Department of Defense
Legacy Resource Management Program

PROJECT NUMBER (14-768)

Integrated assessment of breeding bird populations and habitat needs on DOD installations

Nick Van Lanen, Annual Report containing habitat relationship models and predictive distribution maps

12/15/2016

Monitoring Avian Populations on Colorado and Wyoming Military Installations

Photo by Greg Levandoski

BIRD CONSERVANCY OF THE ROCKIES

Bird Conservancy of the Rockies is a nonprofit dedicated to bird conservation.

Mission: To conserve birds and their habitats

Vision: Native bird populations are sustained in healthy ecosystems

Core Values: (Our goals for achieving our mission)
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.*

Bird Conservancy of the Rockies accomplishes its mission by:
• *Monitoring long-term bird population trends to provide a scientific foundation for conservation action.*
• *Researching bird ecology and population response to anthropogenic and natural processes to evaluate and adjust management and conservation strategies using the best available science.*
• *Educating people of all ages through active, experiential programs that create an awareness and appreciation for birds.*
• *Fostering good stewardship on private and public lands through voluntary, cooperative partnerships that create win-win situations for wildlife and people.*
• *Partnering with state and federal natural resource agencies, private citizens, schools, universities, and other non-governmental organizations to build synergy and consensus for bird conservation.*
• *Sharing the latest information on bird populations, land management and conservation practices to create informed publics.*
• *Delivering bird conservation at biologically relevant scales by working across political and jurisdictional boundaries in western North America.*

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Executive Summary

The Department of Defense (DOD) is charged with both the responsible stewardship of public lands and with facilitating adequate military training exercises to maintain military readiness. In order to achieve these outcomes concurrently, wildlife status and habitat requirement information specific to DOD installations is required. Both the North American Bird Conservation Initiative (NABCI) and DOD have developed recommendations for effective monitoring of avian populations to meet basic monitoring objectives and address these desired outcomes. Bird Conservancy of the Rockies, with assistance from a broad partnership, has developed a large-scale, integrated monitoring program entitled "Integrated Monitoring in Bird Conservation Regions" (IMBCR) which addresses the recommendations put forth by both NABCI and the DOD.

With funding assistance provided through the Legacy program, Bird Conservancy of the Rockies staff conducted avian monitoring using methods consistent with the IMBCR program on five DOD installations; Fort Carson, Pueblo Chemical Depot, Pinon Canyon Maneuver Site, and the U.S. Air Force Academy in Colorado, as well as Camp Guernsey in Wyoming. We utilized avian point count data collected on the installations to develop robust installation-wide density, population, and occupancy estimates for all bird species with a sufficient number of detections. Due to the integrated nature of the IMBCR program, metrics produced for the participating installations can be compared between installations, as well as to biologically-relevant or adjacent state and regional estimates.

Additionally, we developed multi-scale habitat relationship models for seven priority grassland species (Burrowing Owl, *Athene canicularia*; Grasshopper Sparrow, *Ammodramus savannarum*; Western Meadowlark, *Sturnella neglecta*; Lark Bunting, *Calamospiza melanocorys*; Loggerhead Shrike, *Lanius ludovicianus*; Vesper Sparrow, *Pooecetes gramineus*; and Cassin's Sparrow, *Aimophila cassinii*) that were detected on the installations. The local-scale component of these models identified vegetation characteristics likely to increase the probability of priority species' occupancy. This information will allow for model-based inference regarding avian response to military training or habitat manipulation actions. The large-scale component of these models also provides predicted priority species densities based on the amount of grassland or shrubland (derived from remote sensing models) at the 1 km² scale. This information can be used to determine if the examined grassland species require large, intact patches of either shrubland or grassland habitat.

Finally, we mapped predicted density values for each priority species across the Bird Conservation Region 17 (Badlands and Prairies) and 18 (Shortgrass Prairie) portions of the participating installations. This spatially-explicit information can be used to inform landscape planning efforts within the installations and steer disturbance activities away from high-quality habitat.

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INTRODUCTION

Inventory and monitoring data are fundamental to the management of wildlife populations (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). 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); 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. In particular, Department of Defense (DOD) managers require effective monitoring to facilitate the stewardship of priority species while ensuring that necessary training exercises can continue on DOD installations in order to maintain military readiness.

A coordinated approach to bird population monitoring has been identified as a priority by both the broad avian community and the DOD (U.S. North American Bird Conservation Initiative 2007, Bart et al. 2012). Bird Conservancy of the Rockies (hereafter, "Bird Conservancy") and its partners designed an integrated monitoring program entitled "Integrated Monitoring in Bird Conservation Regions" (IMBCR) which directly addresses the goals stated in these documents. Specifically, seven objectives of the IMBCR program meet both the DOD and NABCI goals:

1) provide robust density, population, and occupancy estimates that account for incomplete detection and are comparable across installations and 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 DOD priority species;
4) provide specific habitat association data for priority bird species to address habitat management issues;
5) identify the presence of, and model occupancy for, threatened and endangered species;
6) 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 that will serve as a node to the Avian Knowledge Network (AKN); and
7) generate tools, and make them available through the AKN, which will guide conservation efforts and provide a better measure of conservation success on installations.

With the assistance of the Legacy program (project 14-768), Bird Conservancy successfully collected avian and habitat data using IMBCR methodology on five installations (U.S. Air Force Academy, Pinon Canyon Maneuver Site, Fort Carson, Pueblo Chemical Depot, and Camp Guernsey) within the Southern Rockies/Colorado Plateau, Badlands and Prairies, and Shortgrass Prairie Bird Conservation Regions (BCRs) during the 2015 breeding season. Data collected on DOD installations were analyzed in concert with data from more than 1,400 avian surveys conducted during the 2015 breeding season under the IMBCR program. By monitoring DOD installations with methodology consistent with the IMBCR program, installation managers can benefit from a larger number of species with robust density, population and occupancy estimates, improved estimate precision, and the ability to compare individual installation estimates to other regional estimates (statewide or BCR-wide) obtained through the IMBCR program. Additionally, using data collected under the IMBCR program we generated predictive density distribution maps and habitat association models for seven DOD priority species (Burrowing Owl, *Athene canicularia*; Grasshopper Sparrow, *Ammodramus savannarum*; Western Meadowlark, *Sturnella neglecta*; Lark Bunting, *Calamospiza melanocorys*; Loggerhead Shrike, *Lanius ludovicianus*; Vesper Sparrow,

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Pooecetes gramineus; and Cassin's Sparrow, *Aimophila cassinii*) to provide installations with spatially-explicit information regarding the occurrence of these species on the selected installations.

The objectives of this study were to allow DOD natural resource managers to obtain status information for breeding bird species and to assess DOD priority bird populations and habitat quality on individual DOD installations. We attempted to address these objectives by providing avian abundance and occurrence estimates that are comparable across installations as well as to state and regional estimates. In addition, we modeled avian-habitat relationships at the landscape and local scales to inform managers of predicted species response to habitat modification, and generated maps which illustrate high density areas for priority species on each installation.

METHODS

Study Area
We included five DOD installations in our study area: Fort Carson, Pueblo Chemical Depot, Pinon Canyon Maneuver Site, and the U.S. Air Force Academy in Colorado, and Camp Guernsey in Wyoming. Two of the five DOD installations, Pueblo Chemical Depot and Pinon Canyon Maneuver Site, fall entirely within BCR 18 (Shortgrass Prairie). Two installations, U.S. Air Force Academy and Fort Carson, fall largely within BCR 18 but also extend into BCR 16 (Southern Rockies and Colorado Plateau). Camp Guernsey lies within BCR 17 (Badlands and Prairies) (Fig. 1). Excerpts from the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report (White et al. 2016) describing the respective BCRs are provided below:

BCR 16: Southern Rockies and Colorado Plateau
The Southern Rockies and Colorado Plateau Bird Conservation Region is a diverse area ranging from the southern Rocky Mountains in the east to the Wasatch and Uinta mountains in the west. In the center of the region are the tablelands of the Colorado Plateau. Within this region, vegetation types transition from shrub steppe; pinon-juniper; montane shrubland; mixed conifer and aspen; and alpine tundra with increasing elevation (Parrish et al. 2002). BCR 16 is centered on the Four Corners Region and consists mainly of Colorado, Utah, New Mexico and Arizona, with portions extending into southern Wyoming and Idaho.
(White et al. 2016)

BCR 17: Badlands and Prairies
The Badlands and Prairies Bird Conservation Region is characterized by rolling plains and mixed-grass prairie that contain large, continuous tracts of intact dry grassland managed predominately as ranchland (US North American Bird Conservation Initiative 2000). The Black Hills and western portions of BCR 17 contain pine and spruce forests at higher elevations. BCR 17 covers portions of five states: Montana; North Dakota; South Dakota; Wyoming and Nebraska.
(White et al. 2016)

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 (Playa Lakes Joint Venture Landbird Team 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 North American Bird Conservation Initiative 2000). BCR 18 stretches north-south in the rain shadow of the Rocky Mountains and covers portions of Colorado, Wyoming, Nebraska, Kansas, Oklahoma, South Dakota, Texas and New Mexico.
(White et al. 2016)

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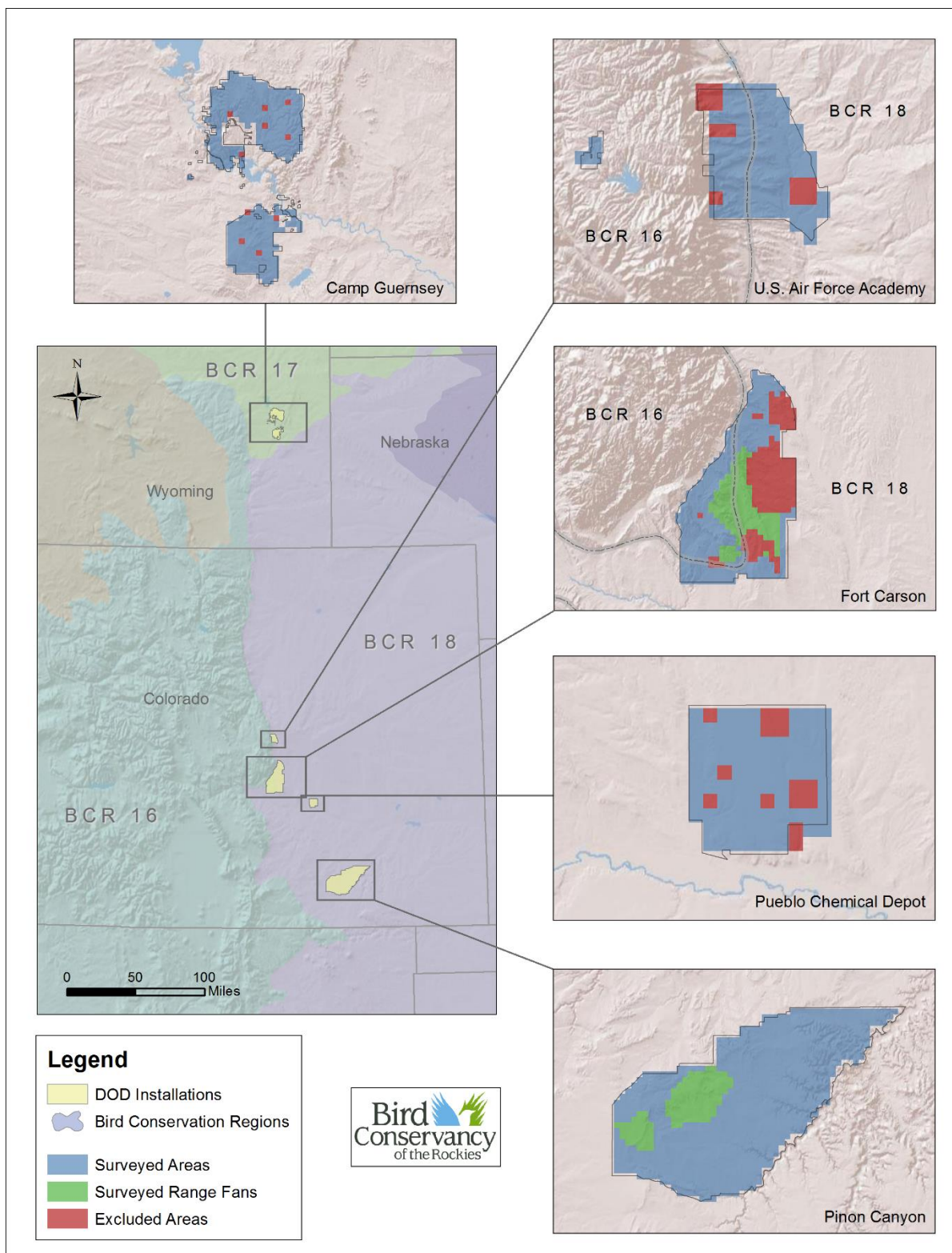
Figure 1. Overview of study area and surveyed locations on five DOD installations.

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Study Design

According to the IMBCR sampling design (White et al. 2016), we defined the sampling frame by superimposing a uniform grid of 1 km² sample units over the study area. We used a stratified design and randomly selected sample units within the installations using generalized random-tessellation stratification (Stevens and Olson 2004, package spsurvey, R Development Core Team 2014). We excluded sensitive (impact) areas from the sampling frame for all installations when the natural resource managers anticipated that access would be restricted.

Strata were created after consultation with the natural resource managers from the participating installations to address the managers' specific management questions and information needs. Camp Guernsey and Pueblo Chemical Depot were each represented by a single stratum. The U.S. Air Force Academy was divided into two strata; areas of the installation falling within BCR 18 and areas of the installation falling within BCR 16. Pinon Canyon Maneuver Site was divided into two strata; non-range fan areas and range fan areas. Lastly, Fort Carson was divided into four strata; non-range fan areas within BCR 16, non-range fan areas within BCR 18, range fan areas within BCR 16, and non-range fan areas within BCR 18.

Sampling Units

The sampling units were defined by the 1 km² grid cells. Each sampling unit contained 16 point count locations arranged in a 4X4 matrix with point count stations separated by 250-m (Fig. 2).

Sampling Methods

Point count locations within a sampling unit were surveyed on a single day during the avian breeding season between the middle of May and the end of June. We sampled avian abundance and occurrence between one-half hour before and five hours after official local sunrise at each accessible point count location. Technicians conducted 6-min point counts at each point count location (Alldredge et al. 2007). Counts were conducted on mornings with low wind speeds and little to no precipitation. We measured the distance to each bird detected using a laser rangefinder. Prior to conducting point counts, we collected vegetation data within a 50-m radius of the point using ocular estimation (White et al. 2016). Vegetation data included the dominant habitat type and relative abundance; percent cover and

Figure 2. Example 1 km² sampling unit containing 16 point count stations.

mean height of trees and shrubs by species; as well as grass height and proportions of several ground cover types. Technicians recorded vegetation data quietly to allow birds time to return to their normal habits prior to beginning each count.

Statistical Analyses

Distance Analysis

Statistical procedures for strata-level density estimation were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

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:

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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 ≥ 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 ≥ 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 ≥ 80) and 3) remedial measures were used for species with moderate departures from the assumptions of distance sampling (Buckland et al. 2001).

Beginning in 2015, 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 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 km² 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) ~ 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).
(White et al. 2016)

Occupancy Analysis
Statistical procedures for strata-level occupancy estimation were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

Occupancy estimation is most commonly used to quantify the proportion of sample units (i.e., 1 km² cells) occupied by an organism (MacKenzie et al. 2002). The application of occupancy modeling requires multiple surveys of the sample unit in space or time to estimate a detection probability (MacKenzie et al. 2006). The detection probability adjusts the proportion of sites occupied to account for species that were present but undetected (MacKenzie et al. 2002). We used a removal design (MacKenzie et al. 2006), to estimate a detection probability for each species, in which we binned minutes one and two, minutes three and four and minutes five and six to meet the assumption of a monotonic decline in the detection rates through time. After the target species was detected at a point, we set all subsequent sampling intervals at that point to "missing data" (MacKenzie et al. 2006). The 16 points in each sampling unit served as spatial replicates for estimating the proportion of points occupied within the sampled sampling units. We used a 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 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)

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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). (White et al. 2016)

Automated Analysis

We used automated analysis procedures previously described in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

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. (White et al. 2016)

Multi-scale Habitat-relationship Modeling

We extended an open population *N*-mixture model developed by Chandler et al. (2011) to estimate population density, and probabilities of availability and detection. We included IMBCR data collected within BCR 18 between 2010 and 2015 as well as data collected on Camp Guernsey in 2013 and 2015 for the analysis. We removed observations with a radial distance >125m. We binned the 6-min point count duration into three, two-minute time occasions (Alldredge et al. 2007). Our parameterization of the open population N-mixture model (Chandler et al. 2011, Sparks et al. in prep) estimated the availability parameter using spatial rather than temporal replicates. We estimated density (λ), small-scale occupancy (θ) and detection probability (p) within the 1 km² sampling grid. Density was modeled using the Poisson distribution. We modeled θ, which represents the probability of a species being present within the 125 m-radius of the point count station given the species was present on the 1 km^2 sampling unit, using a Binomial distribution. We modeled p using a removal model where the vector of counts was considered to be multinomial. We estimated parameters of the generalized multinomial mixture model by maximizing the integrated likelihood function in the R package unmarked (Fiske and Chandler 2011, R Development Core Team 2015). We ranked models using AIC (Akaike 1973). We developed predicted distribution maps by model-averaging density predictions across models within four AIC of the top-

ranked model (i.e., ΔAIC ≤ 4). Predicted densities are displayed using raster images with cell sizes of 1 km², generated from the U.S. National Grid grid layers for the five DOD installations (FGDC 2001). We did not map predicted densities within the BCR 16 portions of installations because these data were excluded from the analysis.

Model Justification and Construction
We used the method of multiple working hypotheses (Chamberlin 1965) to develop alternate *a priori* hypotheses for the effects of covariates on detection, small-scale occupancy, and density of seven grassland-associated species: Burrowing Owl, Cassin's Sparrow, Grasshopper Sparrow, Lark Bunting, Loggerhead Shrike, Vesper Sparrow, and Western Meadowlark. We evaluated spatial variation in detection by allowing the detection probability to vary by a continuous shrub cover covariate collected by the avian observers at the point count station and a categorical year covariate. The ocular estimate of shrub cover was thought to impact the likelihood that an observer would visually detect individuals while the year covariate accounted for differences in observers, habitat, and weather across years. We modeled the spatial variation in small-scale occupancy using IMBCR vegetation data collected at the point count stations. The following local vegetation covariates were included in our models: percent grass cover, grass height, percent herbaceous cover and percent shrub cover. We allowed avian density to vary by the proportion of grassland cover, proportion of shrubland cover, and center-point longitude and latitude coordinates within the 1 km² sampling grid.

The proportion of grassland and shrubland cover used in the large-scale density estimation at the 1 km² scale was estimated by measuring the percentage of grassland and shrubland in the 1 km² grid cells using the "Existing Vegetation Type" layer in the LANDFIRE dataset (USGS 2012). For percent grassland, we extracted vegetation types with a National Vegetation Classification System Physiognomic Class (EVT_CLASS) of 'herbaceous – grassland' and a System Group Physiognomy (EVT_PHYS) of 'grassland'. Additional LANDFIRE existing vegetation type class names were removed to exclude shrubland, high elevation montane/subalpine grasslands, mountain meadows, introduced grasslands (modified/managed habitat), and recently logged areas. For percent shrubland, we used an EVT_CLASS of 'Shrubland', 'Dwarf-shrubland', or 'herbaceous-shrub-steppe' and an EVT_PHYS of Shrubland, removing all grassland or tree lifeforms (EVT_LF). In addition, we added two shrubland types previously excluded from grassland vegetation.

We used a sequential, parameter-wise model building strategy to determine the strength of evidence within the model set (Lebreton et al. 1992, Doherty et al. 2012). First, we constructed detection models using all subsets of covariates for detection (including an intercept-only model), while holding small-scale occupancy and density constant using the global models. Second, we built small-scale occupancy models using all subsets of covariates for small-scale occuapncy (including an intercept-only model), while modeling detection using the top-ranked model for detection and holding abundance constant at the global model. Lastly, we developed density models using all subsets of covariates for density (including an intercept-only model), while holding detection and small-scale occupancy constant using the top-ranked models for the parameters from the first and second steps.

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RESULTS

Strata-level Density and Occupancy Estimation Results

U.S. Air Force Academy

Strata-level density and occupancy estimates for the U.S. Air Force Academy were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

> We obtained results for the US Air Force Academy in Colorado by compiling and jointly analyzing data from two strata.
>
> Field technicians completed all 20 planned surveys (100%) in 2015. Technicians conducted 239 point counts within the 20 surveyed grid cells between 3 June and 25 June. They detected 106 bird species, including 22 priority species (Appendix C).
>
> Bird Conservancy estimated densities and population sizes for 78 species, 22 of which are priority species. The data yielded robust density estimates (CV < 50%) for 32 of these species.
> Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout the US Air Force Academy in Colorado for 76 species, 20 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 47 of these species.
>
> To view a map of survey locations and get species counts within the US Air Force Academy in Colorado 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 2015, 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 2015, hit "Add Filter", then "Run Query".
>
> [US Air Force Academy Results](#)
> (White et al. 2016)

Fort Carson

Strata-level density and occupancy estimates for Fort Carson were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

> We obtained results for Fort Carson in Colorado by compiling and jointly analyzing data from four strata.
>
> Field technicians completed 27 of 30 planned surveys (90%) in 2015. Technicians conducted 329 point counts within the 27 surveyed grid cells between 13 May and 14 June. They detected 110 bird species, including 23 priority species (Appendix C).
>
> Bird Conservancy estimated densities and population sizes for 80 species, 20 of which are priority species. The data yielded robust density estimates (CV < 50%) for 25 of these species.
>
> Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout Fort Carson in Colorado for 75 species, 21 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 35 of these species.
>
> To view a map of survey locations and get species counts within Fort Carson across all years of the project follow the web link below and hit the "Run Query" button highlighted in red located

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near the top of the page. If you want to limit results to 2015, 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 2015, hit "Add Filter", then "Run Query".

[Fort Carson Results](#)

1. Range Fan Areas in Fort Carson
We obtained results for Range Fan Areas in Fort Carson by compiling and jointly analyzing data from two strata.

Field technicians completed 13 of 14 planned surveys (92.9%) in 2015. Technicians conducted 171 point counts within the 13 surveyed grid cells between 6 June and 14 June. They detected 84 bird species, including 19 priority species (Appendix C).

Bird Conservancy estimated densities and population sizes for 64 species, 17 of which are priority species. The data yielded robust density estimates (CV < 50%) for 15 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout Range Fan Areas in Fort Carson for 61 species, 17 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 23 of these species.

To view a map of survey locations and get species counts within Range Fan Areas in Fort Carson 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 2015, 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 2015, hit "Add Filter", then "Run Query".

[Range Fan Areas in Fort Carson Results](#)

2. All Other Areas in Fort Carson
We obtained results for All Other Areas in Fort Carson by compiling and jointly analyzing data from two strata.

Field technicians completed 14 of 16 planned surveys (87.5%) in 2015. Technicians conducted 158 point counts within the 14 surveyed grid cells between 13 May and 8 June. They detected 92 bird species, including 19 priority species (Appendix C).

Bird Conservancy estimated densities and population sizes for 66 species, 16 of which are priority species. The data yielded robust density estimates (CV < 50%) for 12 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout All Other Areas in Fort Carson for 59 species, 15 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 21 of these species.

To view a map of survey locations and get species counts within All Other Areas in Fort Carson 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 2015, 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 2015, hit "Add Filter", then "Run Query".

[All Other Areas in Fort Carson Results](#)
(White et al. 2016)

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Pinon Canyon Maneuver Site
Strata-level density and occupancy estimates for Pinon Canyon Maneuver Site were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

We obtained results for Pinon Canyon Maneuver Site in Colorado by compiling and jointly analyzing data from two strata.

Field technicians completed all 35 planned surveys (100%) in 2015. Technicians conducted 445 point counts within the 35 surveyed grid cells between 11 May and 24 May. They detected 103 bird species (Appendix C).

Bird Conservancy estimated densities and population sizes for 69 species. The data yielded robust density estimates (CV < 50%) for 23 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout Pinon Canyon Maneuver Site in Colorado for 63 species. The data yielded robust occupancy estimates (CV < 50%) for 28 of these species.

To view a map of survey locations and get species counts within Pinon Canyon Maneuver Site 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 2015, 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 2015, hit "Add Filter", then "Run Query".

 [Pinon Canyon Maneuver Site Results](#)

Range Fan Areas in Pinon Canyon Maneuver Site
We obtained results for Range Fan Areas in Pinon Canyon Maneuver Site by analyzing data from one stratum.

Field technicians completed all 10 planned surveys (100%) in 2015. Technicians conducted 120 point counts within the 10 surveyed grid cells between 18 May and 24 May. They detected 70 bird species, including 10 priority species (Appendix C).

Bird Conservancy estimated densities and population sizes for 47 species, 5 of which are priority species. The data yielded robust density estimates (CV < 50%) for 10 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout Range Fan Areas in Pinon Canyon Maneuver Site for 40 species, 5 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 14 of these species.

To view a map of survey locations and get species counts within Range Fan Areas in Pinon Canyon Maneuver Site 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 2015, 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 2015, hit "Add Filter", then "Run Query".

 [Range Fan Areas in Pinon Canyon Maneuver Site Results](#)

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All Other Areas in Pinon Canyon Maneuver Site
We obtained results for All Other Areas in Pinon Canyon Maneuver Site by analyzing data from one stratum.

Field technicians completed all 25 planned surveys (100%) in 2015. Technicians conducted 325 point counts within the 25 surveyed grid cells between 11 May and 24 May. They detected 88 bird species, including 12 priority species (Appendix C).

Bird Conservancy estimated densities and population sizes for 60 species, 7 of which are priority species. The data yielded robust density estimates (CV < 50%) for 19 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout All Other Areas in Pinon Canyon Maneuver Site for 57 species, 8 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 24 of these species.

To view a map of survey locations and get species counts within b)   All Other Areas in Pinon Canyon Maneuver Site 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 2015, 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 2015, hit "Add Filter", then "Run Query".

