated proportion of 1 km² sample units occupied (Psi), percent coefficient of variation of Psi (Psi % CV), and number of sample cells with one or more detections used to calculate occupancy (nTran) are shown.

Year	D	N	D %CV	n	Psi	Psi %CV	nTran
2010	10.29	121,630	25	15	0.901	16	10
2011	5.92	69,980	42	6	0.889	28	6
2012	3.89	45,931	31	14	0.702	6	12
2013	3.48	41,132	37	11	0.536	8	10

5. Occupancy rates can be multiplied by the land area in a region of interest to estimate the area occupied by a species. For example, if a stratum comprises 120,000 km² and the occupancy estimate for Western Meadowlark is 0.57, managers can estimate that 68,400 km² (120,000 km² * 0.57) of habitat within that stratum are occupied by Western Meadowlarks.

   Example: Sprague's Pipit is a priority species in Montana as designated by Montana Fish, Wildlife, and Parks. The occupancy estimate for Sprague's Pipit is 0.028 and the total area of the Montana superstratum is 381,540km². Multiplying the occupancy estimate by the area gives an estimate of 10,683km² of habitat occupied by Sprague's Pipit in Montana. This information can be used by land managers to set goals for how much habitat should be provided for the species in Montana.

Value as a Management Tool

The availability of consistent monitoring data at multiple scales is an important challenge for avian conservation (Ruth et al. 2003). The IMBCR program is well positioned to address conservation and management needs of a wide range of stakeholders, landowners, and government entities at various spatial scales. The program was designed to provide accurate information about bird populations from local management units to BCRs. The hierarchical framework of nested strata is useful for partitioning bird populations according to management units, and aggregating bird populations at various scales to support large-scale conservation efforts. At the management unit scale, IMBCR population estimates can be used to support local management efforts. Whereas, monitoring at regional and BCR scales provides land managers with dependable knowledge about the status and change of bird populations at ecologically relevant scales (US North American Bird Conservation Initiative 2009). In addition, population estimates at the management unit scale can be compared to those at the BCR scale to place the population estimates in a regional context. The large-scale context provides biological information for conservation planning and allows an assessment of conservation responsibility.

By focusing on multiple scales relevant to management and conservation, IMBCR can easily be integrated within an interdisciplinary approach to bird conservation that combines monitoring, research and management (Ruth et al. 2003). The IMBCR program accommodates the principles of adaptive monitoring (Lindenmayer and Likens 2009) because it: 1) addresses well-defined and tractable questions; 2) is underpinned by rigorous science ; 3) is based on a conceptual model of how bird populations function; and 4) is relevant to the management of natural resources. Under the adaptive monitoring framework, the objectives, sampling design, data collection, analysis, and interpretation are iterative; allowing the program to evolve and develop in response to new information or new management questions. For example, the IMBCR program allows for different stratification schemes and the re-stratification of local management units to better address partner management objectives. The flexible hierarchical design accommodates annual re-stratification and fluctuation of sampling intensity without compromising the regional population estimates. Because IMBCR strata are based on fixed attributes rather than existing vegetation types, this program is in a strong position to directly tie changes in bird populations to changes in vegetation at multiple scales. The hierarchical stratification scheme is well suited for linking bird population responses to climate and landscape change at biogeographical scales (Opdam and Wascher 2004). Finally, the IMBCR program uses the best available science to support the management of natural resources by providing bird population estimates that appropriately account for spatial variation and incomplete detection (Pollock et al. 2002, Rosenstock et al. 2002, Thompson 2002). The population density estimates are useful for evaluating temporal and spatial trends in population size. Occupancy estimates track temporal and spatial trends in the area occupied, including range contraction and expansion.

IMBCR and Adaptive Resource Management

Monitoring is integral to the management and conservation of wildlife populations (Marsh and Trenham 2008, Sauer and Knutson 2008). In particular, monitoring is necessary for the adaptive management of wildlife populations (Nichols and Williams 2006, Lyons et al. 2008). Monitoring in adaptive management is used to: 1) make state-dependent management decisions; 2) evaluate the effectiveness of management; and 3) improve understanding of the system (Lyons et al. 2008). For example, management decisions may depend on the state of a bird population and a threshold can be set to trigger a management action when the population reaches a predetermined level. Bird population monitoring is also necessary to determine if management actions implemented in previous management cycle(s) are achieving conservation objectives. Population estimates within management units can be compared over time and space, and to average conditions in the region to evaluate effectiveness of management actions. Monitoring data are also useful for evaluating competing hypotheses about how bird populations respond to system dynamics. A better understanding of regional bird population dynamics will help land managers predict species responses to landscape change and large-scale conservation efforts (Jones 2011, Noon et al. 2012).

Population estimates for a particular species or group of species can be used to make informed management decisions to focus conservation efforts. For example, management units with large populations can be targeted for protection or management units with small populations can be prioritized for conservation action. Although IMBCR does not employ vegetation stratification, the monitoring data can easily be post stratified to estimate vegetation-specific population density and occupancy rates. The IMBCR program is a rich data source for modeling habitat relationships, as well as developing spatially explicit abundance and occupancy maps. Recently, Bird Conservancy completed a project to determine multi-scale habitat relationships for sagebrush birds. This project used vegetation data collected at sampling points to model habitat relationships, and digital land cover data within sampling units to map bird occupancy rates at large-scales. In addition, Bird Conservancy adapted a hierarchical model developed by Chandler et al. (2011) to the IMBCR design that allows the prediction and mapping of bird population densities at large-scales (Figure 8). The IMBCR design provides a legitimate way to extend the population estimates to un-sampled regions, and the models provide population estimates that account for incomplete detection. The population estimation approach to species distribution modeling represents an improvement over opportunistic, index-based approaches (Rota et al. 2011), especially when the fate of declining species depends on conservation action. Large-scale species distribution maps and local habitat relationships are useful for answering the “where” and “what to do” questions in conservation planning (Wilson et al. 2007). Bird distributions can be summarized for un-sampled management units and regions, extending the ability of IMBCR to inform management and assess conservation responsibility.