 All Other Areas in Pinon Canyon Maneuver Site Results
(White et al. 2016)

Pueblo Chemical Depot
Strata-level density and occupancy estimates for the Pueblo Chemical Depot were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

We obtained results for Pueblo Chemical Depot in Colorado by analyzing data from one stratum.

Field technicians completed all 15 planned surveys (100%) in 2015. Technicians conducted 195 point counts within the 15 surveyed grid cells between 13 May and 2 June. They detected 58 bird species, including 5 priority species (Appendix C).

Bird Conservancy estimated densities and population sizes for 40 species, 4 of which are priority species. The data yielded robust density estimates (CV < 50%) for 13 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout Pueblo Chemical Depot in Colorado for 37 species, 4 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 15 of these species.

To view a map of survey locations and get species counts within Pueblo Chemical Depot 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 2015, 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 2015, hit "Add Filter", then "Run Query".

 Pueblo Chemical Depot Results
(White et al. 2016)

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Camp Guernsey
Strata-level density and occupancy estimates for Camp Guernsey were initially reported in the Integrated Monitoring in Bird Conservation Regions (IMBCR): 2015 Field Season Report:

We obtained results for Camp Guernsey in Wyoming by analyzing data from one stratum.

Field technicians completed all 20 planned surveys (100%) in 2015. Technicians conducted 244 point counts within the 20 surveyed grid cells between 20 May and 7 June. They detected 92 bird species, including 8 priority species (Appendix C).

Bird Conservancy estimated densities and population sizes for 72 species, 6 of which are priority species. The data yielded robust density estimates (CV < 50%) for 23 of these species.

Bird Conservancy estimated the proportion of 1 km² grid cells occupied (Psi) throughout Camp Guernsey in Wyoming for 65 species, 5 of which are priority species. The data yielded robust occupancy estimates (CV < 50%) for 27 of these species.
To view a map of survey locations and get species counts within Camp Guernsey 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 2015, 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 2015, hit "Add Filter", then "Run Query".

Camp Guernsey Results
(White et al. 2016)

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Multi-scale Habitat Relationship Models

Lark Bunting
The best model for density (λ) of the Lark Bunting included two covariates: the proportion of grassland cover and the proportion of shrubland cover (Table A.1). There was nearly equal support for the second best model including latitude and longitude (ΔAIC = 0.97, Table A.1). Density (λ) of the Lark Bunting showed a positive effect for proportion of grassland cover (Fig. 3, Table A.2) and a negative effect for proportion of shrubland cover (Fig. 3, Table A.2). The 95% confidence interval (CI) for the proportion of grassland and shrubland cover excluded zero, indicating a measurable difference for the effect size of this covariate (Table A.2). The predicted distribution across the five DOD installations is shown in Fig. 4. Please refer to appendices H – L to view full page maps of Lark Bunting distribution on the individual installations.

The best approximating model for small-scale occupancy (θ) of the Lark Bunting included the effects of grass cover, grass height, and herbaceous cover (Table A.1). The second best model included shrub cover (ΔAIC = 1.99, Table A.1). The third best model, including the effect of grass cover and herbaceous cover, was four times less plausible than the top model as determined by AIC (Table A.1). The small-scale occupancy of the Lark Bunting increased with increasing grass cover and herbaceous cover and declined with increasing grass height (Fig. 5, Table A.2). The 95% CIs for the effects of grass cover, grass height, and herbaceous cover excluded zero, indicating measurable differences for the effect sizes of these covariates (Table A.2).

The best model for the detection (*p*) of the Lark Bunting included year and shrub cover (Table A.1). There was little support for the second best model, containing the effect of year and shrub cover (ΔAIC = 5.3).

Figure 3. The density of Lark Bunting by A) proportion of grassland cover and B) proportion of shrubland cover, 2010 – 2015. The bold lines are estimates of density (λ) and the gray regions are 95% confidence intervals.

Figure 4. Predicted distribution of Lark Bunting, showing model-averaged population density (birds/km²) across five DOD installations. Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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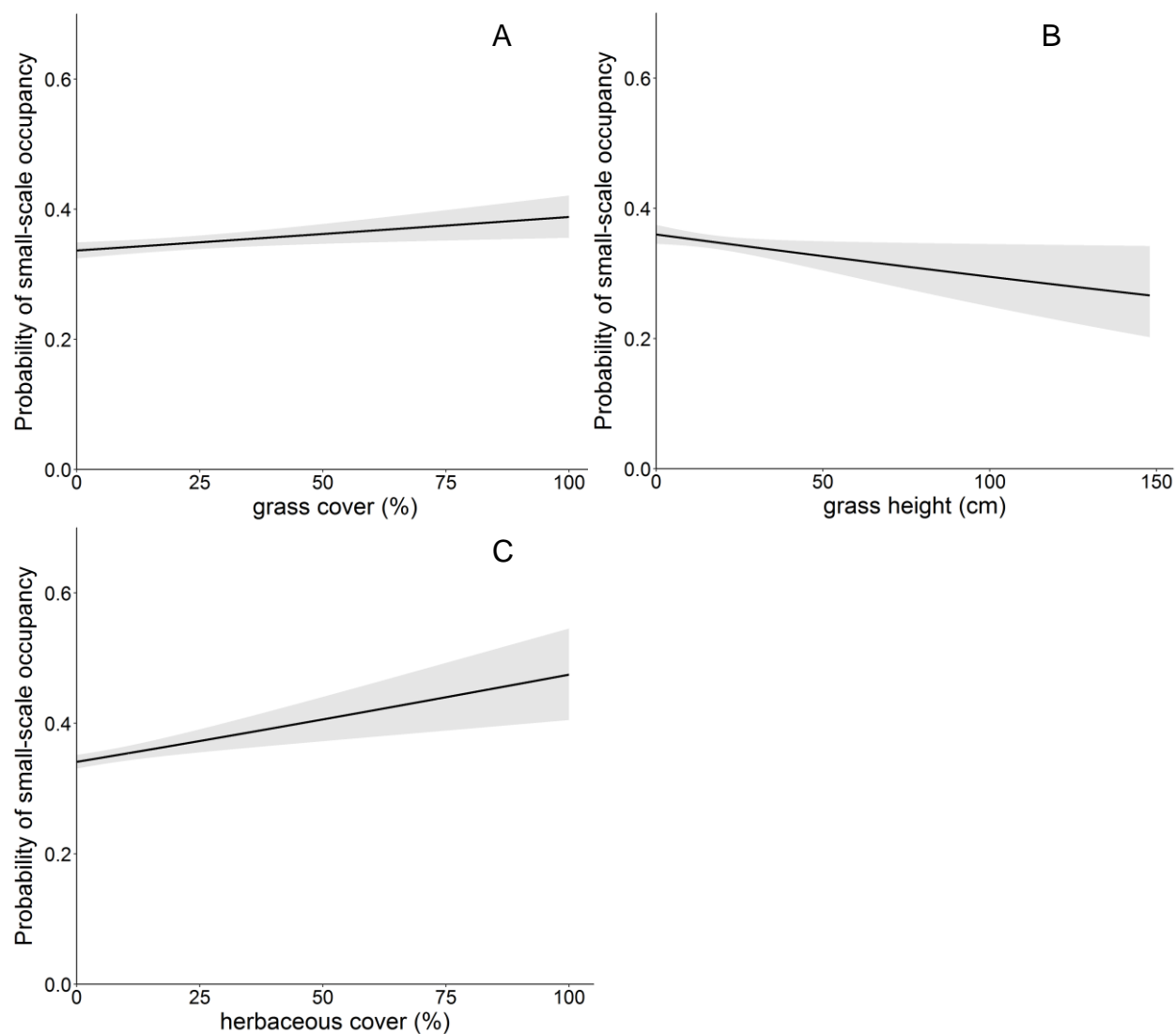
Figure 5. The small-scale occupancy of Lark Bunting by A) grass cover, B) grass height, and C) herbaceous cover, 2010 – 2015. The bold lines are estimates of small-scale occupancy (θ) and the gray regions are 95% confidence intervals.

Western Meadowlark
The best model for the density (λ) of Western Meadowlark contained the covariates latitude, longitude, proportion of grassland cover, and proportion of shrubland cover (Table B.1). There was nearly equal support for the second-best model which excluded the proportion of shrubland cover (ΔAIC = 0.14). Western Meadowlark density (λ) increased with the proportion of grassland and shrubland. The 95% CI for the effect of proportion of grassland excluded zero, indicating a measurable difference for the effect size of this covariate (Fig. 6, Table B.2). The predicted distribution across the five DOD installations is shown in Fig. 7. Please refer to appendices H – L to view full page maps of Western Meadowlark distribution on the individual installations.

The best approximating model for small-scale occupancy (θ) of the Western Meadowlark included the effects of grass cover, grass height, herbaceous cover, and shrub cover (Table B.1). The second best model carried only half the support of the top model and excluded grass height (Table B.1). The effects of grass cover and herbaceous cover were positive and the effect of shrub cover was negative. The 95% CI for the effects of grass cover, herbaceous cover, and shrub cover excluded zero, indicating measurable differences for the effect sizes of these covariates (Fig. 8, Table B.2).

The best model for the detection (p) of the Western Meadowlark was the constant model (Table B.1). The constant rate of detection was p = 0.73 (SE = 0.01). There was nearly equal support for the second top model (ΔAIC = 0.52, Table B.1) which included shrub cover and indicated that detection decreased with increasing shrub cover (Table B.1).

Figure 6. The density of Western Meadowlark by proportion of grassland, 2010 – 2015. The bold lines are estimates of density (λ) and the gray regions are 95% confidence intervals.

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Figure 7. Predicted distribution of Western Meadowlark, showing model-averaged population density (birds/km²) across five DOD installations. Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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Figure 8. The small-scale occupancy of Western Meadowlark by A) grass cover, B) herbaceous cover, and C) shrub cover, 2010 – 2015. The bold lines are estimates of small-scale occupancy (θ) and the gray regions are 95% confidence intervals.

Grasshopper Sparrow

The best model for the density (λ) of the Grasshopper Sparrow contained the covariates latitude, longitude, and proportion of grassland cover (Table C.1). The second best model included proportion of shrubland cover and carried only half the support of the best model (ΔAIC = 1.38). Grasshopper Sparrow density (λ) increased with proportion of grassland cover. The 95% CI for the effect of proportion of grassland cover excluded zero, indicating a measurable difference for the effect size of this covariate (Fig. 9, Table C.2). The predicted distribution across the five DOD installations is shown in Fig. 10. Please refer to appendices H – L to view full page maps of Grasshopper Sparrow distribution on the individual installations.

The best model for small-scale occupancy (θ) of the Grasshopper Sparrow included the effects of grass cover, grass height, herbaceous cover, and shrub cover (Table C.1). The second best model included the effects of grass cover, grass height, and shrub cover and had approximately three times less support than the best model (Table C.1). Small scale occupancy increased with increasing grass cover and grass height and decreased with increasing herbaceous cover and shrub cover (Fig. 11, Table C.2). The 95% CI for the effects of grass cover, grass height, herbaceous cover, and shrub cover excluded zero, indicating measurable differences for the effect sizes of these covariates (Table C.2).

The best model for the detection (p) of the Grasshopper Sparrow included year and shrub cover (Table C.1). There was no support for the second best model containing the effect of year, with shrub cover excluded (ΔAIC = 11.76). Detection decreased as shrub cover increased (Table C.2).
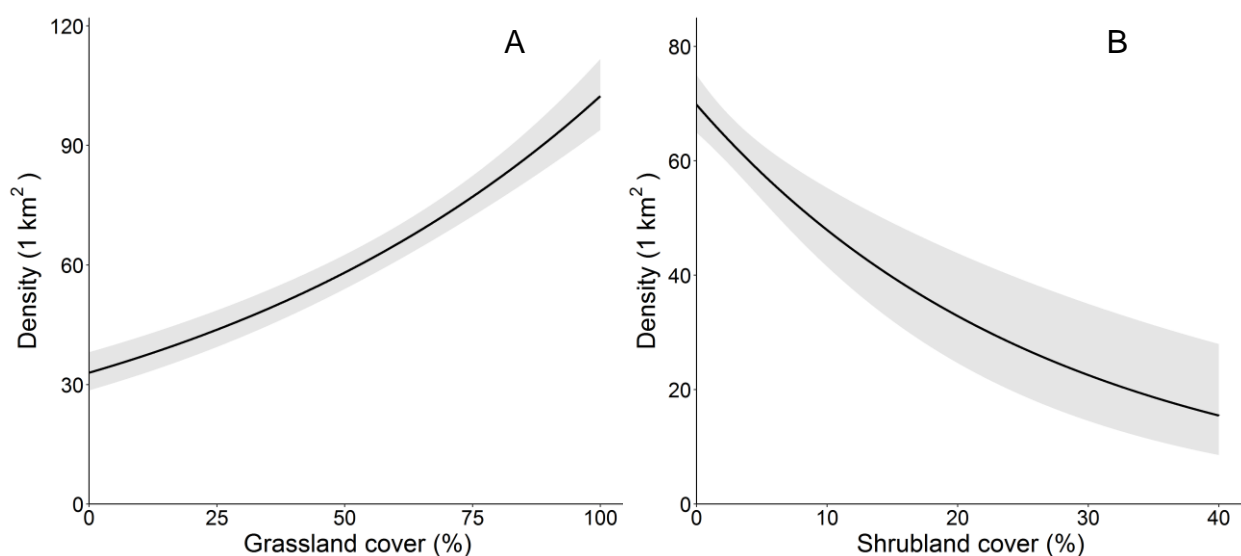

Figure 9. The density of Grasshopper Sparrow by proportion of grassland, 2010 – 2015. The bold lines are estimates of density (λ) and the gray regions are 95% confidence intervals.

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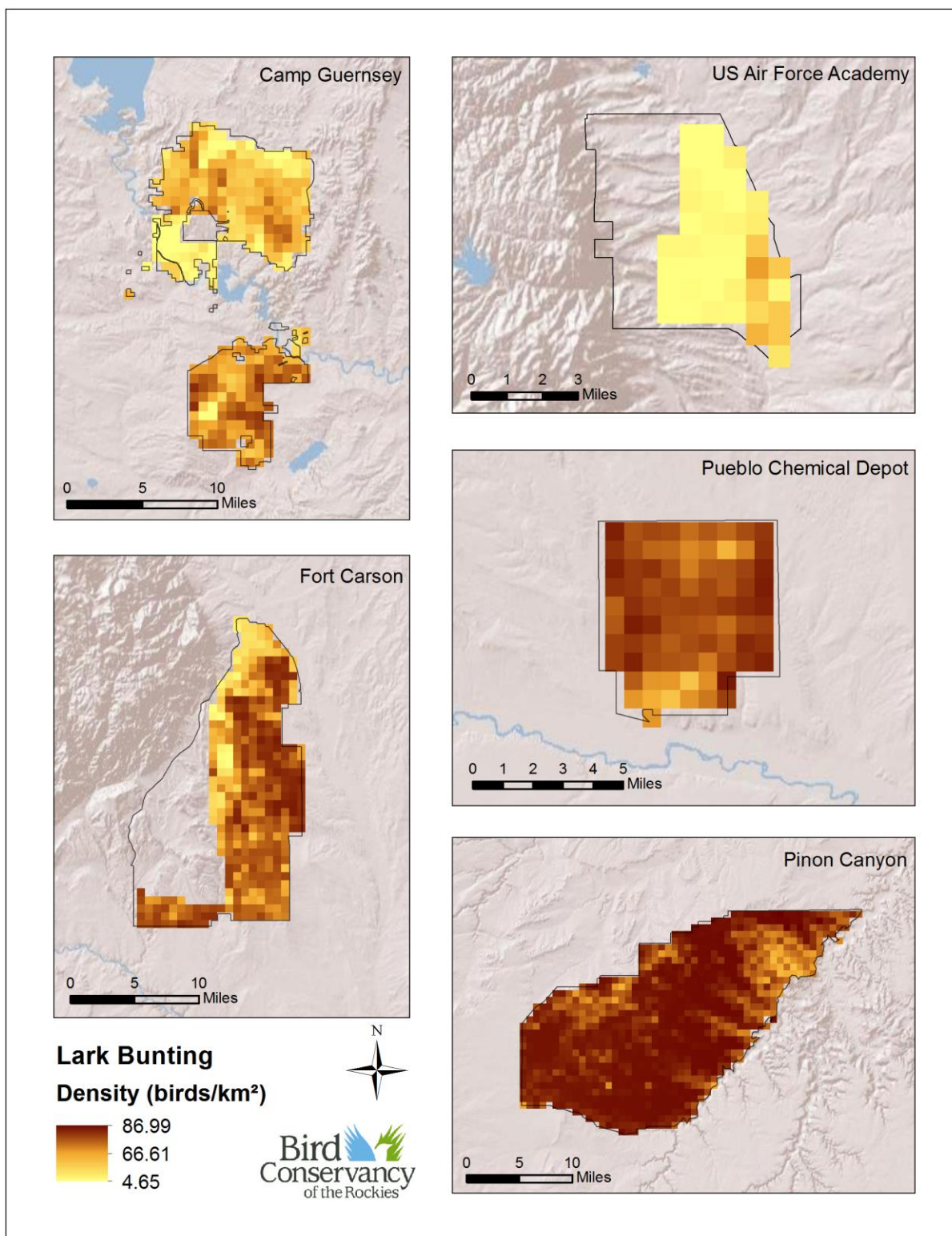*Connecting people, birds and land*

Figure 10. Predicted distribution of Grasshopper Sparrow, showing model-averaged population density (birds/km²) across five DOD installations. Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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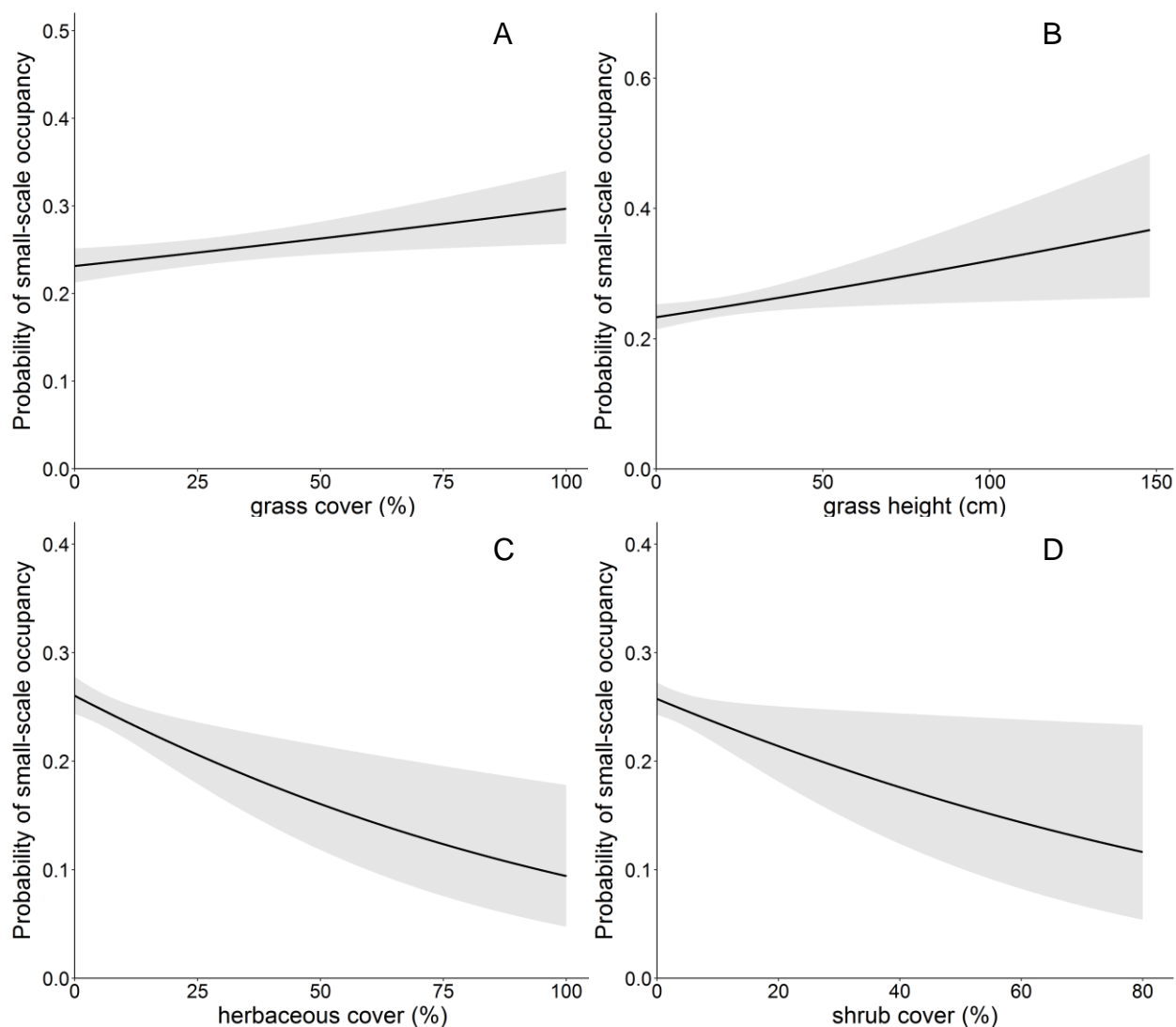
Figure 11. The small-scale occupancy of Grasshopper Sparrow by A) grass cover, B) grass height, C) herbaceous cover, and D) shrub cover, 2010 – 2015. The bold lines are estimates of small-scale occupancy (θ) and the gray regions are 95% confidence intervals.

Loggerhead Shrike

The best model for the density (λ) of the Loggerhead Shrike contained the covariates latitude, longitude, and proportion of grassland cover (Table D.1). The second best model included proportion of shrubland cover and was approximately two times less plausible than the best model (ΔAIC = 1.09). Loggerhead Shrike density (λ) increased with proportion of grassland cover. The 95% CI for the effect of proportion of grassland cover excluded zero, indicating a measurable difference for the effect size of this covariate (Fig 12, Table D.2). The predicted distribution across the five DOD installations is shown in Fig. 13. Please refer to appendices H – L to view full page maps of Lark Bunting distribution on the individual installations.

The best model for small-scale occupancy (θ) of the Loggerhead Shrike included herbaceous and shrub cover (Table D.1). The second best model included the effects of grass height, herbaceous cover, and shrub cover (ΔAIC = 1.66). The second best model had approximately two times less support than the best model (Table D.1). Small scale occupancy increased with increasing shrub cover and decreased with increasing herbaceous cover (Fig. 14, Table D.2). The 95% CI for the effects of herbaceous cover and shrub cover excluded zero, indicating measurable differences for the effect sizes of these covariates (Table D.2).

The best model for the detection (p) of the Loggerhead Shrike included year and shrub cover (Table D.1). There was nearly equal support for the second best model, containing the effect of year (ΔAIC = 0.70). Detection increased as shrub cover increased (Table D.2).
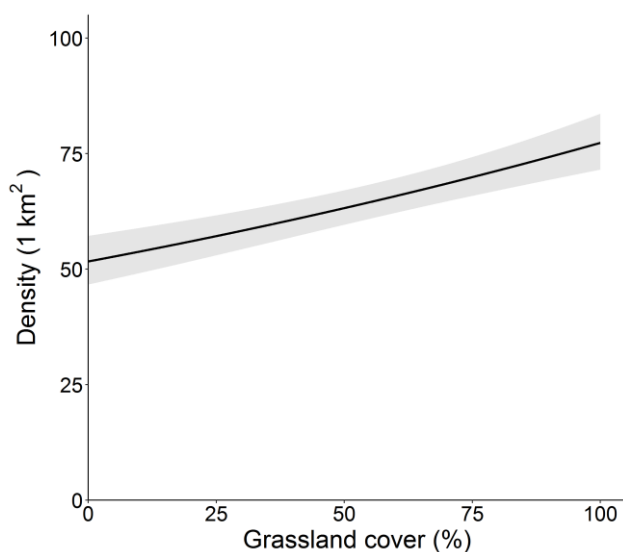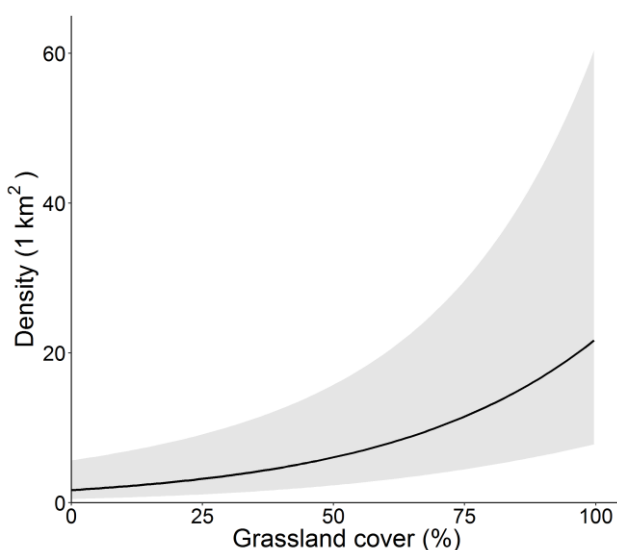

Figure 12. The density of Loggerhead Shrike by proportion of grassland, 2010 – 2015. The bold lines are estimates of density (λ) and the gray regions are 95% confidence intervals.
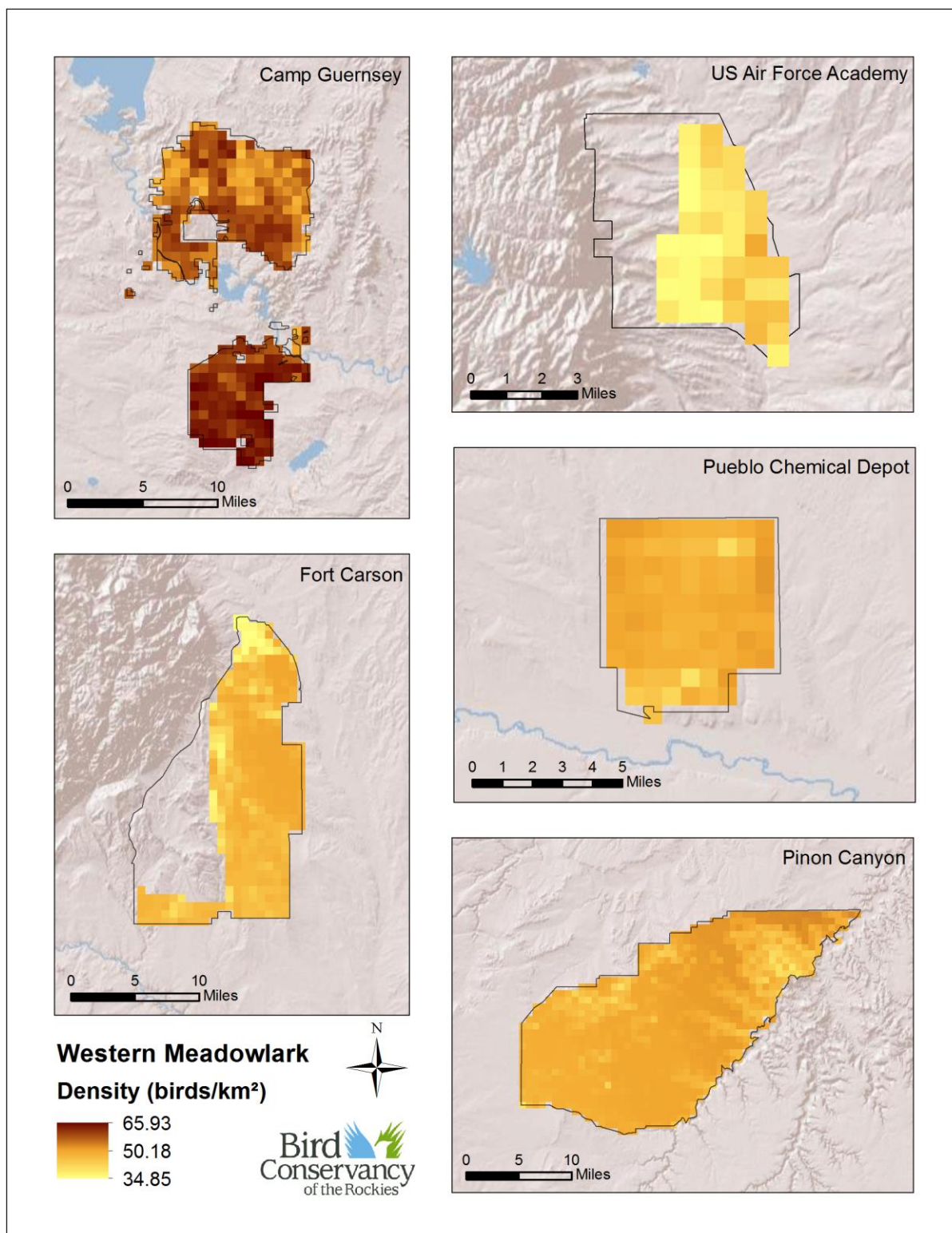
Figure 13. Predicted distribution of Loggerhead Shrike, showing model-averaged population density (birds/km²) across five DOD installations. Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
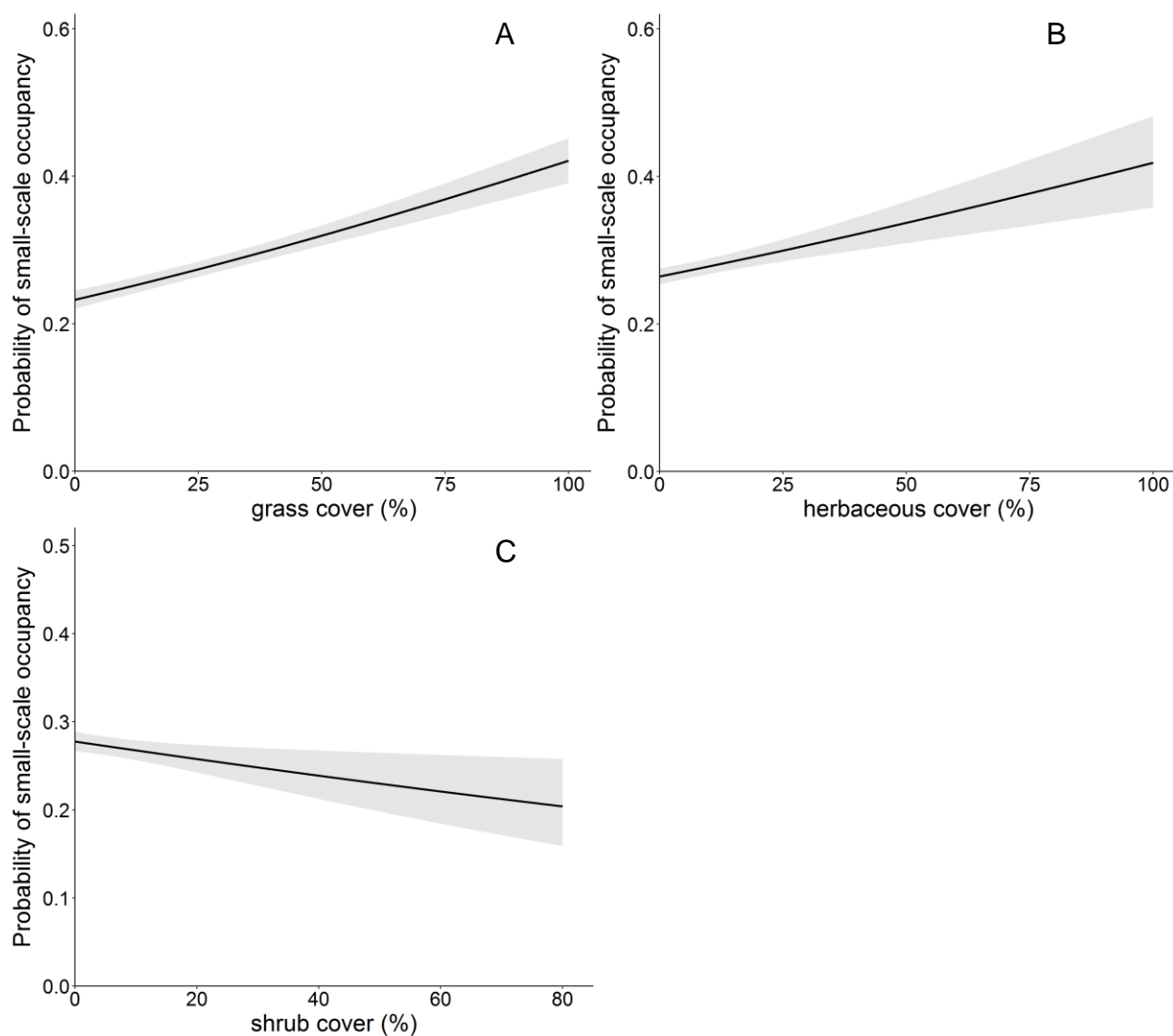
Figure 14. The small-scale occupancy of Loggerhead Shrike by A) herbaceous cover and B) shrub cover, 2010 – 2015. The bold lines are estimates of small-scale occupancy (θ) and the gray regions are 95% confidence intervals.

Vesper Sparrow

The best model for the density (λ) of Vesper Sparrow contained latitude, longitude, and proportion of shrubland cover (Table E.1). There was nearly equal support for the second best model including the proportion of grassland cover (ΔAIC = 0.08). Density (λ) of the Vesper Sparrow showed a positive effect for proportion of shrubland cover. The 95% CI for the effect of the proportion of shrubland cover excluded zero, indicating a measurable difference for the effect size of this covariate (Fig. 15, Table E.2). The predicted distribution across the five DOD installations is shown in Fig. 16. Please refer to appendices H – L to view full page maps of Vesper Sparrow distribution on the individual installations.

The best model for small-scale occupancy (θ) of the Vesper Sparrow included the effect of shrub cover (Table E.1). There was high model selection uncertainty for small-scale occupancy. There was nearly equal support for the second and third top models including the effects for shrub cover and herbaceous cover (Table E.1). The evidence ratio indicated the fourth best model was two times less plausible than the top model (Table E.1). The small-scale occupancy of the Vesper Sparrow decreased with increasing shrub cover (Table E.2). The 95% CI for the effect of shrub cover included zero, indicating marginal precision in relation to the effect size for this covariate (Table E.2).

The best model for the detection (p) of the Vesper Sparrow included covariates for year (Table E.1). There was nearly equal support for the second best model containing the additional effect of shrub cover (ΔAIC = 0.96). The second best model indicated detection increased with increasing shrub cover (Table E.2).
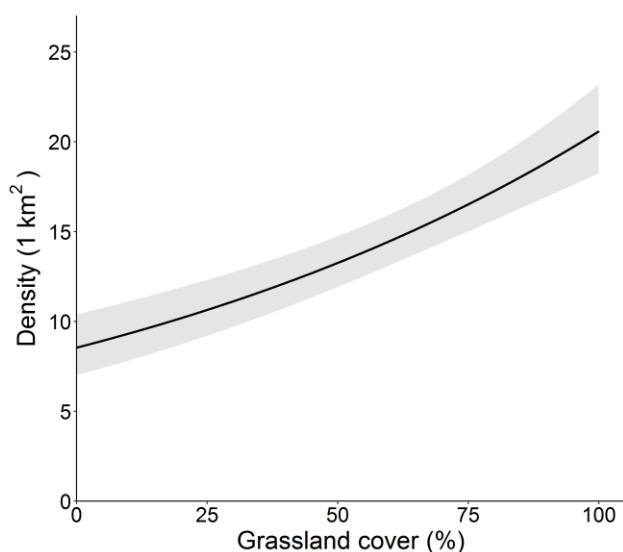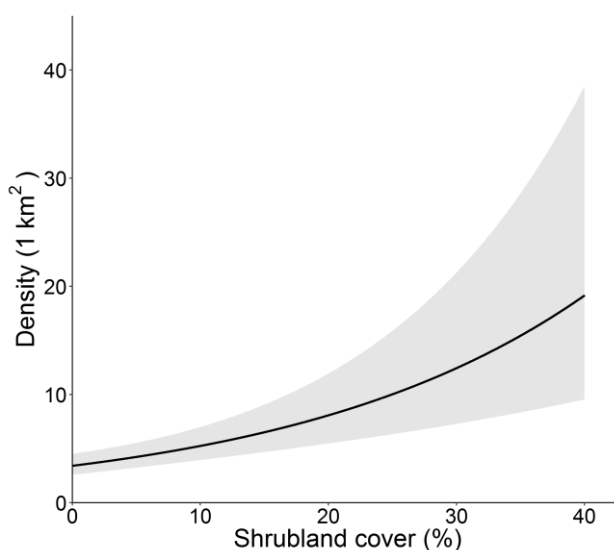

Figure 15. The density of Vesper Sparrow by proportion of shrubland, 2010 – 2015. The bold lines are estimates of density (λ) and the gray regions are 95% confidence intervals.
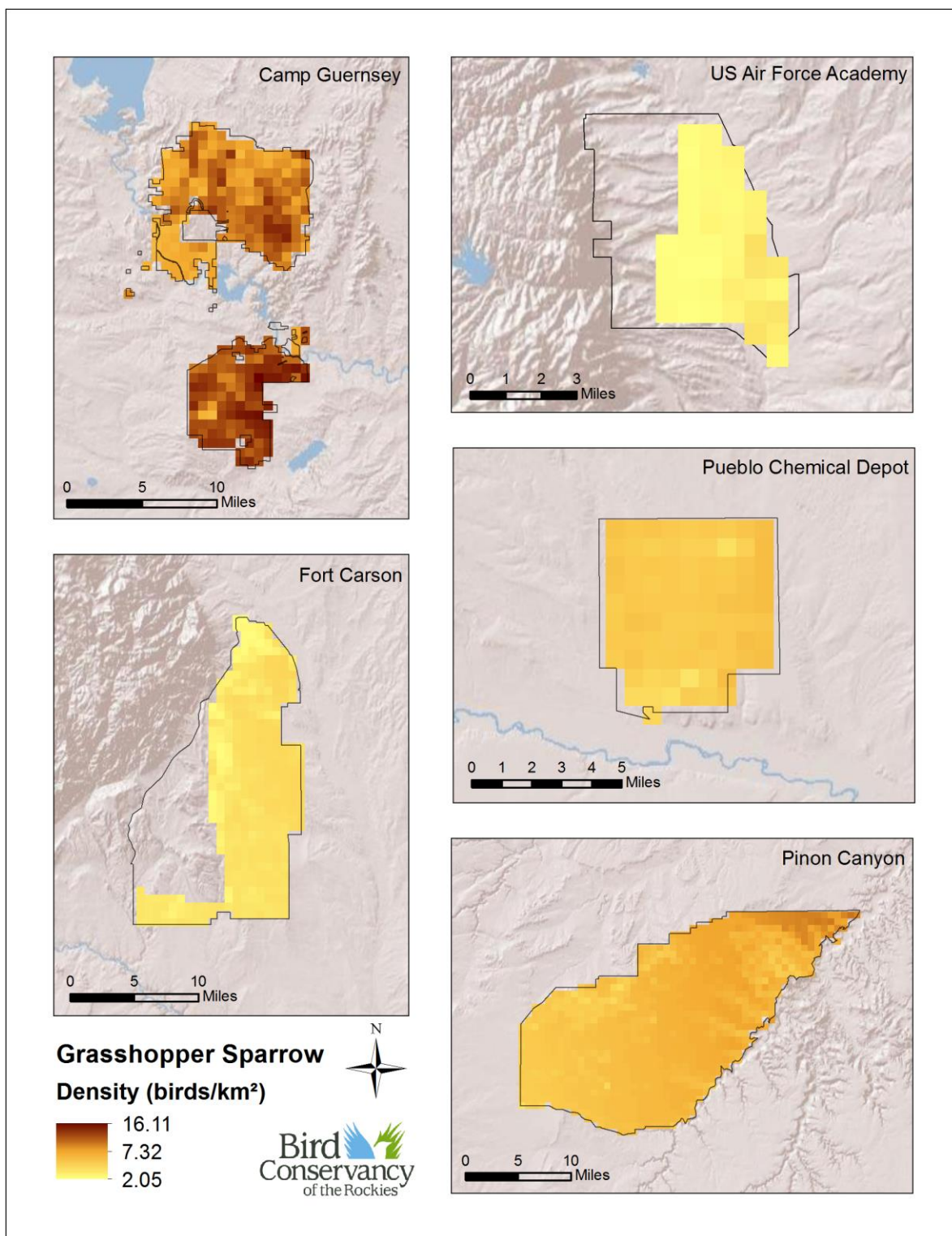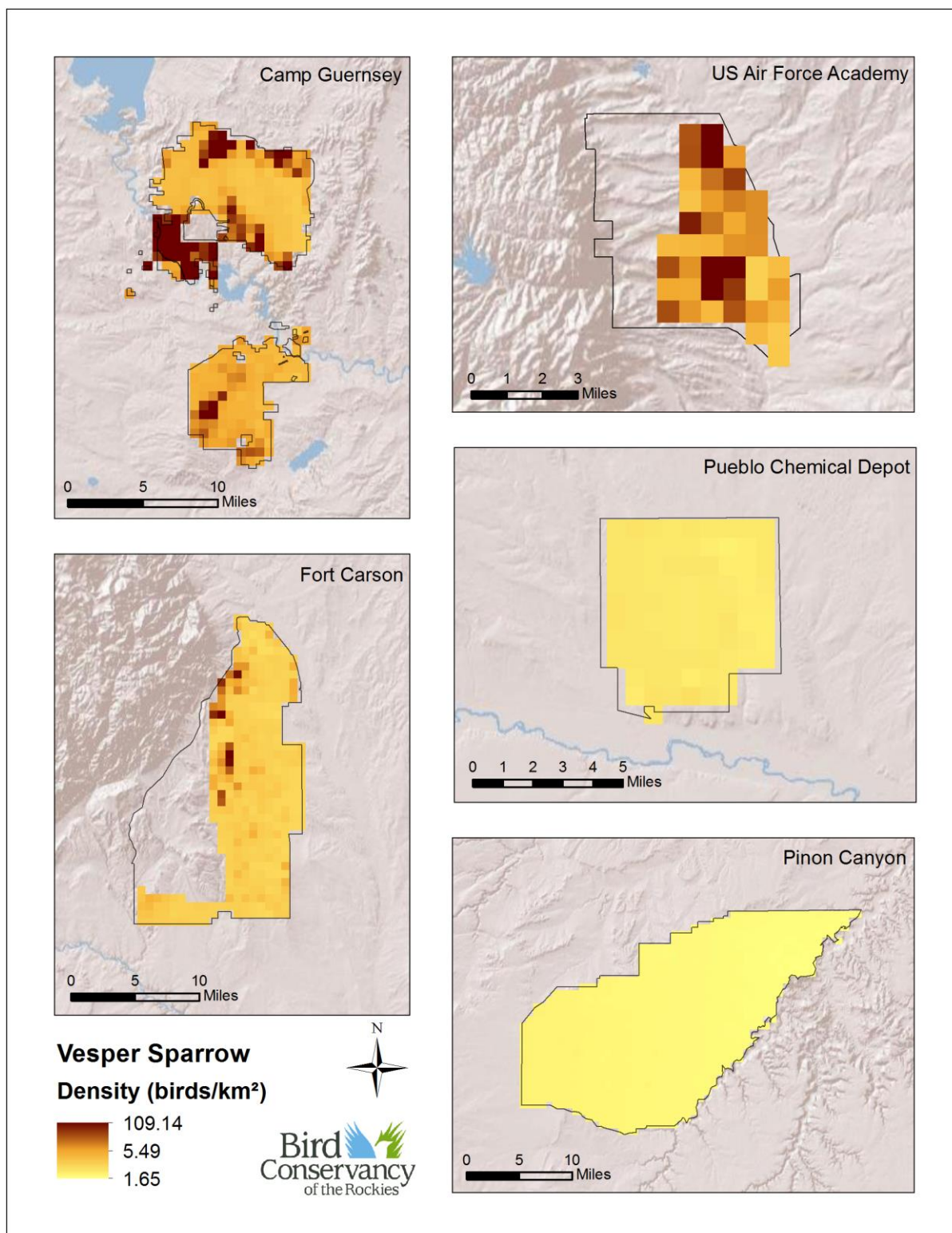
Figure 16. Predicted distribution of Vesper Sparrow, showing model-averaged population density (birds/km²) across five DOD installations.Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

Burrowing Owl

The best model for the density (λ) of the Burrowing Owl contained latitude and longitude covariates (Table F.1). There was nearly equal support for the second best model including the proportion of grassland cover (ΔAIC = 0.44). The 95% CI for proportion of grassland cover included zero (CI = -0.09 – 0.83), indicating marginal precision in relation to the effect size for this covariate (Table F.2). The predicted distribution across the five DOD installations is shown in Fig. 17. Please refer to appendices H – L to view full page maps of Burrowing Owl distribution on the individual installations.

The best model for small-scale occupancy (θ) of the Burrowing Owl included the effect of grass height (Table F.1). There was nearly equal support for the second best model including the effects for grass cover and grass height (Table F.1). The evidence ratio indicated the third best model was approximately three times less plausible than the best model (Table F.1). The small-scale occupancy of the Burrowing Owl decreased with increasing grass height (Fig. 18, Table F.2). The 95% CI for the effect of grass height excluded zero, indicating measurable differences for the effect of this covariate (Table F.2).

The best model for detection (p) for the Burrowing Owl was the constant model (Table F.1). The constant rate of detection was $p = 0.57$ (SE = 0.11). The second best model contained the effect of shrub cover (ΔAIC = 1.69).

Figure 17. Predicted distribution of Burrowing Owl, showing model-averaged population density (birds/km²) across five DOD installations. Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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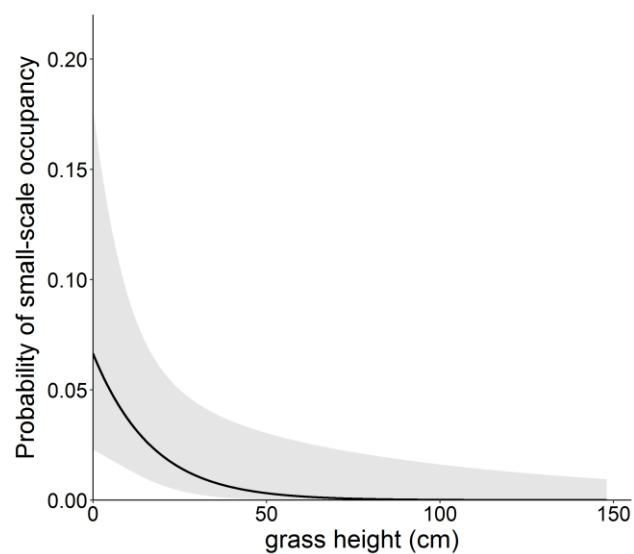
Figure 18. The small-scale occupancy of Burrowing Owl by grass height, 2010 – 2015. The bold lines are estimates of small-scale occupancy (θ) and the gray regions are 95% confidence intervals.

Cassin's Sparrow

The best model for the density (λ) of Cassin's Sparrow contained the latitude, longitude, and proportion of grassland cover covariates (Table G.1). There was nearly equal support for the second best model including the proportion of shrubland cover (ΔAIC = 0.65). Density (λ) of the Cassin's Sparrow showed a positive effect for proportion of grassland cover. The 95% CI for the effect of grassland cover excluded zero, indicating a measurable difference for the effect of this covariate (Fig. 19, Table G.2). The predicted distribution across the five DOD installations is shown in Fig. 20. Please refer to appendices H – L to view full page maps of Cassin's Sparrow distribution on the individual installations.

The best model for small-scale occupancy (θ) of the Cassin's Sparrow included grass height, herbaceous cover, and shrub cover covariates (Table G.1). The second best model included the effects for herbaceous cover and shrub cover (ΔAIC = 1.39, Table G.1). The evidence ratio indicated the third best model was approximately three times less plausible than the best model (Table G.1). The small-scale occupancy of the Cassin's Sparrow increased with increasing grass height, herbaceous cover, and shrub cover (Table G.2). The 95% CI for the effect of herbaceous cover and shrub cover excluded zero, indicating measurable differences for these effects of these covariates (Fig. 21, Table G.2).