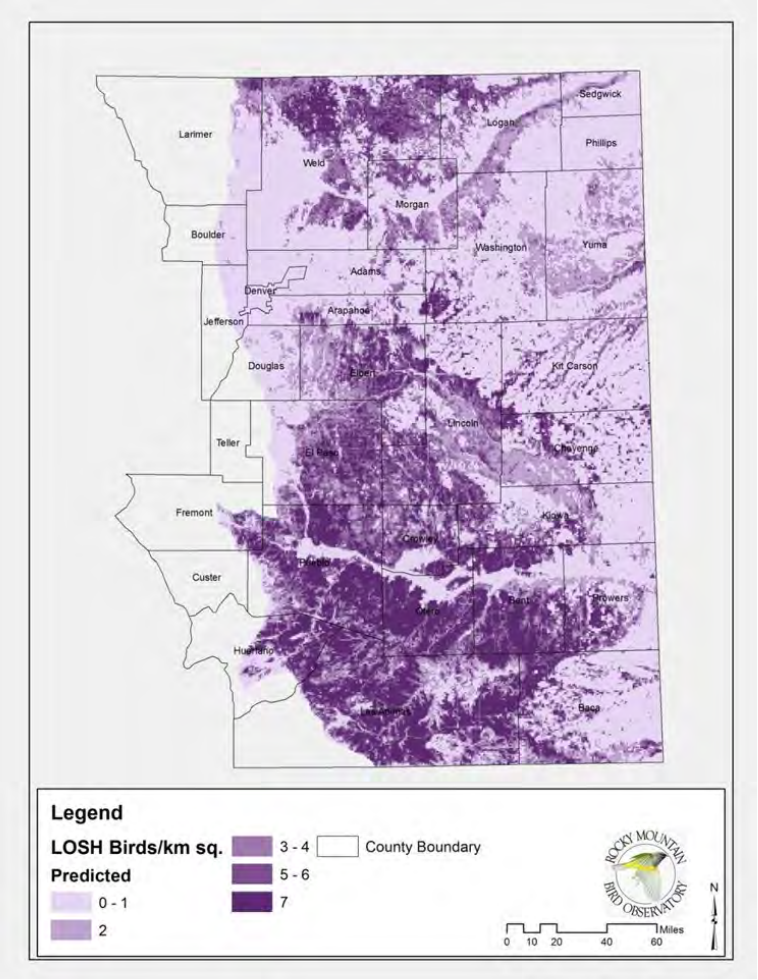

Figure 3. Loggerhead Shrike predicted distribution showing population density within the Colorado Shortgrass Prairie Bird Conservation Region (Sparks et al.)

The IMBCR data provide a source for the development of decision support tools to help land managers and resource professionals address important conservation issues. Bird Conservancy is currently developing a decision support tool that will assist resource professionals, land managers, and private landowners in managing the sagebrush bird community. The foundation of the tool will be species distribution maps used to prioritize landscapes for conservation and bird-habitat relationships used to evaluate the effectiveness of conservation practices. Decision support tools that integrate biological, social, and economic objectives are important for cost effective conservation outcomes in working landscapes.

Future Directions and Limitations

Land managers and conservation organizations can use IMBCR population estimates to better understand annual trends in landbird populations (US North American Bird Conservation Initiative 2009). Simulations using 10 years of data from a similar avian monitoring program (J. Blakesley, Bird Conservancy, unpublished) indicated the IMBCR program would have 80% power to detect an average annual decline of 3% in a population within 25 years when % CVs of the estimates are ≤ 40%. A similar trend could be detected within 30 years with a % CV of ≤ 50%. The ability to detect population trends for any species is a function of the sampling effort, abundance, and annual variation of abundance for individual species. Some grassland bird species such as Lark Bunting shift their breeding ranges from year to year based on environmental conditions (Shane 2000), resulting in local abundance estimates that fluctuate significantly among years. More precise density estimates will be required to monitor population trends within 25-30 years for species exhibiting larger degree annual variation in density and abundance estimates. Currently, we are investigating Bayesian trend estimation, which should have greater power to detect a trend, and will provide probability estimates of population decline. The IMBCR data can also be used to investigate population, metapopulation, and community dynamics over time. Annually surveyed sampling units provide information on dynamic processes that give rise to the patterns of abundance, occupancy and species richness over time.

The primary limitation in estimating avian population parameters using the IMBCR approach is sample size within strata. A minimum number of two samples per stratum is necessary to estimate regional density and occupancy. 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, estimates from large, under-sampled strata often receive more weight than estimates from small, well sampled strata.

Conclusion

Although the importance of long-term and intensive population monitoring is well known, it is expensive, with costs typically determining sampling effort. The IMBCR design reduces costs through cooperation with multiple partners, one of the stated goals of effective collaboration and coordinated bird monitoring (US North American Bird Conservation Initiative 2007). Partners and managers can investigate other priority species and taxa with only slight modifications to the IMBCR design, further reducing costs associated with developing new studies and monitoring programs. Ideally, these cost savings can be used to increase sample efforts, particularly in under-sampled strata, and conduct additional avian-habitat relationship analyses.

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