The best model for the detection (*p*) for the Cassin's Sparrow varied by year and shrub cover (Table G.1). The second best model was approximately six times less plausible than the best model (ΔAIC = 3.44).
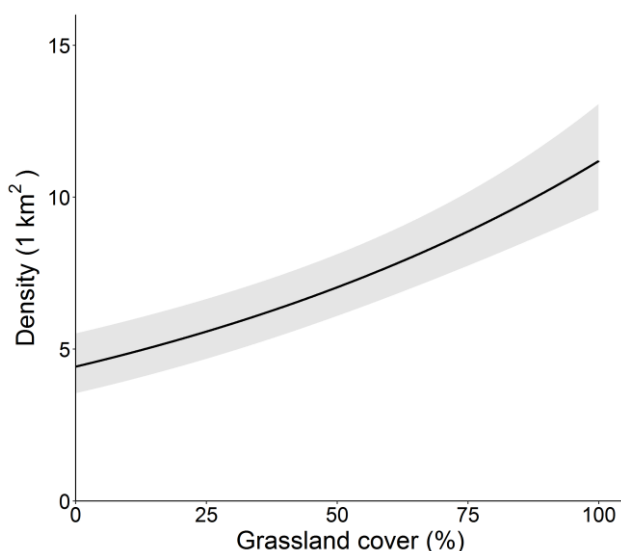
Figure 19. The density of Cassin's Sparrow by proportion of grassland, 2010 – 2015. The bold lines are estimates of density (λ) and the gray regions are 95% confidence intervals.
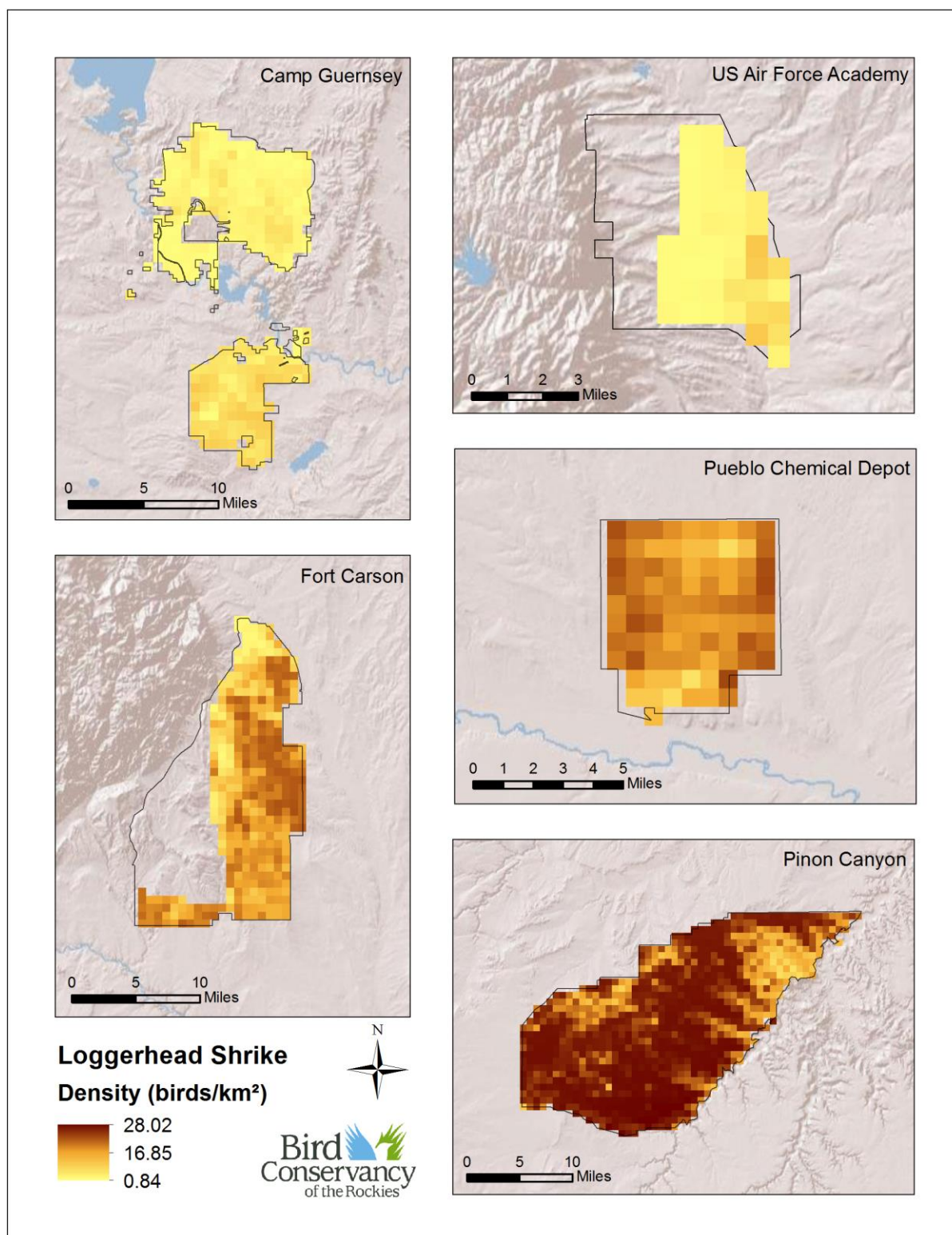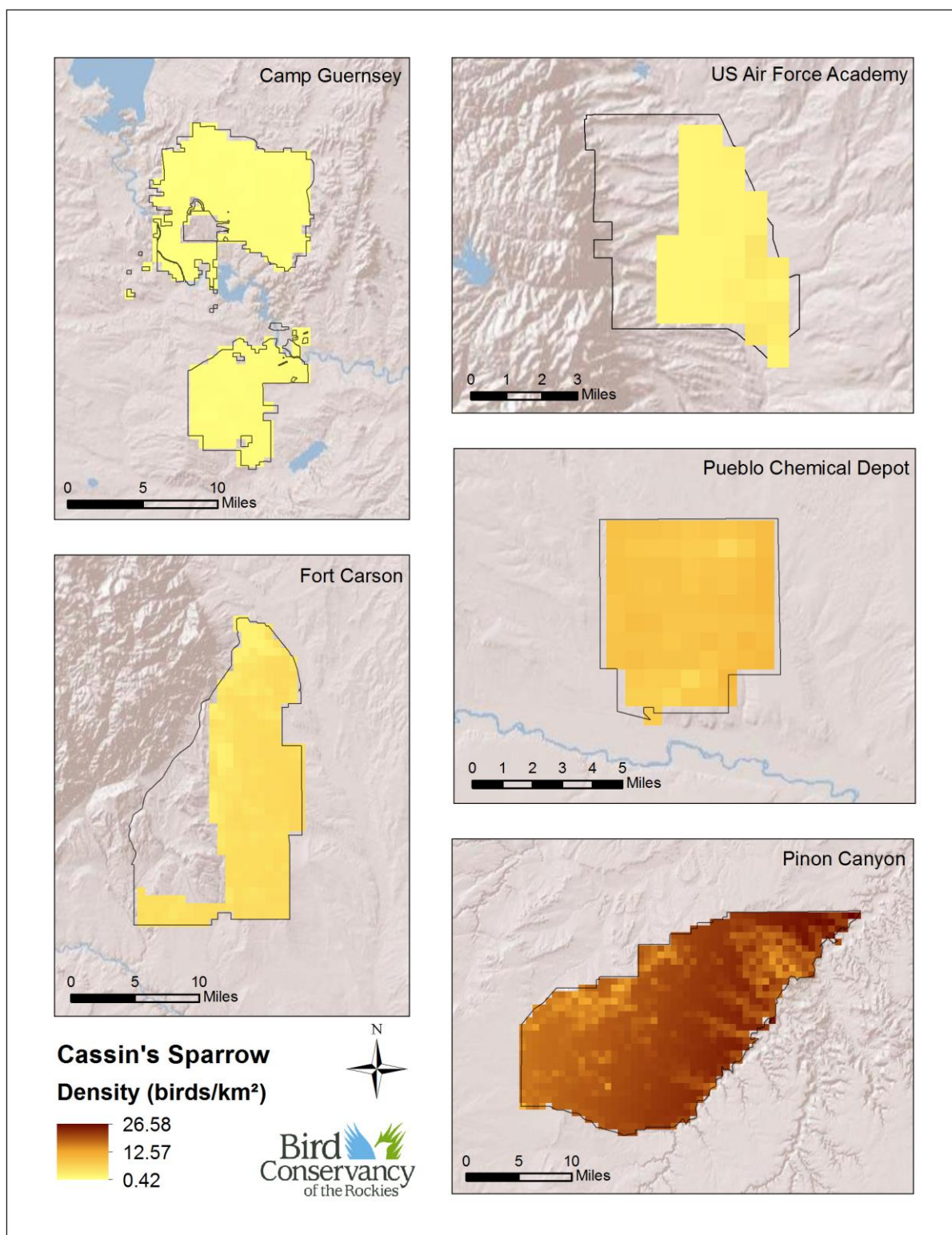
Figure 20. Predicted distribution of Cassin's Sparrow, showing model-averaged population density (birds/km²) across five DOD installations. Legend displays maximum, minimum, and mean predicted density values. Installation areas in BCR 16 are not included in predictions.
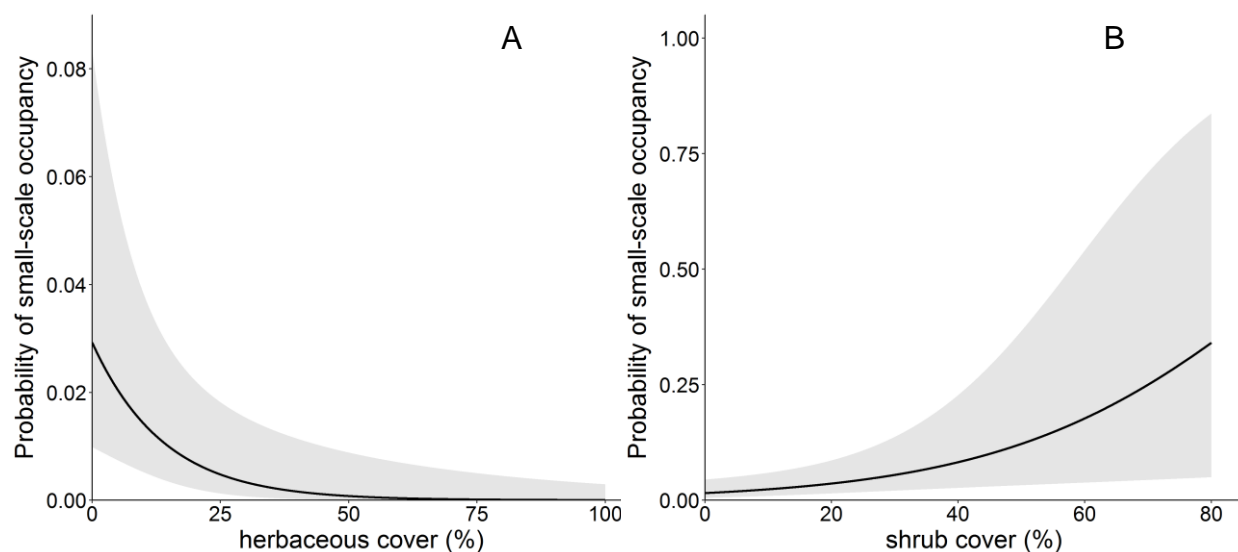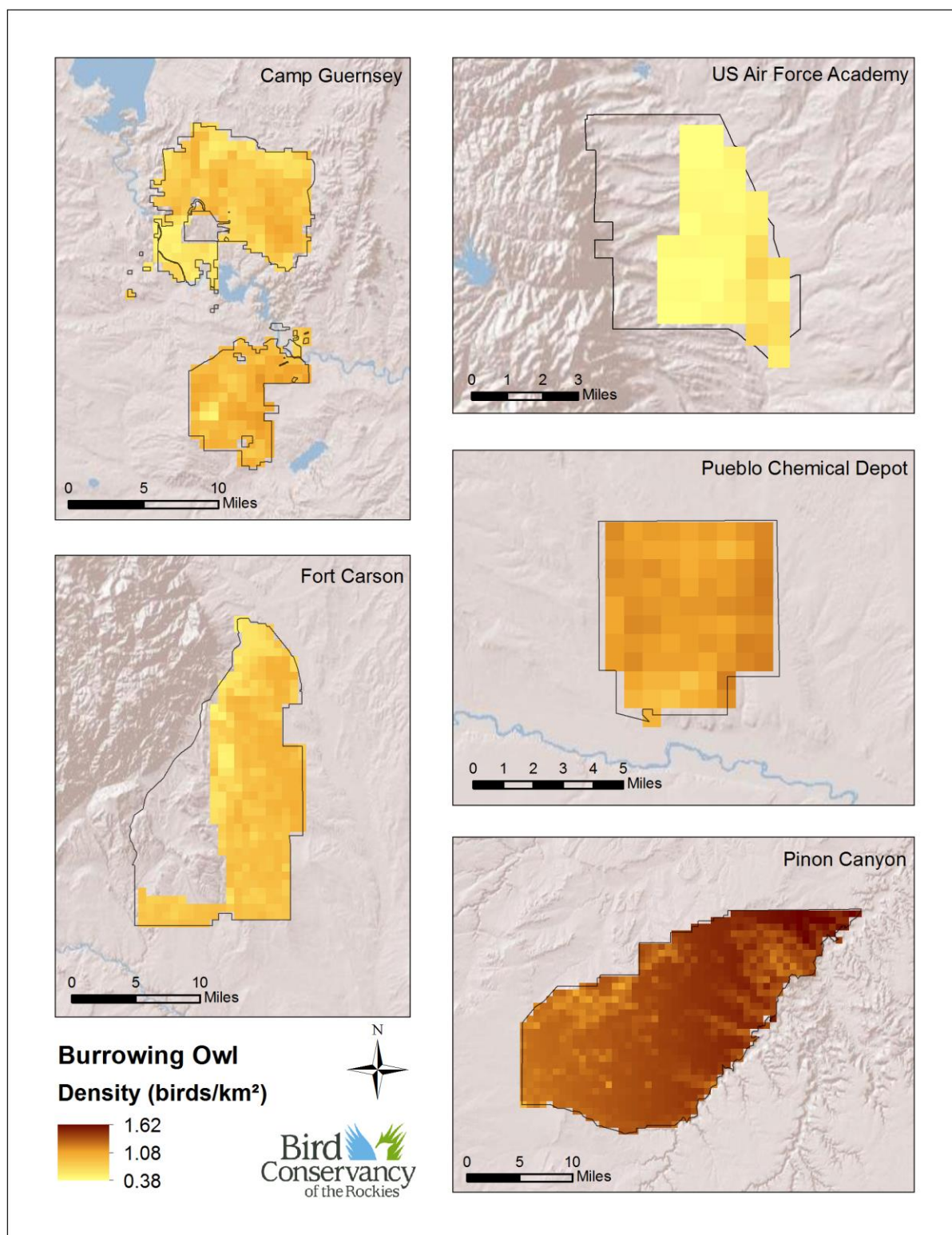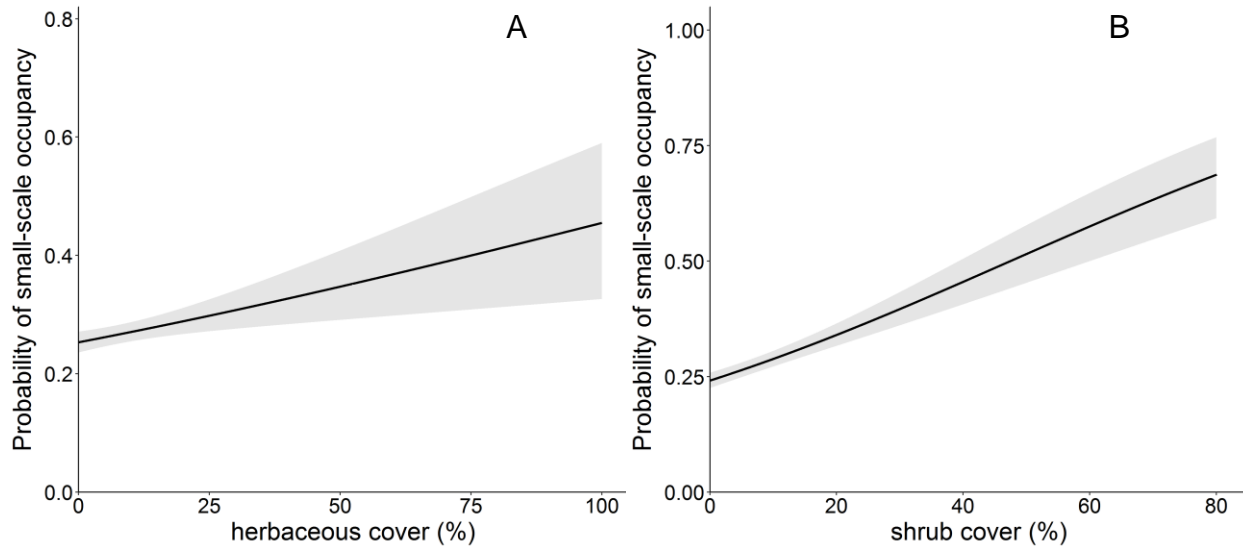
Figure 21. The small-scale occupancy of Cassin's Sparrow by A) herbaceous cover and B) shrub cover, 2010 – 2015. The bold lines are estimates of small-scale occupancy (θ) and the gray regions are 95% confidence intervals.

DISCUSSION

Strata-level Density and Occupancy Estimates

The occupancy and density estimates provided at the stratum level can serve as a useful metric for evaluating the status of avian populations. We recommend density and occupancy rates for the installation of interest be compared to other DOD installations located nearby as well as to state-wide and regional estimates, such as the intersection of BCR and state (i.e., the Colorado portion of BCR 18). Additionally, we encourage Fort Carson and Pinon Canyon Maneuver Site to compare density and occupancy estimates for avian species across the fan and non-fan strata to evaluate the potential impact of training exercises on the presence and density of avian species.

If participating installations wish to continue monitoring efforts for breeding bird species, we recommend continued use of the developed IMBCR-compatible sampling design and pre-existing sample selection for several reasons. First, the IMBCR design represents a robust, statistically valid, spatially-balanced sampling design which eliminates potential road or sampling bias. Secondly, methods employed in the IMBCR design allow for the estimation of detection probabilities which account for incomplete detection. Thirdly, IMBCR data are jointly analyzed, which allows for the development of more precise estimates for a larger number of species than could otherwise be obtained through a stand-alone, installation-specific analysis. Installation managers wishing to collect data consistent with the IMBCR design should contact Bird Conservancy staff to coordinate calibration trainings, acquire sampling locations, review protocols, and receive logistical support regarding the entry, proofing, and analysis of collected data. In the event that population trends are desired, we recommend installations plan for long-term data collection where data are collected intensively (≥ 20 grid cells sampled within the installation) every two or three years.

Multi-scale Habitat Relationship Models

Understanding how birds respond to landscape and local habitat conditions and assessing the spatial distribution of species is fundamental to ecological science and critical for the conservation and management of species. Previously, management efforts relating to shortgrass prairie bird species has

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relied heavily on natural history and land managers' intuition due to little quantitative information on how species respond to vegetation and landscape composition and structure (Johnson and Igl 2001a). We anticipate the developed hierarchical models for priority grassland bird species will provide a less subjective metric for guiding management planning and evaluation.

Linking bird response to habitat at two spatial scales can be a useful tool for managers when developing management plans. Understanding local-scale effects of habitat characteristics on the presence of a species can help quantify and explore management thresholds for a given species and allow the estimation of density and population changes for a species as a result of management actions. For instance, the change in Lark Bunting population within a project area as a result of chaining within shrubland habitat (e.g., shrubland habitat is reduced from 23% to 10%) can be calculated by evaluating the change in expected Lark Bunting density and multiplying it by the number of square km over which the treatment is applied. Furthermore, habitat relationships (e.g., the amount of shrub cover) evident at the small-scale but absent at the large-scale indicate that a mosaic of habitats may provide optimal conditions for a particular species. Conversely, habitat relationships evident at both the large and small scales indicate the need for large, intact, areas of contiguous shrubland or grassland habitat.

The proportion of grassland at the broader scale (1 km^2) had strong positive effects on the predicted densities of Lark Bunting, Western Meadowlark, Loggerhead Shrike and Grasshopper Sparrow and weak positive effects for Burrowing Owl and Vesper Sparrow. This indicates that Lark Bunting, Western Meadowlark, Loggerhead Shrike and Grasshopper Sparrow require large intact areas of grassland and are likely sensitive to habitat fragmentation. Our results align with previous research which demonstrated larger grassland tracks supporting higher densities of breeding sparrows (Johnson and Igl 2001b) and resulting in higher rates of grassland bird nest success (Herkert et al., 2003). Therefore, we recommend that road-less areas within the participating DOD installations are maintained to provide large contiguous blocks of grassland habitat on which these species depend.

At the local scale (4.9 ha), grass cover had strong positive effects with small scale occupancy for Lark Bunting, Grasshopper Sparrow and Western Meadowlark suggesting that management of grass cover is important at both scales for these species. As a result, we recommend that installations, which allow cattle grazing, develop grazing practices to retain grass cover on some grassland patches throughout the breeding season to provide habitat for these species. Additionally, management of large native herbivores to maintain adequate grass cover may improve densities of these species as well. Grass height also had a strong positive effect on small scale occupancy for Grasshopper Sparrow, but had a strong negative effect for Burrowing Owl and Lark Bunting. This suggests that a diversity of grazing pressure may be required to maintain populations of all three species.

The proportion of shrubland at the landscape scale (1 km^2) had weak effects on density for Western Meadowlark, Loggerhead Shrike and Grasshopper Sparrow. There were strong negative effects of shrubland on density at the landscape scale for Lark Bunting and a strong positive effect on density for Vesper Sparrow. Therefore, installations desiring to provide habitat for high densities of Lark Bunting and Vesper Sparrow should retain large areas of both grassland and shrubland habitat types. Grasshopper Sparrow and Western Meadowlark small scale occupancy had a strong negative relationship with shrub cover at the local scale. In contrast, Cassin's Sparrow and Loggerhead Shrike had strong positive effects for shrub cover on small scale occupancy. This indicates that installations which provide habitat for Cassin's Sparrow as well as Grasshopper Sparrow and Western Meadowlark should also retain a mosaic of intact shrubland and grassland habitat.

Managers wishing to employ a multi-species approach to conservation should note the similar large-scale habitat needs of Burrowing Owl, Cassin's Sparrow, and Grasshopper Sparrow. Interestingly, these species likely require different small-scale habitat characteristics with Burrowing Owls typically

being associated with increased amounts of bare ground (and prairie dog colonies), Cassin's Sparrows preferring areas with some shrub cover, and Grasshopper Sparrows preferring areas with large amounts of grass cover. Again, managing for a mosaic within grassland habitat will be important for the effective management of these three species concurrently.

The landscape scale relationships are tied to the spatial distribution of predictive vegetative cover across the landscape and can be visualized in the predicted distribution maps. The distribution models have utility for prioritizing management actions and landscapes, effectively addressing the "what to do" and "where to do it" questions in conservation planning (Wilson et al. 2007). Predicted distribution maps (population size or density) can be summarized for any area of interest, such as administrative boundaries or management units, and confidence intervals can be computed with the parametric bootstrap (Sillett et al. 2012, Royle et al. 2007). Areas harboring low densities of priority avian species may represent regions within the installations where intense training activities would be less likely to detrimentally impact the priority species investigated. Conversely, high density areas for priority species can be identified and efforts can be made to minimize disturbance in these areas.

Lastly, these models can be used within adaptive management (Lyons et al. 2008, Conroy et al. 2012) and for systematic landscape conservation (Margules and Pressey 2000, Westphal et al. 2007). Adaptive management outlines a clear path on how to measure and define management objectives in the face of uncertainty. This process integrates roles from multiple parties, including policy makers and resource managers, into a strong decision-making framework. As a result, a consensus can be reached while negotiating different values and priorities from the multiple parties involved in the decision problem.

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APPENDICES

Appendix A. Model selection and parameter estimate tables for habitat relationships of the Lark Bunting, **2010-2015**.

Table A1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of Lark Bunting. Reported values are number of parameters (K), Akaike Information Criterion, difference between model AIC and minimum AIC (ΔAIC), and AIC weight (wi). Models included have a ΔAIC $\leq$ 4; a competing detection model with ΔAIC > 4 is included for reference.

Model	K	AIC[1]	ΔAIC	wi
λ (Grassland + Shrubland)	15	10196.77	0	0.62
λ (Grassland + Latitude + Longitude + Shrubland)	17	10197.75	0.97	0.38
θ (Grass Cover + Grass Height + Herbaceous Cover)	16	23611.89	0	0.53
θ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	17	23613.88	1.99	0.2
θ (Grass Cover + Herbaceous Cover)	15	23614.48	2.6	0.14
p (Year + Shrub Cover)	17	23613.88	0	0.93
p (Year)	16	23619.18	5.3	0.07

[1] QAIC value was used for λ parameter to account for overdispersion

Table A2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence limits (LCL, UCL) for Lark Bunting abundance (λ), small-scale occupancy (θ), and detection probability (p). Covariate relationships are considered to represent measurable differences for these effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Shrubland)				
Intercept	1.12	0.04	1.05	1.19
Grassland	0.40	0.03	0.34	0.47
Shrubland	-0.23	0.05	-0.32	-0.14
θ (Grass Cover + Grass Height + Herbaceous Cover)				
Intercept	-0.62	0.02	-0.67	-0.58
Grass Cover	0.05	0.02	0.01	0.09
Grass Height	-0.04	0.02	-0.07	0.00
Herbaceous Cover	0.06	0.02	0.03	0.09
p (Year + Shrub Cover)				
Intercept (2015)	0.11	0.04	0.03	0.19
Year (2014)	0.00	0.06	-0.12	0.13
Year (2013)	-0.04	0.08	-0.19	0.11
Year (2012)	0.05	0.08	-0.10	0.20
Year (2011)	-0.36	0.10	-0.55	-0.16
Year (2010)	-0.89	0.11	-1.11	-0.68
Shrub Cover	0.11	0.04	0.04	0.18

Appendix B. Model selection and parameter estimate tables for habitat relationships of the Western Meadowlark, **2010 - 2015**.

Table B1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of Western Meadowlark. Reported values are number of parameters (K), Akaike Information Criterion, difference between model AIC and minimum AIC (ΔAIC), and AIC weight (w*i*). Models included have a ΔAIC ≤ 4.

Model	K	AIC[1]	ΔAIC	w*i*
λ (Grassland + Latitude + Longitude + Shrubland)	12	20937.97	0	0.52
λ (Grassland + Latitude + Longitude)	11	20938.11	0.14	0.48
θ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	11	26582.75	0	0.61
θ (Grass Cover + Herbaceous Cover + Shrub Cover)	10	26584.23	1.49	0.29
p (.)	11	26582.75	0	0.51
p (Shrub Cover)	12	26583.26	0.52	0.4

[1] QAIC value was used for λ parameter to account for overdispersion

Table B2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence limits (LCL, UCL) for Western Meadowlark abundance (λ), small-scale occupancy (θ), and detection probability (p). Covariate relationships are considered to represent measurable differences for these effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Latitude + Longitude + Shrubland)				
Intercept	1.16	0.03	1.10	1.22
Grassland	0.14	0.03	0.10	0.19
Latitude	0.15	0.03	0.10	0.20
Longitude	0.09	0.03	0.04	0.15
Shrubland	0.04	0.03	-0.01	0.09
θ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)				
Intercept	-0.98	0.03	-1.03	-0.93
Grass Cover	0.20	0.02	0.16	0.24
Grass Height	0.03	0.02	0.00	0.06
Herbaceous Cover	0.07	0.01	0.04	0.10
Shrub Cover	-0.04	0.02	-0.08	-0.01
p (.)				
Intercept	0.99	0.03	0.94	1.04

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Appendix C. Model selection and parameter estimate tables for habitat relationships of the Grasshopper Sparrow, **2010 - 2015.**

Table C1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of Grasshopper Sparrow. Reported values are number of parameters (K), Akaike Information Criterion, difference between model AIC and minimum AIC (ΔAIC), and AIC weight (wi). Models included have a ΔAIC ≤ 4; a competing detection model with ΔAIC > 4 is included for reference.

Model	K	AIC	ΔAIC	wi
λ **(Grassland + Latitude + Longitude)**	16	10984.34	0	0.67
λ **(Grassland + Latitude + Longitude + Shrubland)**	17	10985.72	1.38	0.33
θ **(Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)**	17	10985.72	0	0.58
θ **(Grass Cover + Grass Height + Herbaceous Cover)**	16	10988.15	2.43	0.17
θ **(Grass Cover + Herbaceous Cover + Shrub Cover)**	16	10988.94	3.22	0.12
p (Year + Shrub Cover)	17	10985.72	0	1
p (Year)	16	10997.48	11.76	0

Table C2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence limits (LCL, UCL) for Grasshopper Sparrow abundance (λ), small-scale occupancy (θ), and detection probability (p). Covariate relationships are considered to represent measurable differences for these effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ **(Grassland + Latitude + Longitude)**				
Intercept	-0.37	0.05	-0.47	-0.27
Grassland	0.32	0.05	0.23	0.40
Latitude	0.64	0.04	0.57	0.72
Longitude	0.77	0.05	0.68	0.86
θ **(Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)**				
Intercept	-1.12	0.04	-1.20	-1.04
Grass Cover	0.08	0.03	0.02	0.14
Grass Height	0.05	0.02	0.01	0.10
Herbaceous Cover	-0.13	0.04	-0.21	-0.05
Shrub Cover	-0.11	0.05	-0.20	-0.01
p (Year + Shrub Cover)				
Intercept (2015)	0.87	0.08	0.71	1.04
Year (2014)	-0.32	0.15	-0.61	-0.03
Year (2013)	-0.33	0.13	-0.59	-0.07
Year (2012)	-0.77	0.22	-1.19	-0.34
Year (2011)	-0.90	0.16	-1.22	-0.58
Year (2010)	-0.36	0.20	-0.74	0.03
Shrub Cover	-0.24	0.07	-0.37	-0.11

Appendix D. Model selection and parameter estimate tables for habitat relationships of the Loggerhead Shrike, **2010 - 2015.**

Table D1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of Loggerhead Shrike. Reported values are number of parameters (K), Akaike Information Criterion, difference between model AIC and minimum AIC (ΔAIC), and AIC weight (wi). Models included have a ΔAIC $\leq$ 4.

Model	K	AIC[1]	ΔAIC	wi
λ (Grassland + Latitude + Longitude)	15	717.88	0	0.54
λ (Grassland + Latitude + Longitude + Shrubland)	16	718.98	1.09	0.31
λ (Grassland)	13	721.77	3.88	0.08
θ (Herbaceous Cover + Shrub Cover)	15	923.07	0	0.42
θ (Grass Height + Herbaceous Cover + Shrub Cover)	16	924.73	1.66	0.18
θ (Grass Cover + Herbaceous Cover + Shrub Cover)	16	924.8	1.73	0.17
θ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	17	926.48	3.41	0.08
θ (Grass Height + Herbaceous Cover)	15	926.9	3.83	0.06
p (Year + Shrub Cover)	17	926.48	0	0.59
p (Year)	16	927.18	0.7	0.41

[1] QAIC value was used for λ parameter to account for overdispersion

Table D2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence limits (LCL, UCL) for Loggerhead Shrike abundance (λ), small-scale occupancy (θ), and detection probability (p). Covariate relationships are considered to represent measurable differences for these effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Latitude + Longitude)				
Intercept	-1.03	0.48	-1.97	-0.08
Grassland	0.92	0.22	0.50	1.35
Latitude	-0.41	0.18	-0.76	-0.07
Longitude	0.04	0.18	-0.30	0.39
θ (Herbaceous Cover + Shrub Cover)				
Intercept	-3.98	0.52	-4.97	-2.93
Herbaceous Cover	-0.75	0.29	-1.33	-0.21
Shrub Cover	0.40	0.15	0.09	0.69
p (Year + Shrub Cover)				
Intercept (2015)	-1.26	0.59	-2.20	-0.10
Year (2014)	0.04	0.72	-1.36	1.74
Year (2013)	-1.69	0.62	-2.84	-0.39
Year (2012)	-2.37	0.93	-4.18	-0.56
Year (2011)	-2.49	0.72	-3.88	-1.22
Year (2010)	2.90	1.33	0.24	5.35
Shrub Cover	0.58	0.24	0.09	1.02

Appendix E. Model selection and parameter estimate tables for habitat relationships of the Vesper Sparrow, **2010 - 2015.**

Table E1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of Vesper Sparrow. Reported values are number of parameters (K), Akaike Information Criterion, difference between model AIC and minimum AIC (ΔAIC), and AIC weight (w*i*). Models included have a ΔAIC ≤ 4.

Model	K	AIC[1]	ΔAIC	w*i*
λ (Latitude + Longitude + Shrubland)	13	2104.09	0	0.51
λ (Grassland + Latitude + Longitude + Shrubland)	14	2104.17	0.08	0.49
θ (Shrub Cover)	13	3285.59	0	0.14
θ (Herbaceous Cover)	13	3285.65	0.07	0.14
θ (Herbaceous Cover + Shrub Cover)	14	3285.76	0.17	0.13
θ (.)	12	3287.16	1.57	0.07
θ (Grass Height + Herbaceous Cover)	14	3287.37	1.78	0.06
θ (Grass Cover + Herbaceous Cover)	14	3287.46	1.87	0.06
θ (Grass Height + Shrub Cover)	14	3287.51	1.92	0.06
θ (Grass Cover)	13	3287.53	1.95	0.05
θ (Grass Height + Herbaceous Cover + Shrub Cover)	15	3287.54	1.95	0.05
θ (Grass Height)	13	3287.56	1.98	0.05
θ (Grass Cover + Shrub Cover)	14	3287.56	1.98	0.05
θ (Grass Cover + Herbaceous Cover + Shrub Cover)	15	3287.71	2.12	0.05
θ (Grass Cover + Grass Height + Herbaceous Cover)	15	3289.26	3.67	0.02
θ (Grass Cover + Grass Height)	14	3289.46	3.87	0.02
θ (Grass Cover + Grass Height + Shrub Cover)	15	3289.5	3.91	0.02
θ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	16	3289.52	3.94	0.02
p (Year)	16	3289.52	0	0.62
p (Year + Shrub Cover)	17	3290.48	0.96	0.38

[1] QAIC value was used for λ parameter to account for overdispersion

Table E2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence limits (LCL, UCL) for Vesper Sparrow abundance (λ), small-scale occupancy (θ), and detection probability (p). Covariate relationships are considered to represent measurable differences for these effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ (Latitude + Longitude + Shrubland)				
Intercept	-1.67	0.14	-1.94	-1.40
Latitude	0.22	0.12	-0.01	0.44
Longitude	-0.73	0.14	-1.00	-0.46
Shrubland	0.26	0.06	0.16	0.37
θ (Shrub Cover)				
Intercept	-1.47	0.09	-1.65	-1.28
Shrub Cover	-0.13	0.09	-0.30	0.05
p (Year)				
Intercept (2015)	-0.17	0.18	-0.52	0.19

Model Parameter	Estimate	SE	LCL	UCL
Year (2014)	-2.56	0.49	-3.55	-1.63
Year (2013)	0.17	0.31	-0.47	0.73
Year (2012)	0.54	0.39	-0.17	1.32
Year (2011)	-1.35	0.38	-2.02	-0.66
Year (2010)	0.34	0.69	-0.97	1.69

Appendix F. Model selection and parameter estimate tables for habitat relationships of the Burrowing Owl, **2010 - 2015.**

Table F1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of Burrowing Owl. Reported values are number of parameters (K), Akaike Information Criterion, difference between model AIC and minimum AIC (ΔAIC), and AIC weight (wi). Models included have a ΔAIC ≤ 4.

Model	K	AIC[1]	ΔAIC	wi
λ (Latitude + Longitude)	7	261.9	0	0.31
λ (Grassland + Latitude + Longitude)	8	262.34	0.44	0.25
λ (Latitude + Longitude + Shrubland)	8	263.23	1.32	0.16
λ (Grassland)	6	263.75	1.85	0.12
λ (Grassland + Latitude + Longitude + Shrubland)	9	264.05	2.15	0.1
λ (Grassland + Shrubland)	7	265.08	3.18	0.06
θ (Grass Height)	8	458.89	0	0.29
θ (Grass Cover + Grass Height)	9	459.7	0.8	0.2
θ (Grass Height + Herbaceous Cover)	9	460.78	1.88	0.11
θ (Grass Height + Shrub Cover)	9	460.88	1.98	0.11
θ (Grass Cover + Grass Height + Herbaceous Cover)	10	461.62	2.72	0.07
θ (Grass Cover + Grass Height + Shrub Cover)	10	461.68	2.78	0.07
θ (Grass Height + Herbaceous Cover + Shrub Cover)	10	462.76	3.87	0.04
p (.)	11	463.6	0	0.7
p (Shrub Cover)	12	465.29	1.69	0.3

[1] QAIC value was used for λ parameter to account for overdispersion

Table F2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence limits (LCL, UCL) for Burrowing Owl abundance (λ), small-scale occupancy (θ), and detection probability (p). Covariate relationships are considered to represent measurable differences for these effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ (Latitude + Longitude)				
Intercept	-2.55	0.61	-3.75	-1.36
Latitude	0.13	0.30	-0.45	0.72
Longitude	0.59	0.27	0.05	1.13
θ (Grass Height)				
Intercept	-3.68	0.54	-4.71	-2.63
Grass Height	-0.76	0.32	-1.40	-0.13
p (.)				
Intercept	0.27	0.46	-0.64	1.17

Appendix G. Model selection and parameter estimate tables for habitat relationships of the
Cassin's Sparrow, **2010 - 2015.**

Table G1. Model selection for abundance (λ), small-scale occupancy (θ), and detection probability (p) of
Cassin's Sparrow. Reported values are number of parameters (K), Akaike Information Criterion,
difference between model AIC and minimum AIC (ΔAIC), and AIC weight (w*i*). Models included have a
ΔAIC ≤ 4.

Model	K	AIC	ΔAIC	wi
λ (Grassland + Latitude + Longitude)	15	8674.33	0	0.58
λ (Grassland + Latitude + Longitude + Shrubland)	16	8674.97	0.65	0.42
θ (Grass Height + Herbaceous Cover + Shrub Cover)	16	8674.97	0	0.47
θ (Herbaceous Cover + Shrub Cover)	15	8676.37	1.39	0.24
θ (Grass Cover + Grass Height + Herbaceous Cover + Shrub Cover)	17	8676.97	2	0.17
θ (Grass Cover + Herbaceous Cover + Shrub Cover)	16	8678.19	3.21	0.1
p (Year + Shrub Cover)	17	8676.97	0	0.85
p (Year)	16	8680.41	3.44	0.15

Table G2. Best model parameter estimates, standard errors (SE), and lower and upper 95% confidence
limits (LCL, UCL) for Cassin's Sparrow abundance (λ), small-scale occupancy (θ), and detection
probability (p). Covariate relationships are considered to represent measurable differences for these
effects if confidence limits do not overlap zero.

Model Parameter	Estimate	SE	LCL	UCL
λ (Grassland + Latitude + Longitude)				
Intercept	-1.00	0.07	-1.13	-0.86
Grassland	0.33	0.05	0.24	0.42
Latitude	-0.84	0.06	-0.96	-0.72
Longitude	0.76	0.04	0.67	0.84
θ (Grass Height + Herbaceous Cover + Shrub Cover)				
Intercept	-1.03	0.04	-1.11	-0.95
Grass Height	0.07	0.04	0.00	0.14
Herbaceous Cover	0.09	0.03	0.03	0.16
Shrub Cover	0.22	0.02	0.16	0.26
p (Year + Shrub Cover)				
Intercept (2015)	0.87	0.09	0.69	1.06
Year (2014)	0.23	0.16	-0.08	0.55
Year (2013)	0.24	0.16	-0.07	0.54
Year (2012)	0.49	0.17	0.15	0.82
Year (2011)	-0.43	0.14	-0.71	-0.15
Year (2010)	0.08	0.16	-0.23	0.38
Shrub Cover	0.10	0.04	0.02	0.17

Appendix H. Predicted density distribution maps for priority species on Fort Carson**.**
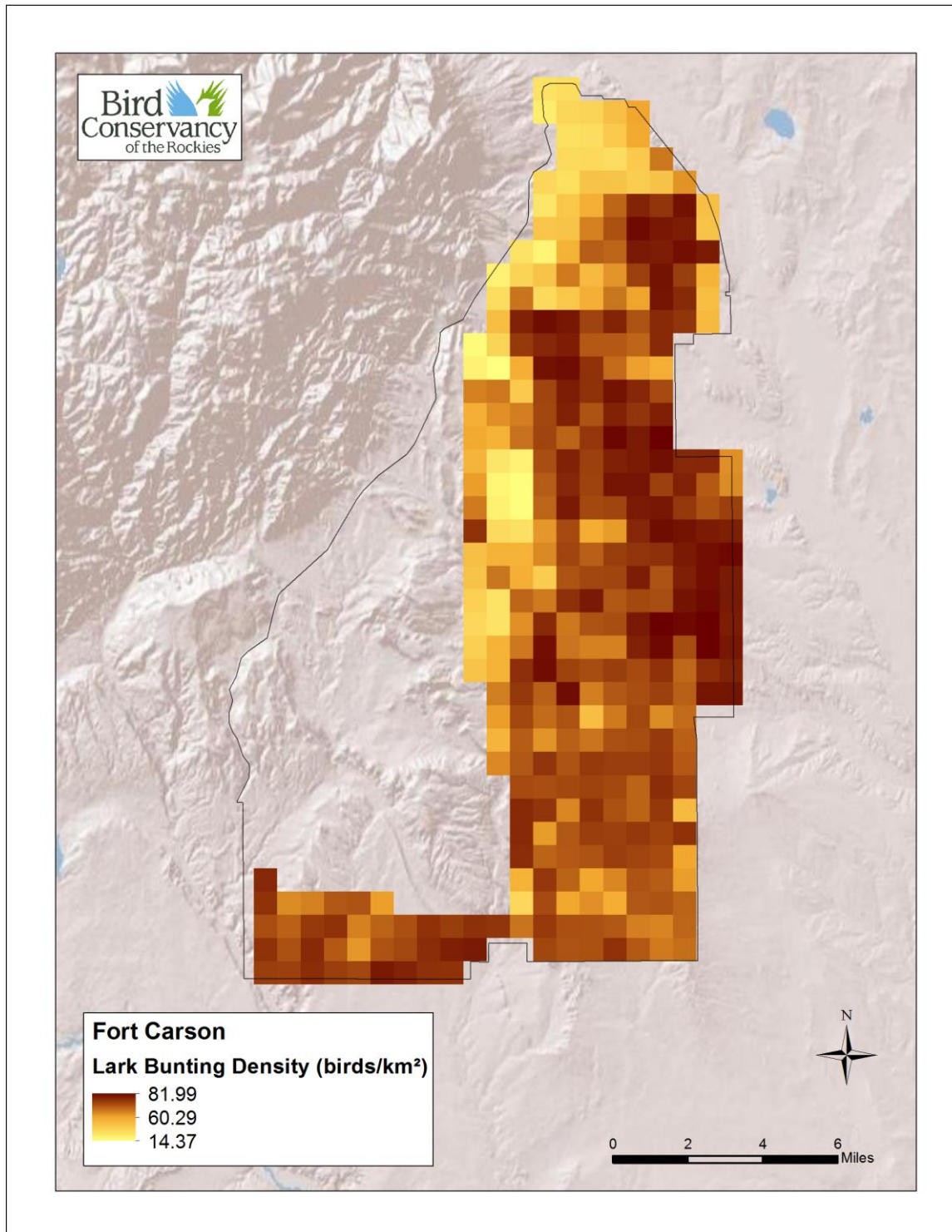
Figure H1. Predicted distribution of Lark Bunting on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
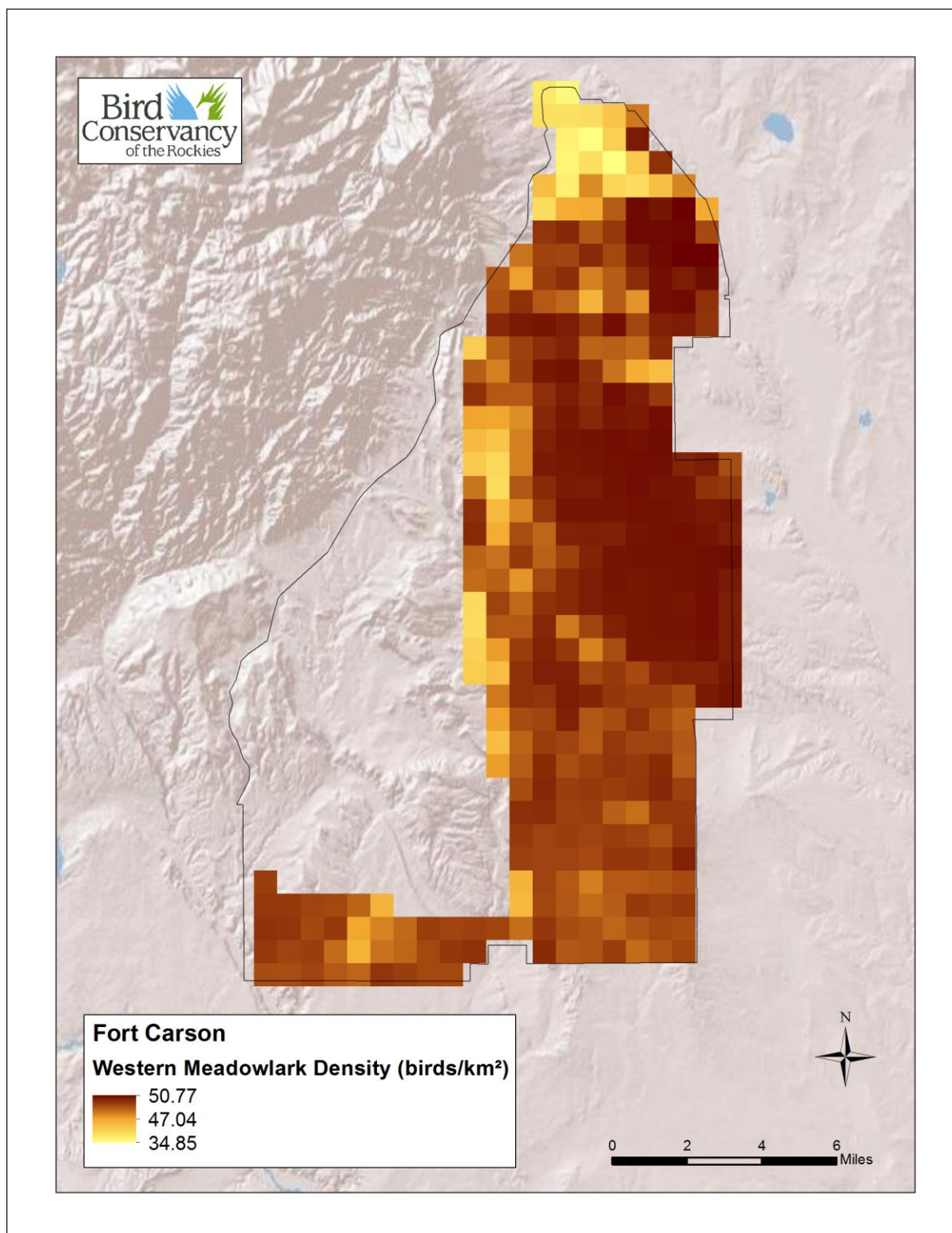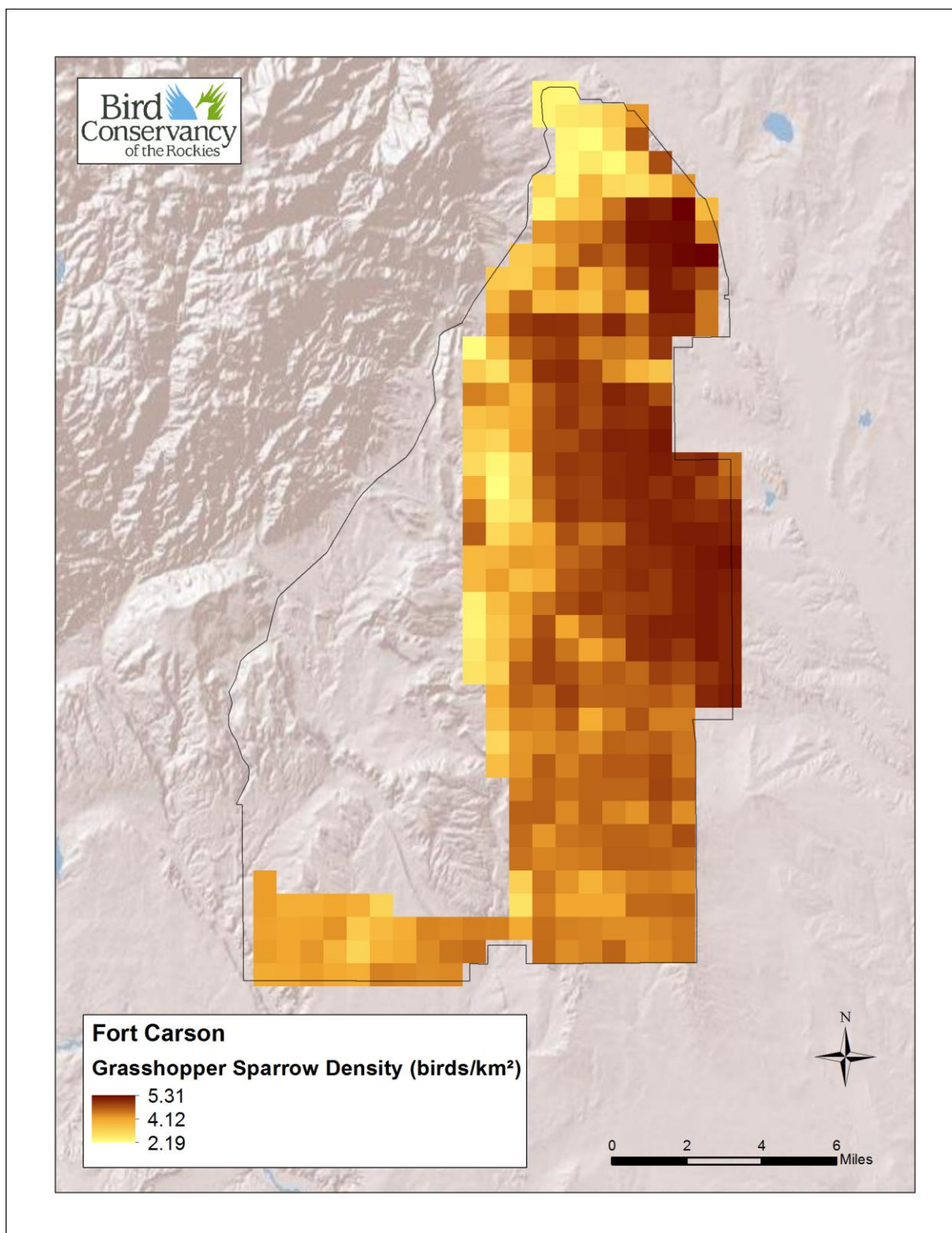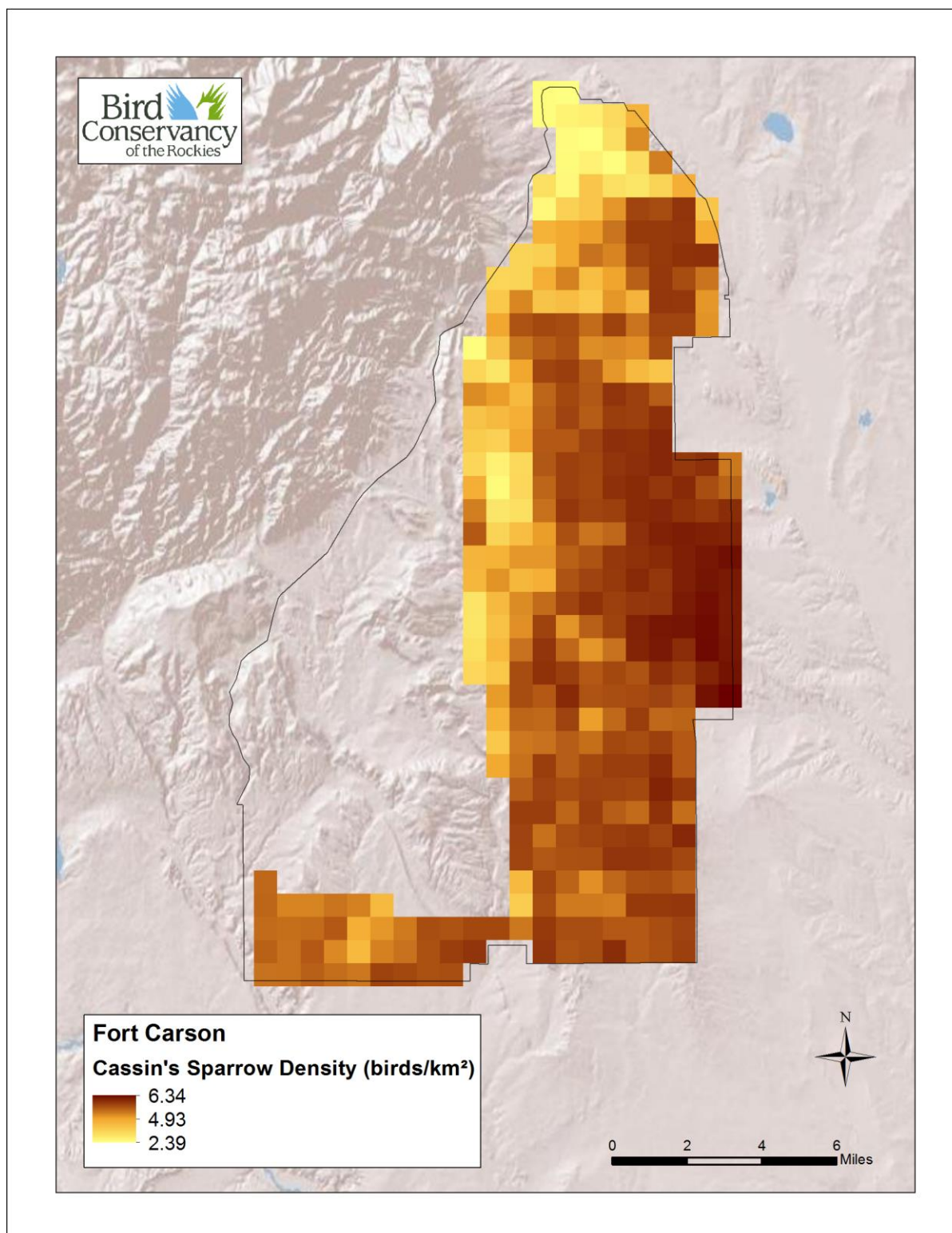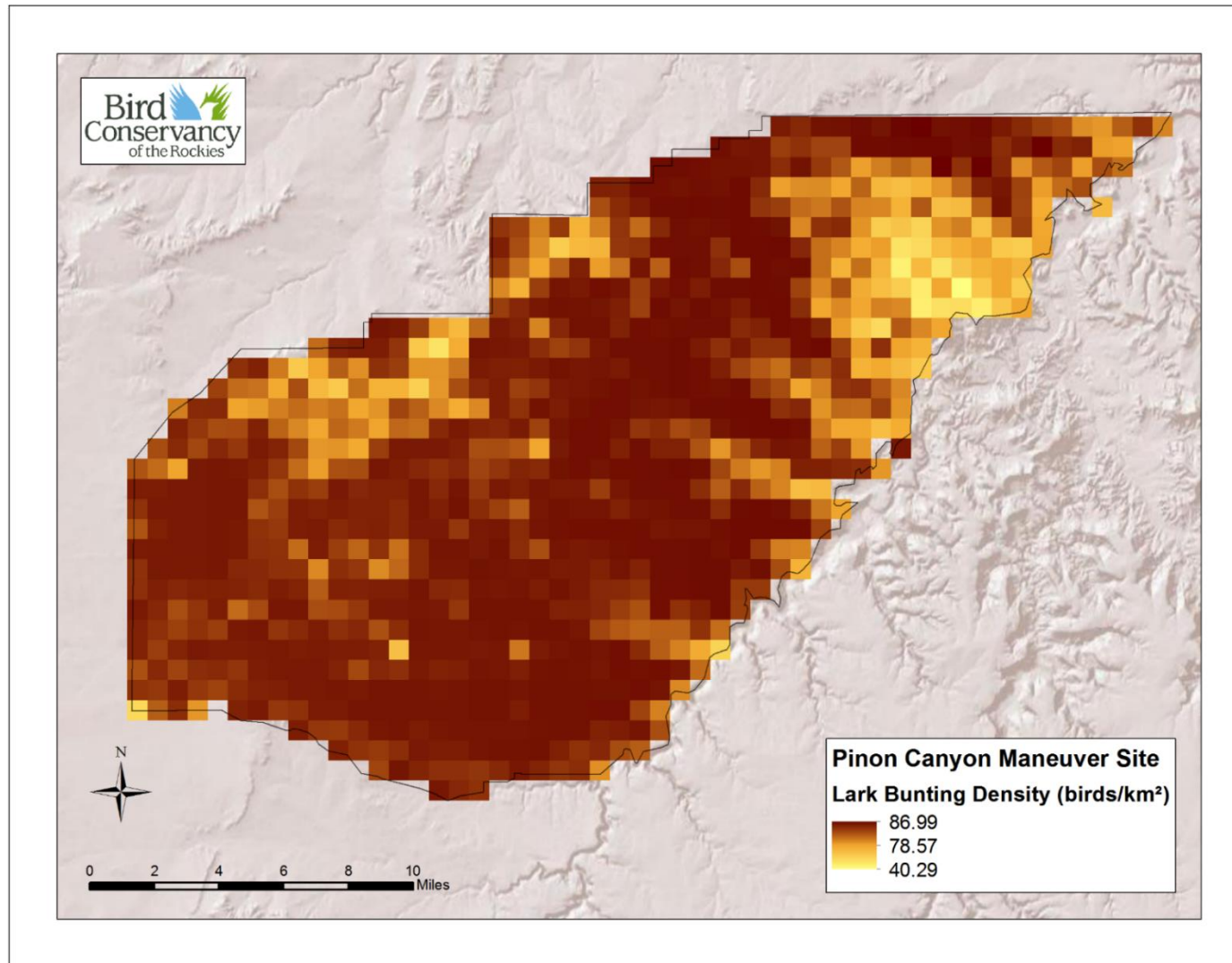
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Figure H2. Predicted distribution of Western Meadowlark on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

Figure H3. Predicted distribution of Grasshopper Sparrow on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
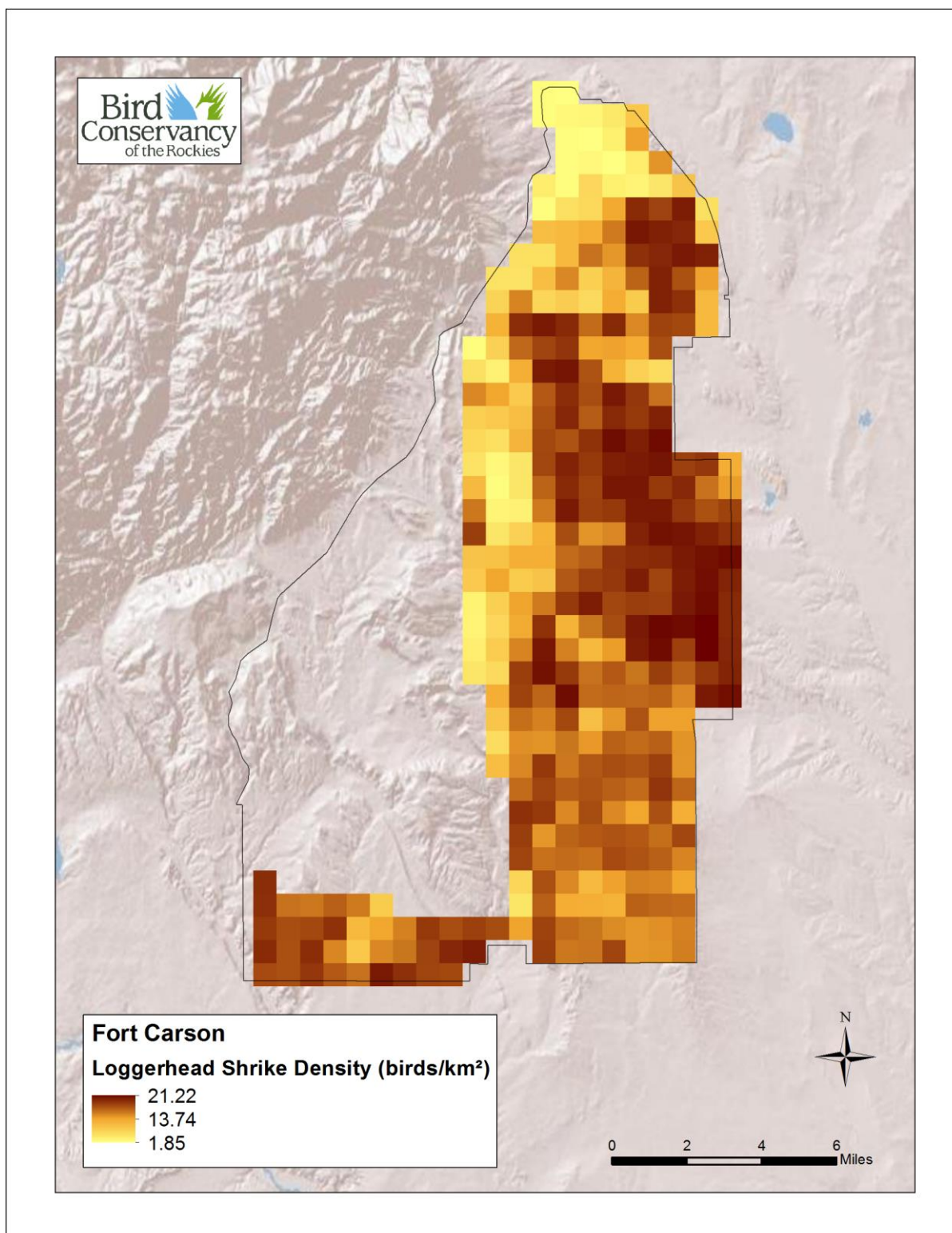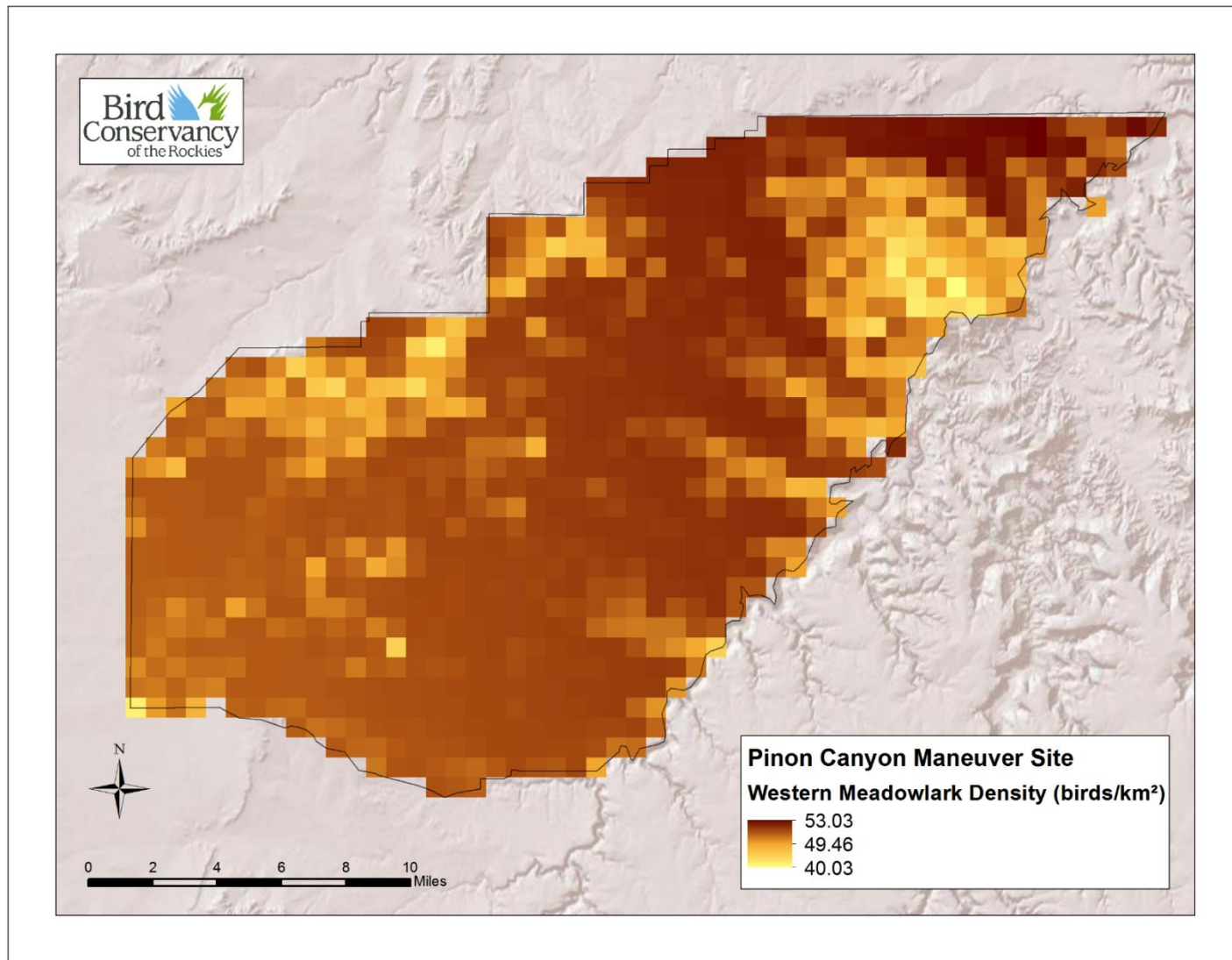
Figure H4. Predicted distribution of Loggerhead Shrike on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
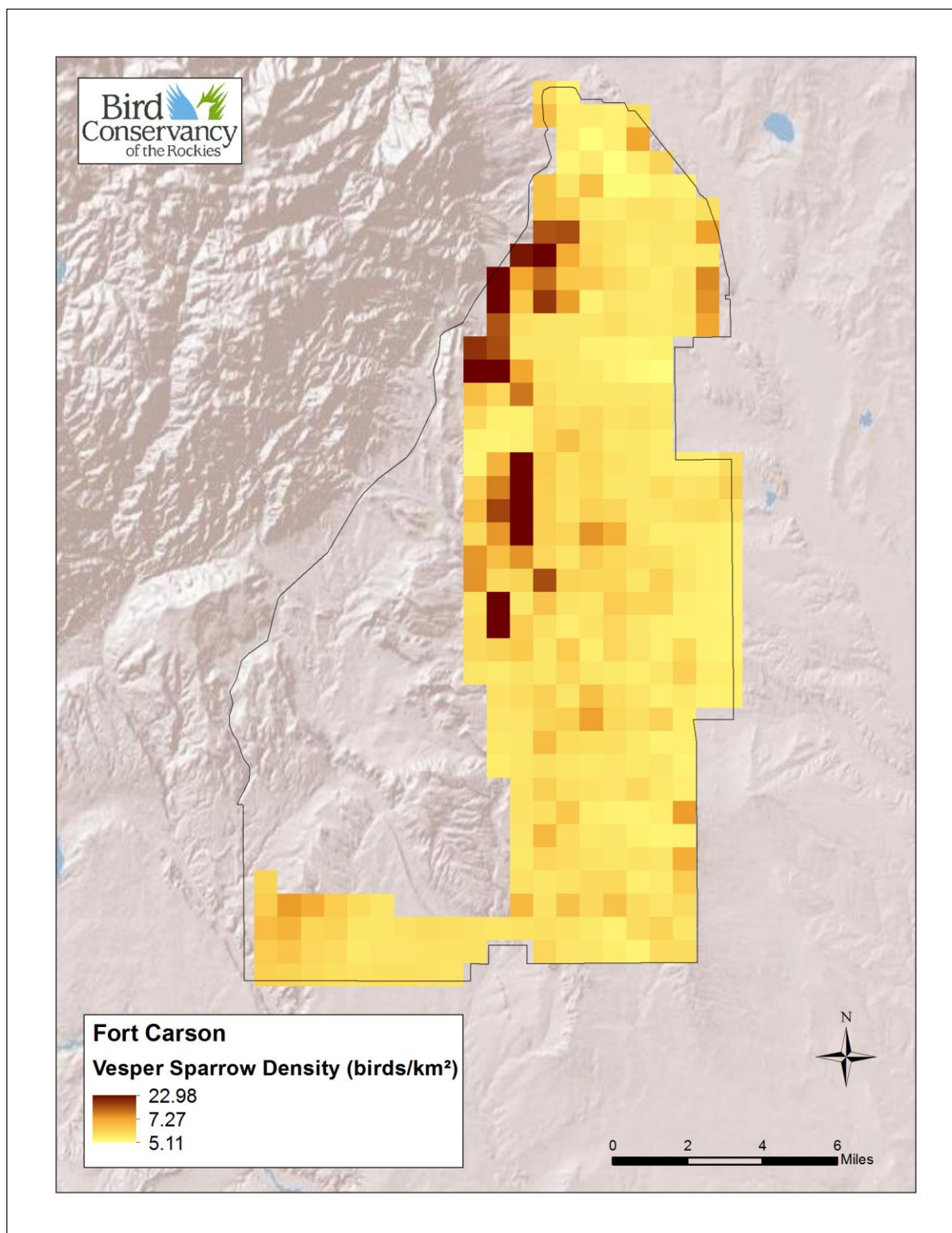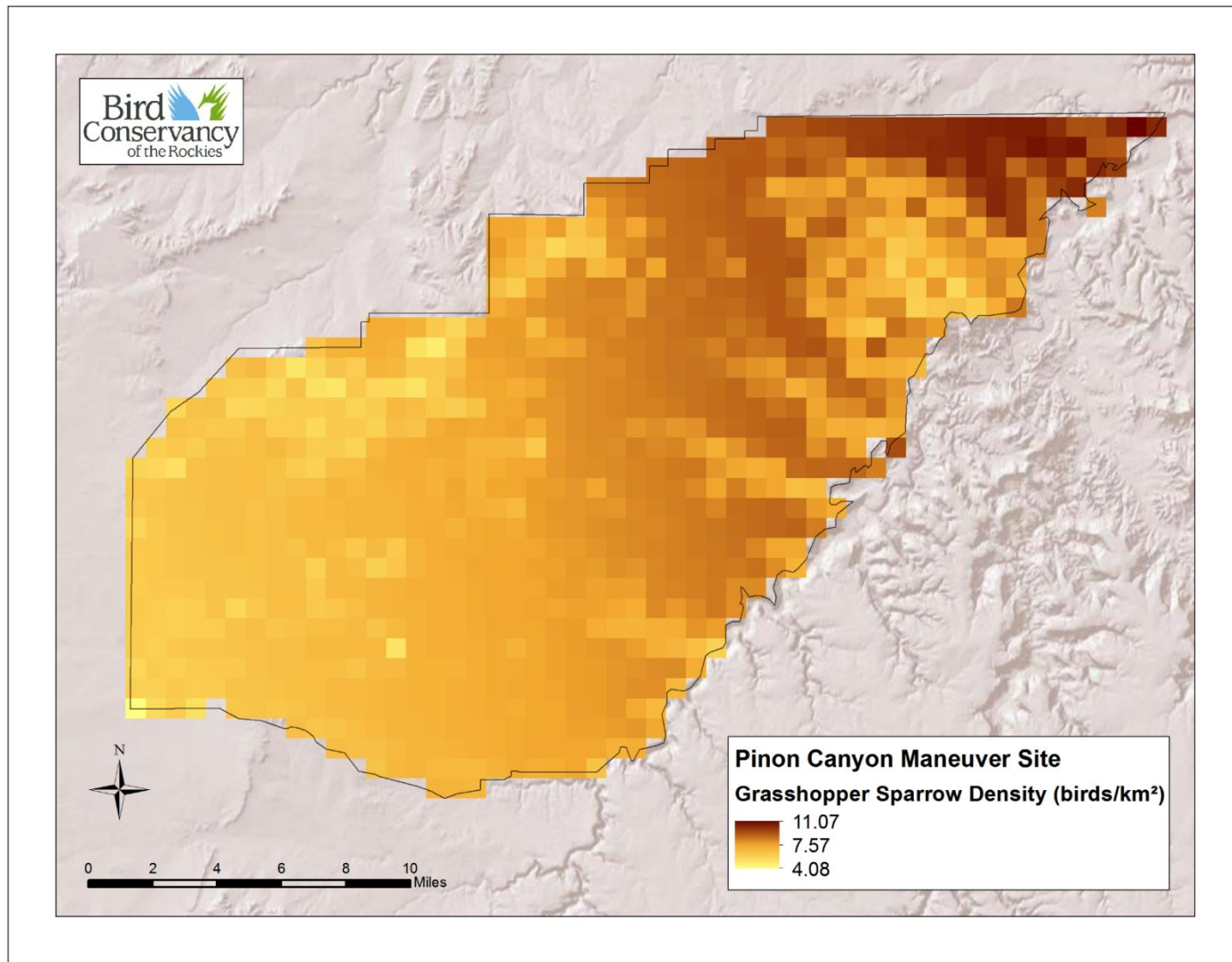
Figure H5. Predicted distribution of Vesper Sparrow on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
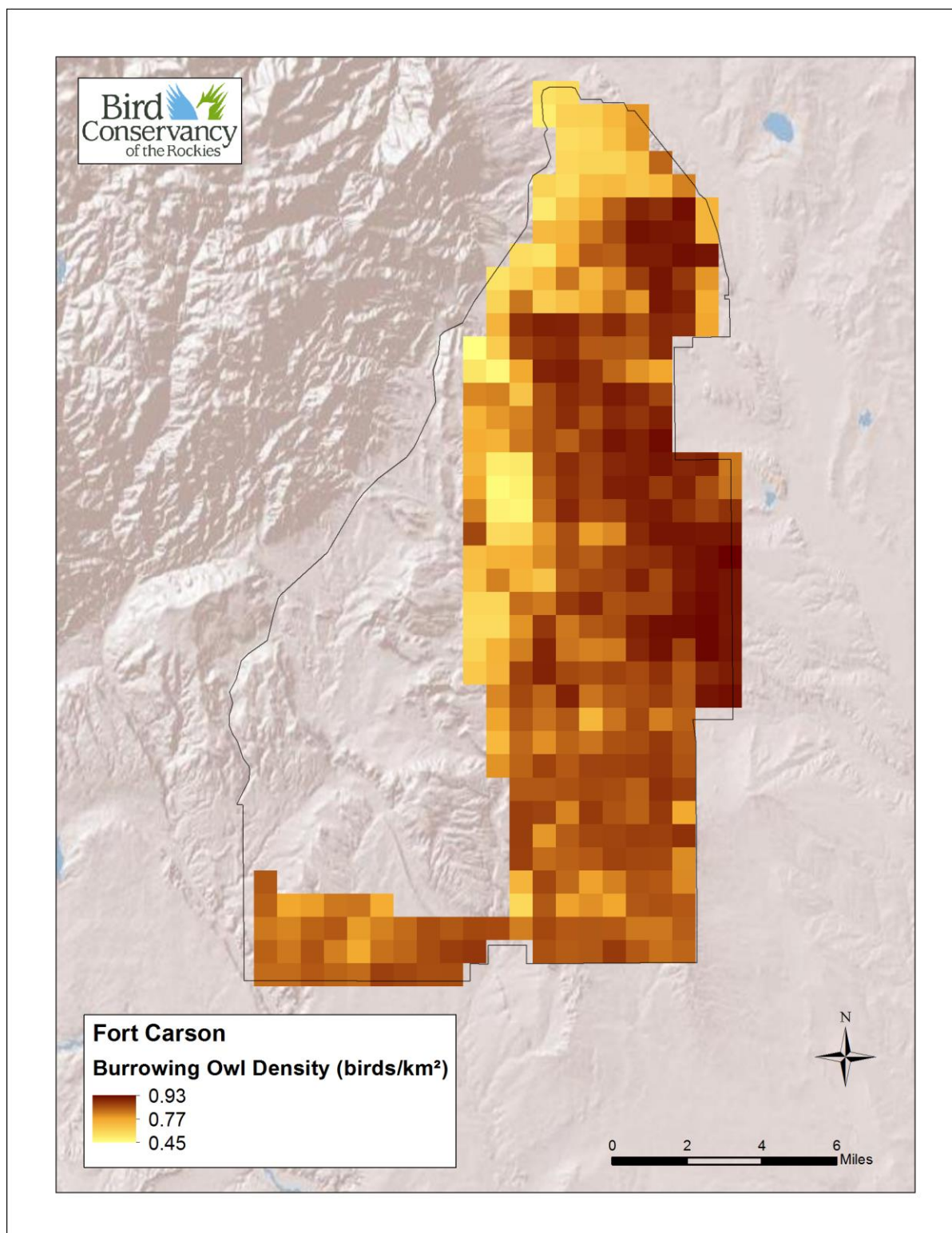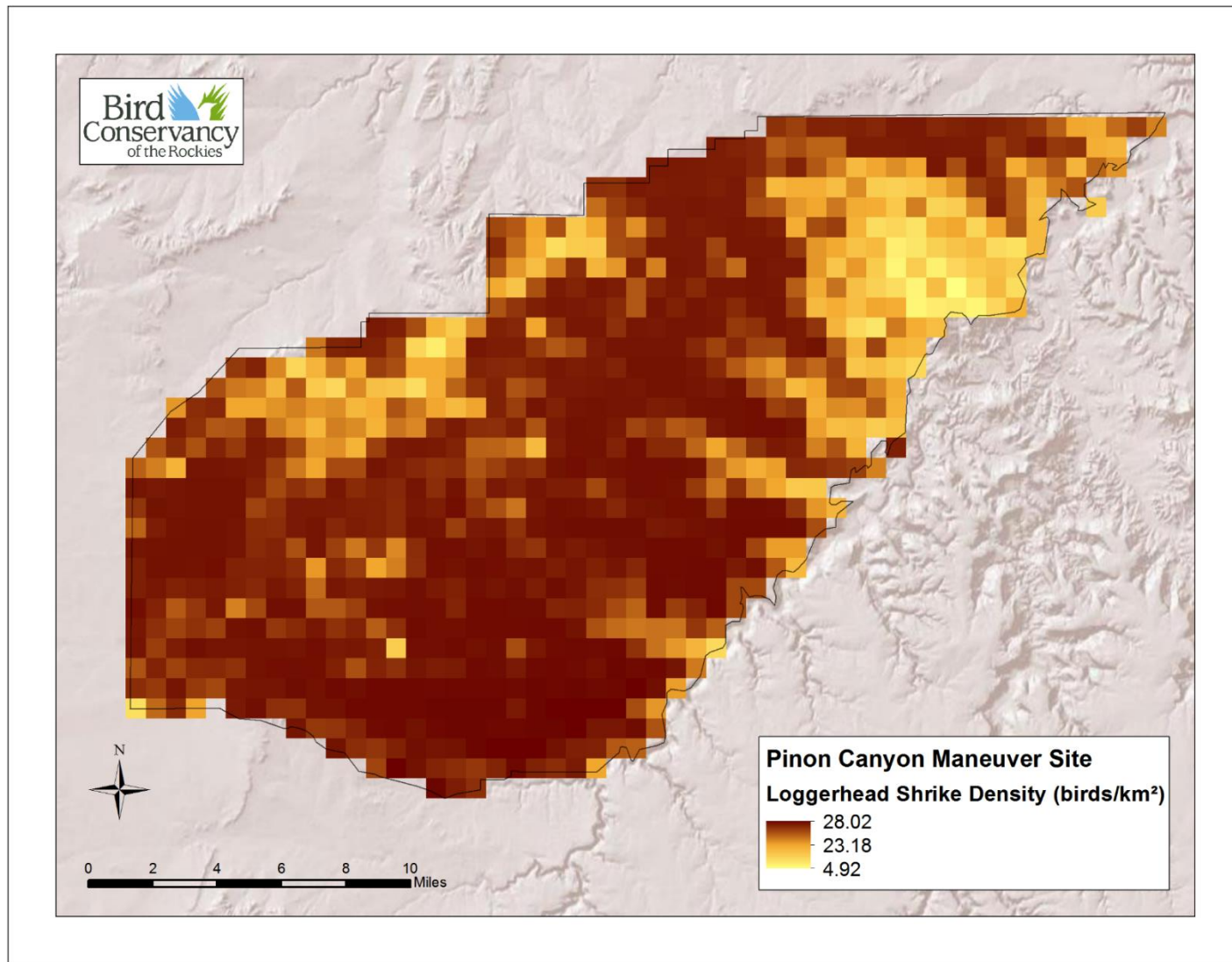
Figure H6. Predicted distribution of Burrowing Owl on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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Figure H7. Predicted distribution of Cassin's Sparrow on Fort Carson, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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Appendix I. Predicted density distribution maps for priority species on Pinon Canyon Maneuver Site**.**

Figure I1. Predicted distribution of Lark Bunting on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
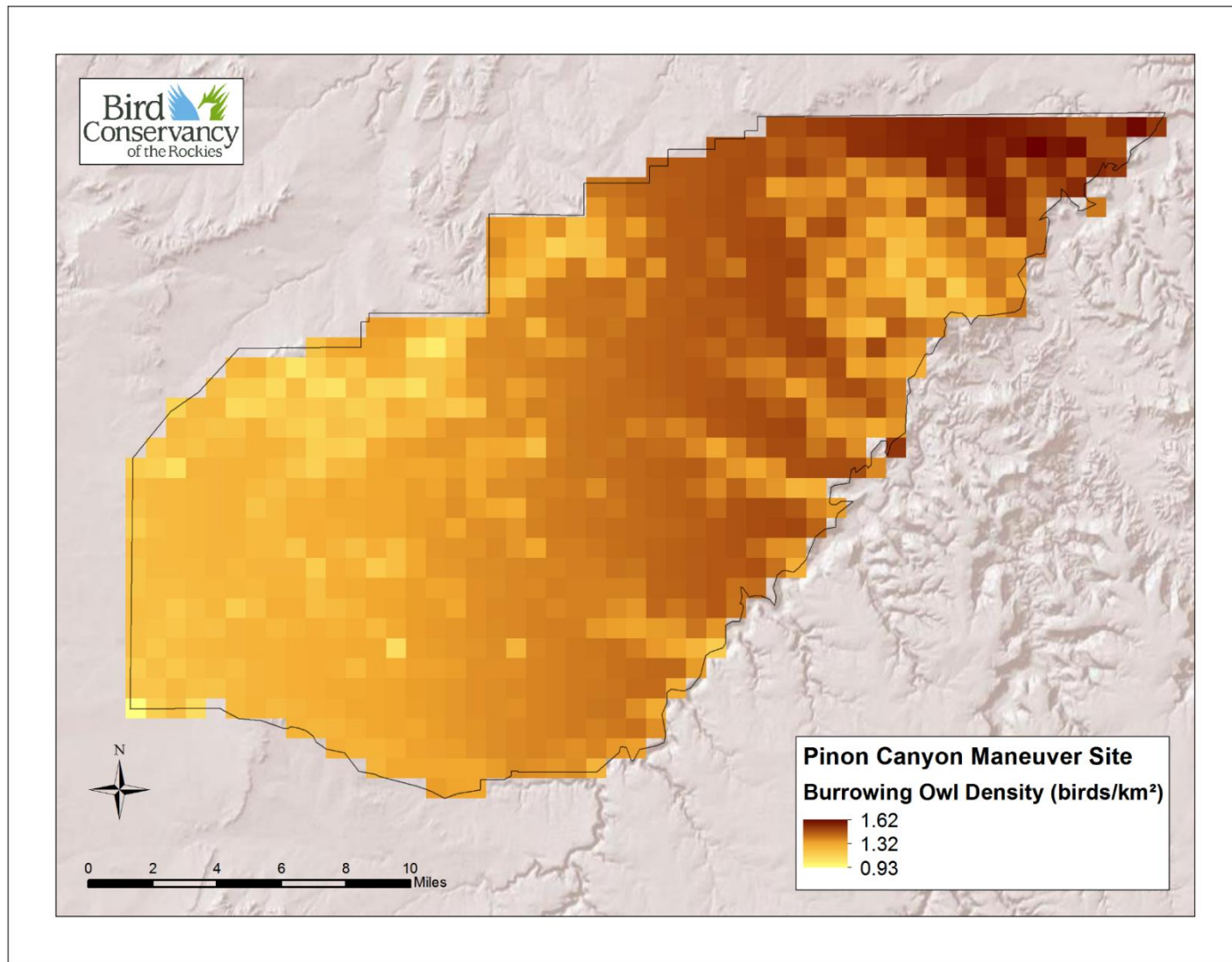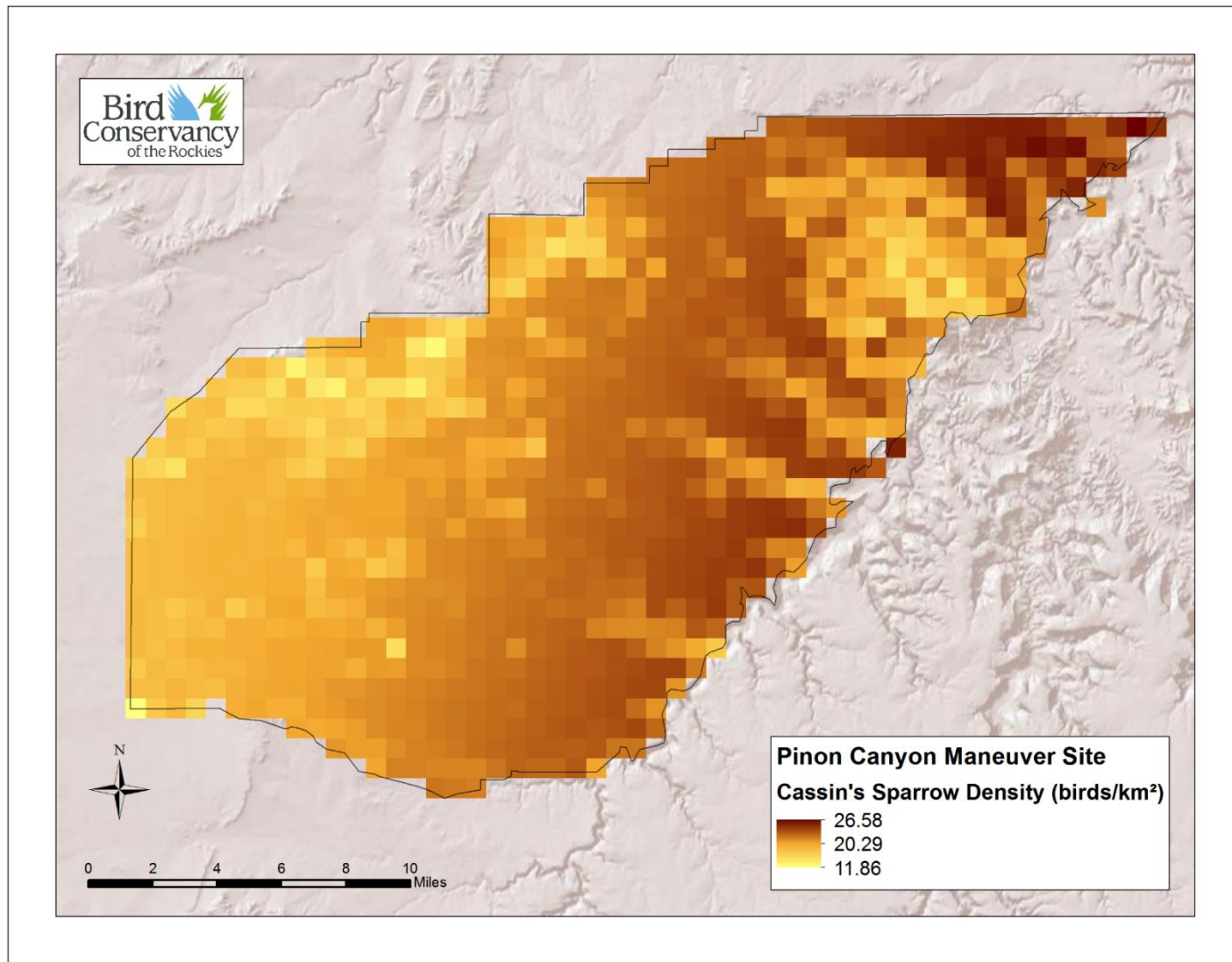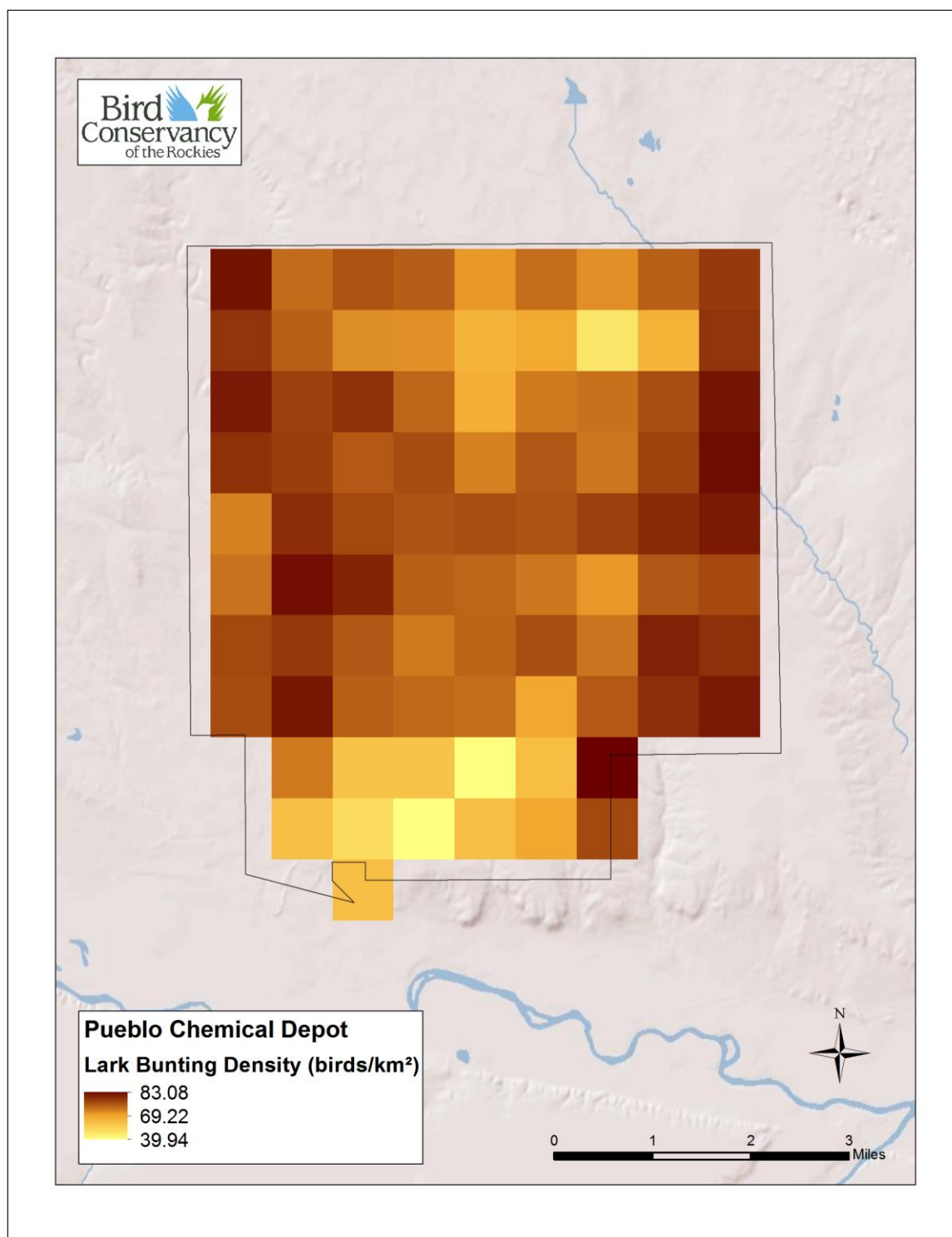
Figure I2. Predicted distribution of Western Meadowlark on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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Figure I3. Predicted distribution of Grasshopper Sparrow on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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Figure I4. Predicted distribution of Loggerhead Shrike on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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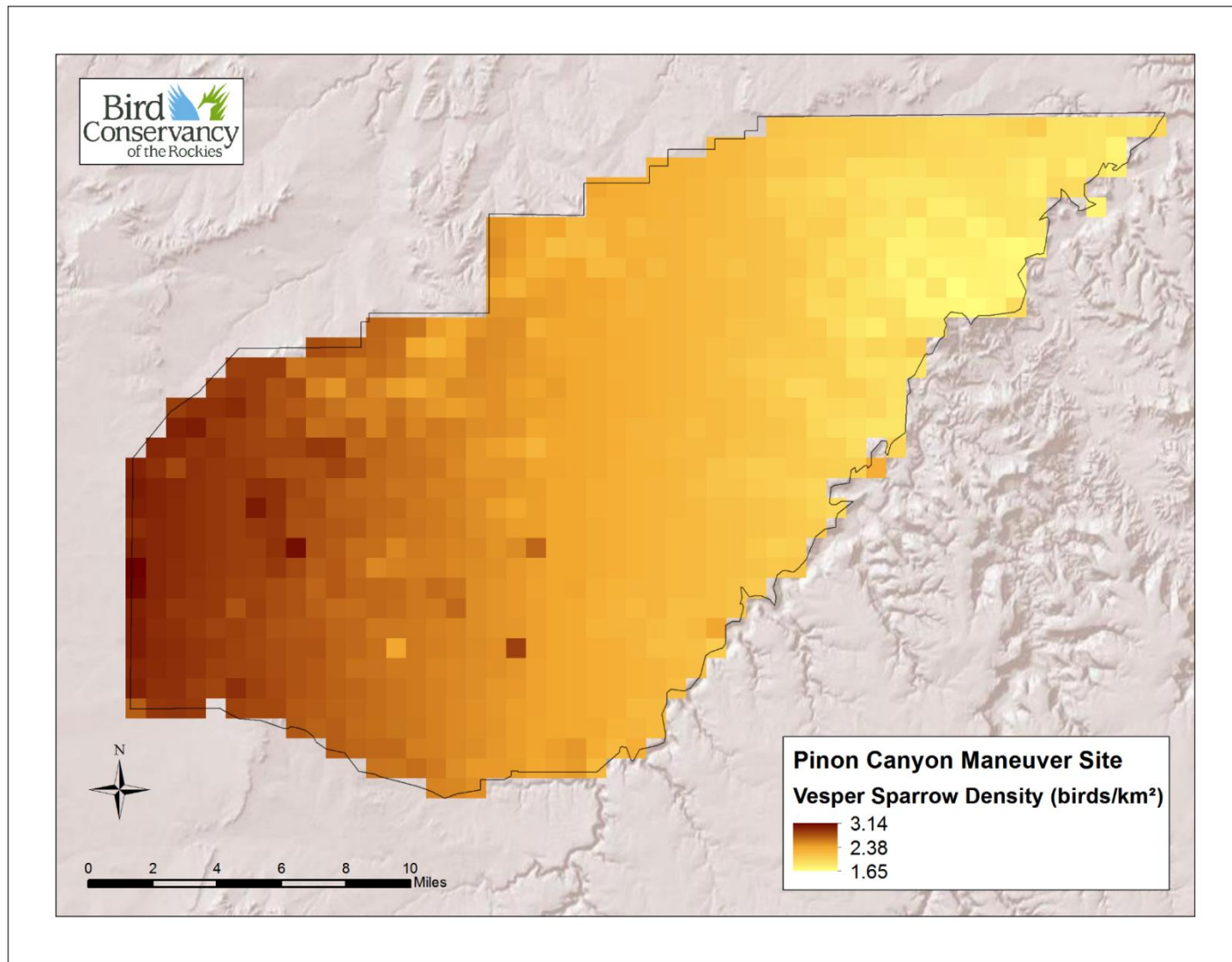
Figure I5. Predicted distribution of Vesper Sparrow on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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Figure I6. Predicted distribution of Burrowing Owl on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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Figure I7. Predicted distribution of Cassin's Sparrow on Pinon Canyon Maneuver Site, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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Appendix J. Predicted density distribution maps for priority species on Pueblo Chemical Depot**.**

Figure J1. Predicted distribution of Lark Bunting on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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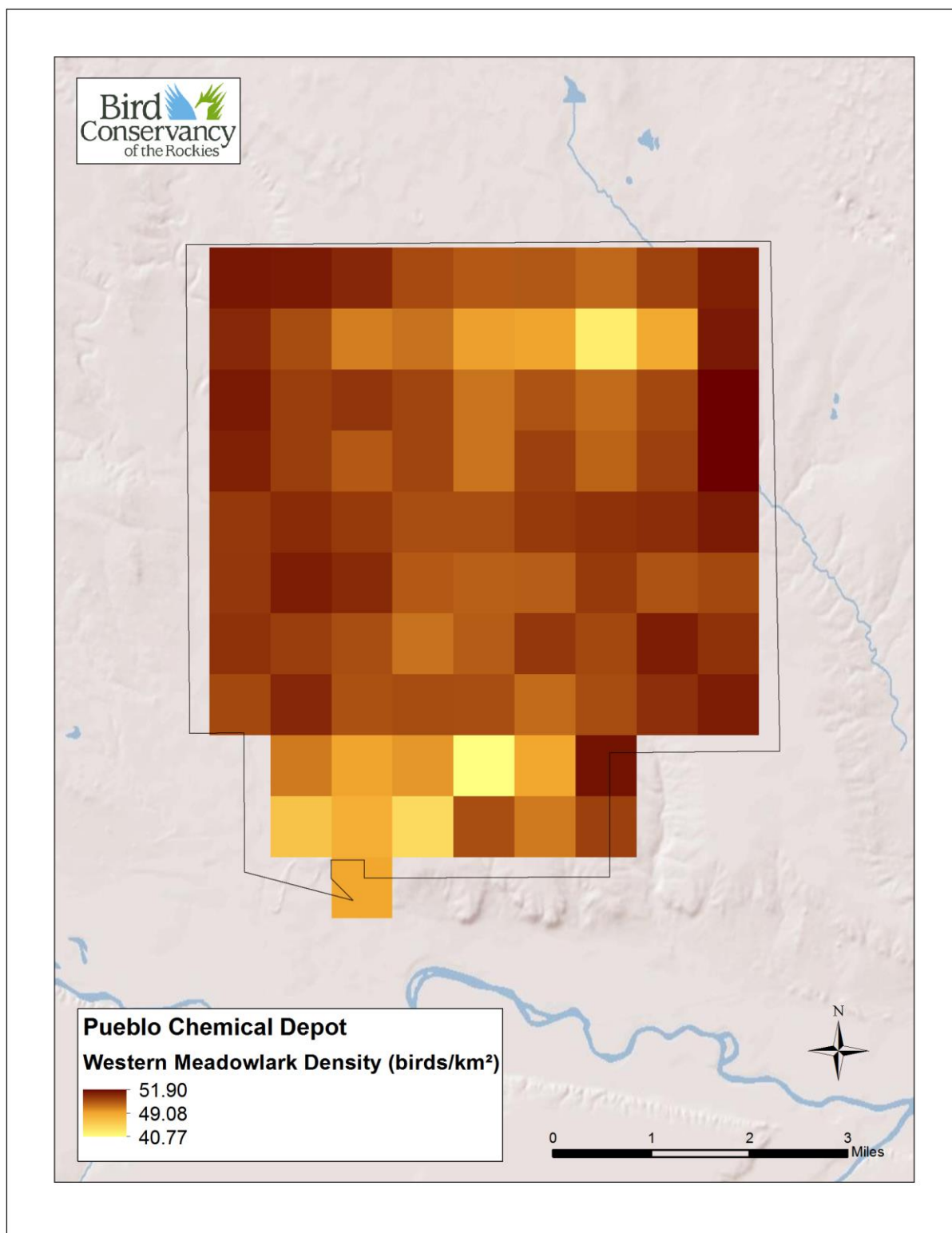
Figure J2. Predicted distribution of Western Meadowlark on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
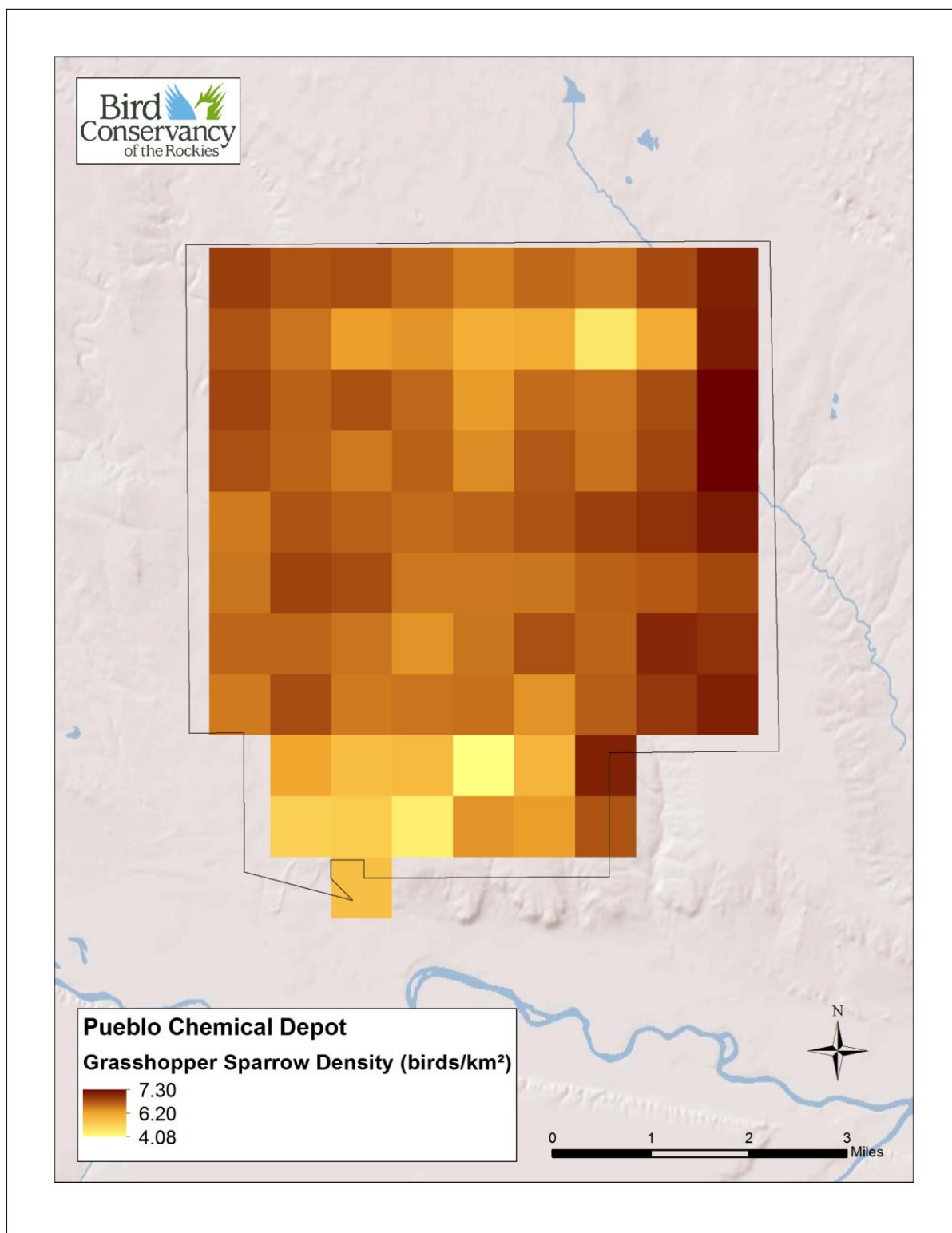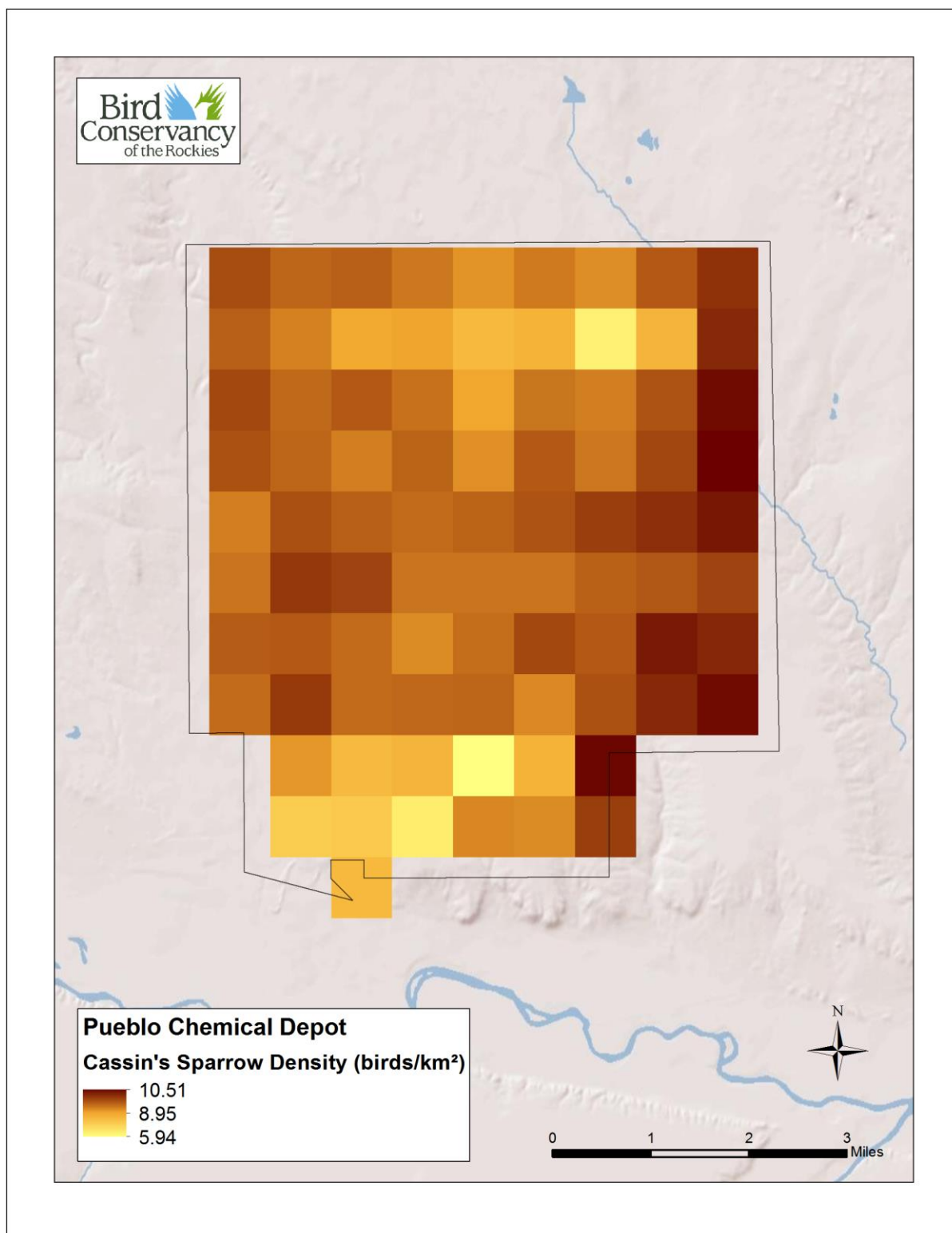
Figure J3. Predicted distribution of Grasshopper Sparrow on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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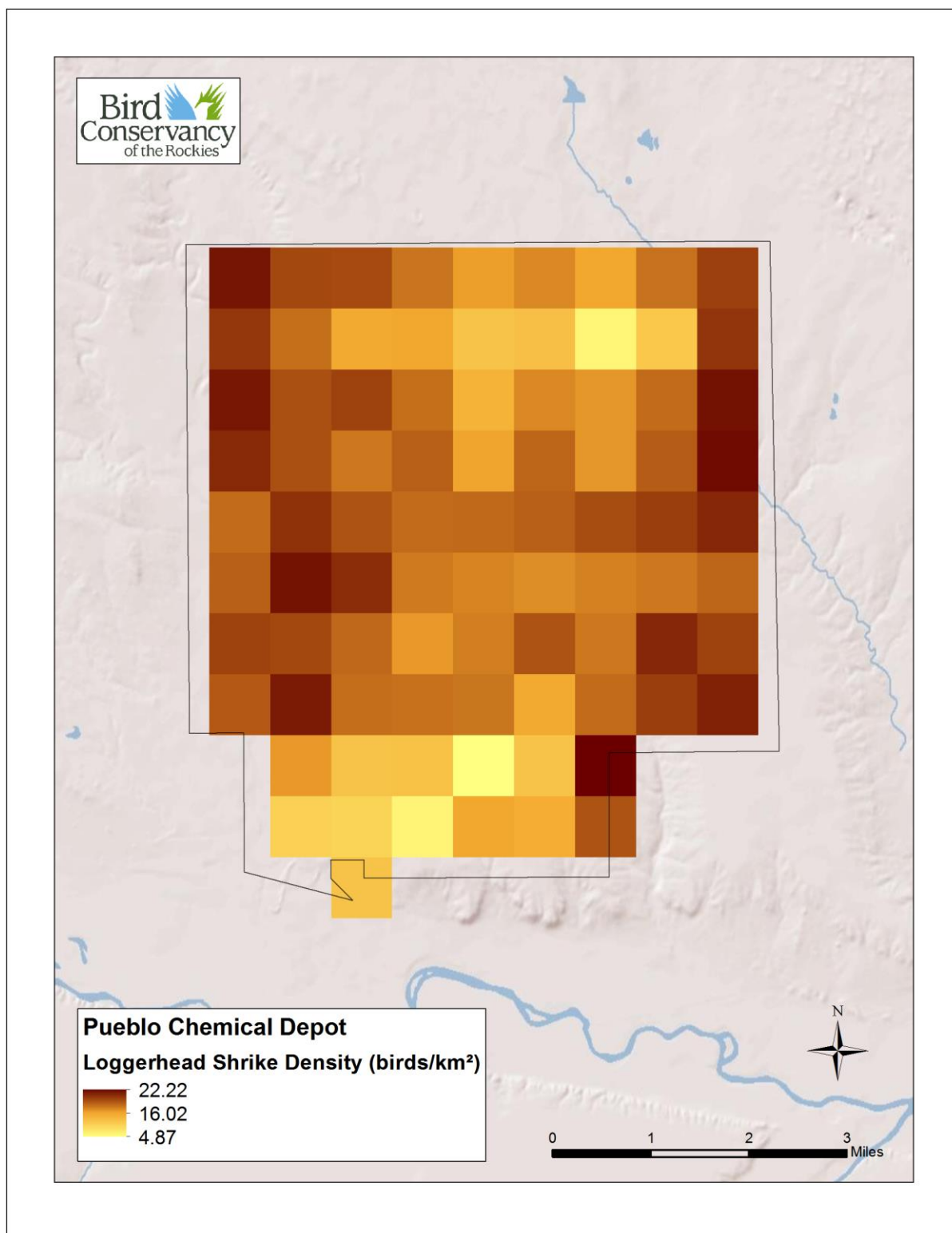
Figure J4. Predicted distribution of Loggerhead Shrike on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
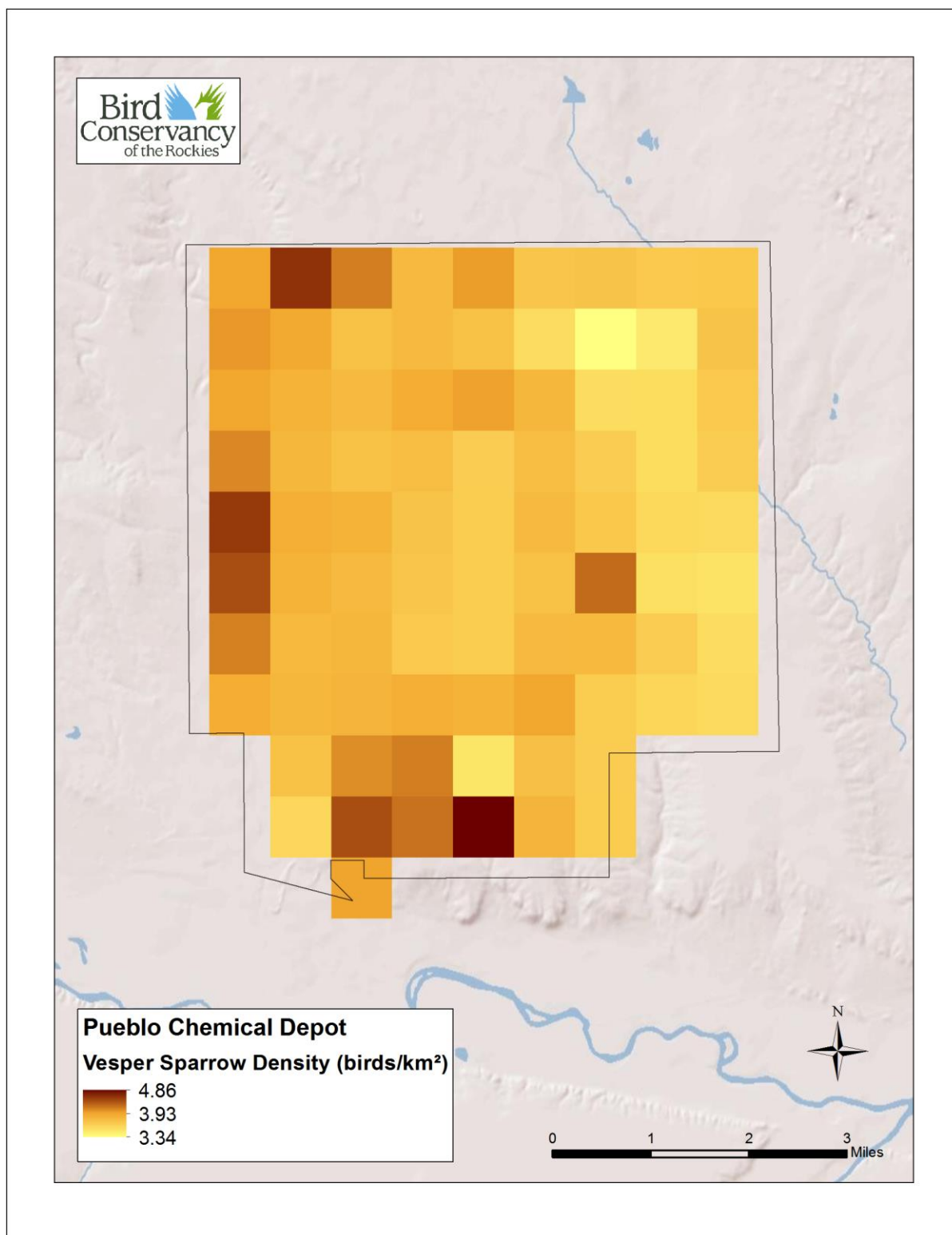
Figure J5. Predicted distribution of Vesper Sparrow on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

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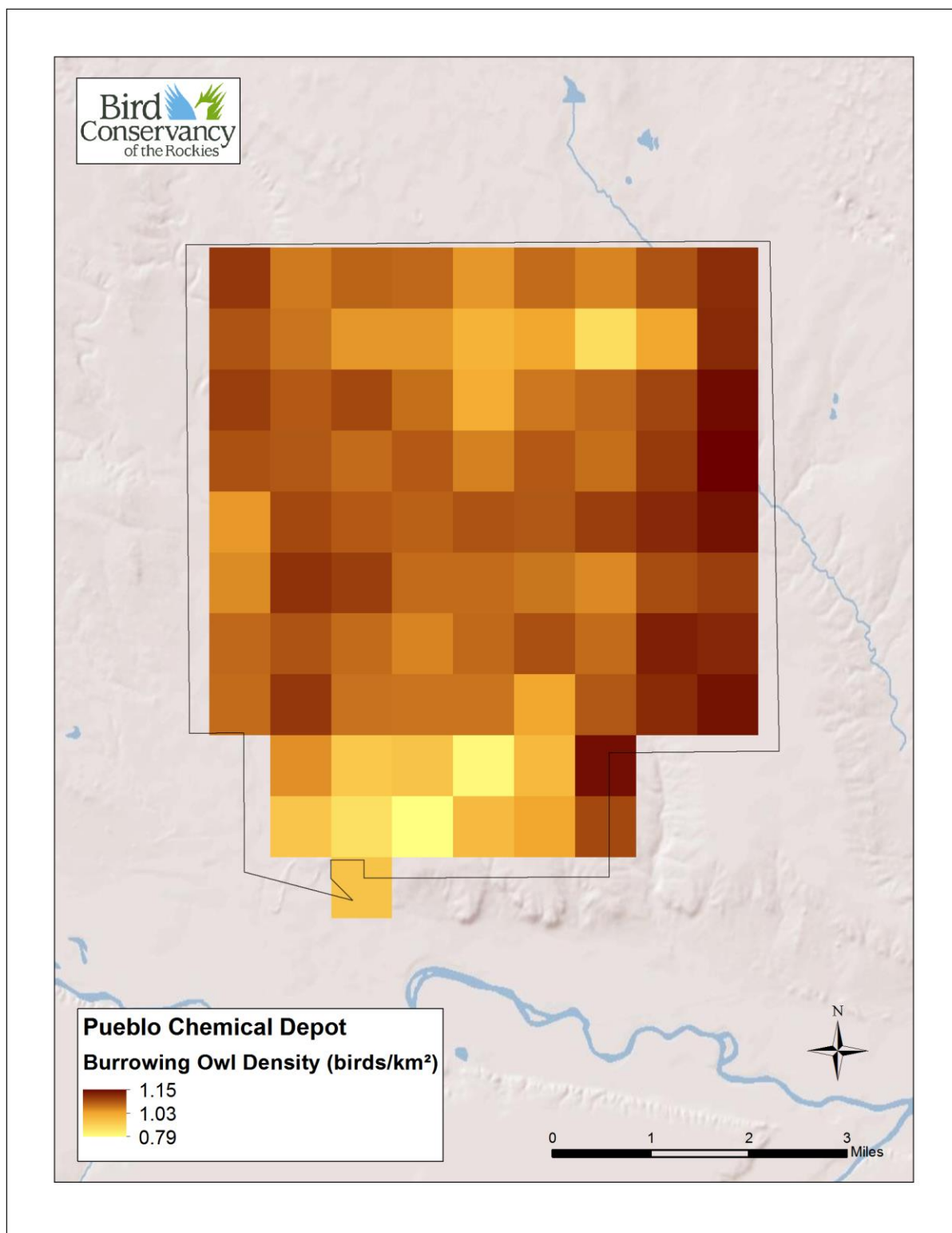
Figure J6. Predicted distribution of Burrowing Owl on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

Figure J7. Predicted distribution of Cassin's Sparrow on Pueblo Chemical Depot, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

Appendix K. Predicted density distribution maps for priority species on the U.S. Air Force Academy**.**
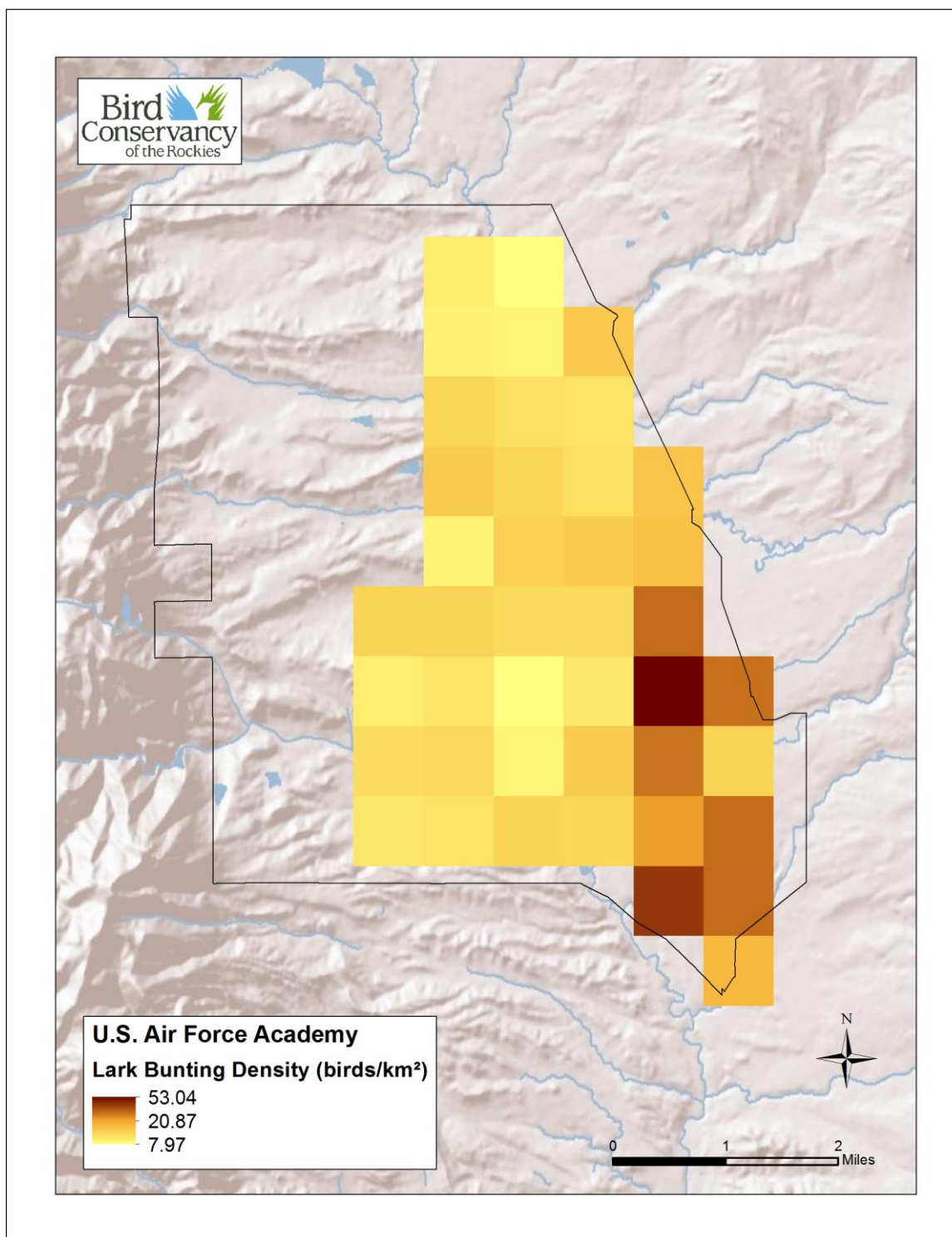
Figure K1. Predicted distribution of Lark Bunting on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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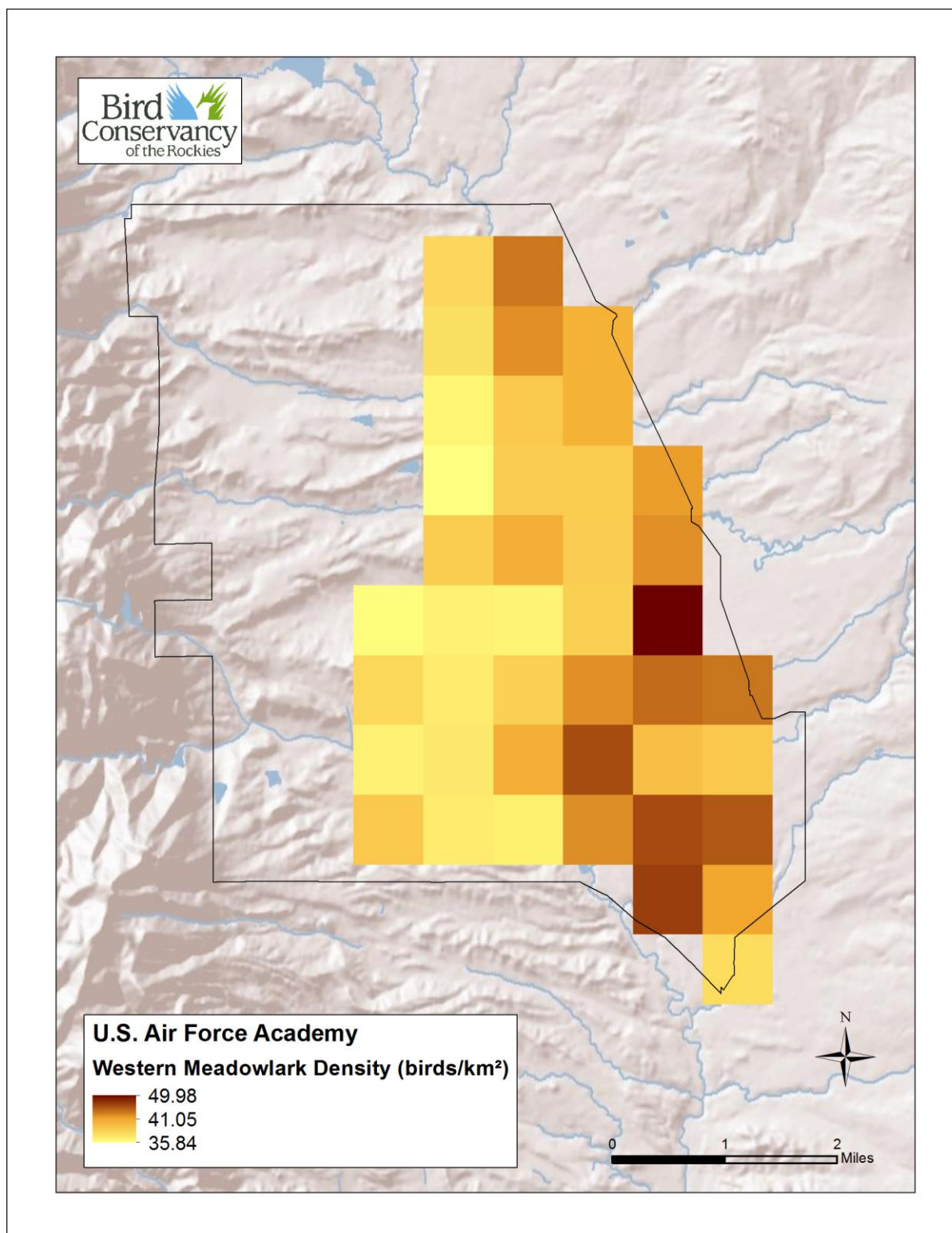
Figure K2. Predicted distribution of Western Meadowlark on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
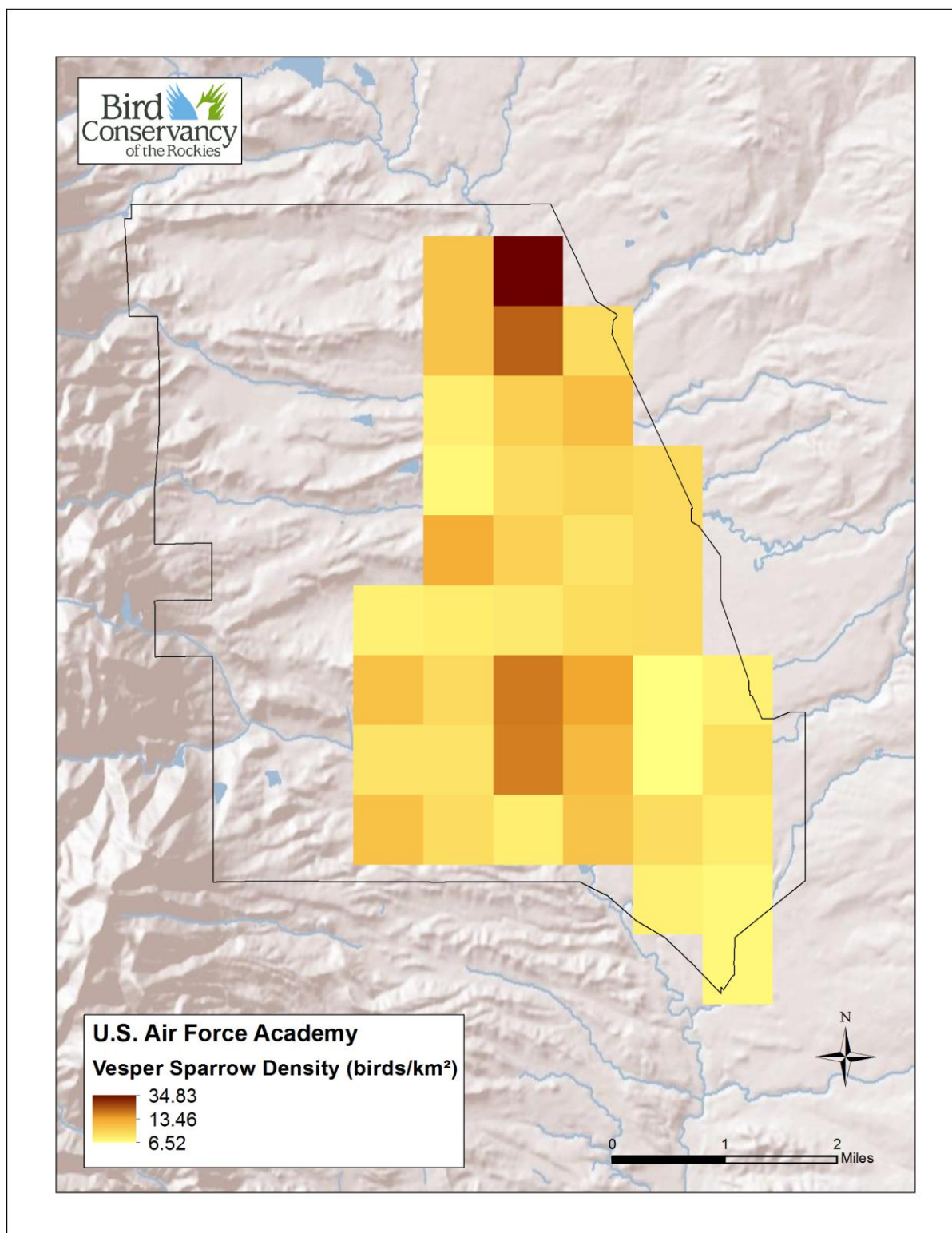
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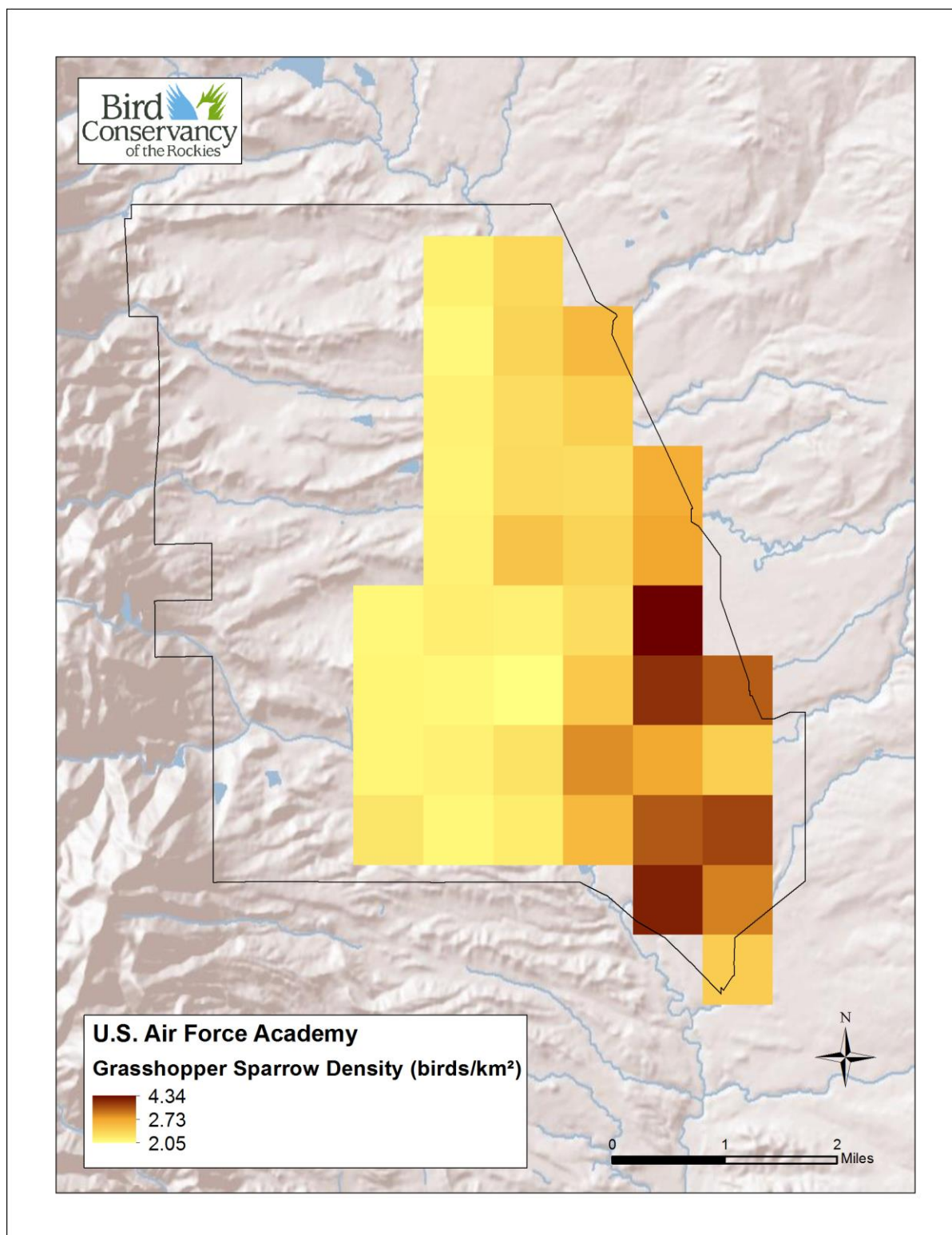
Figure K3. Predicted distribution of Grasshopper Sparrow on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.
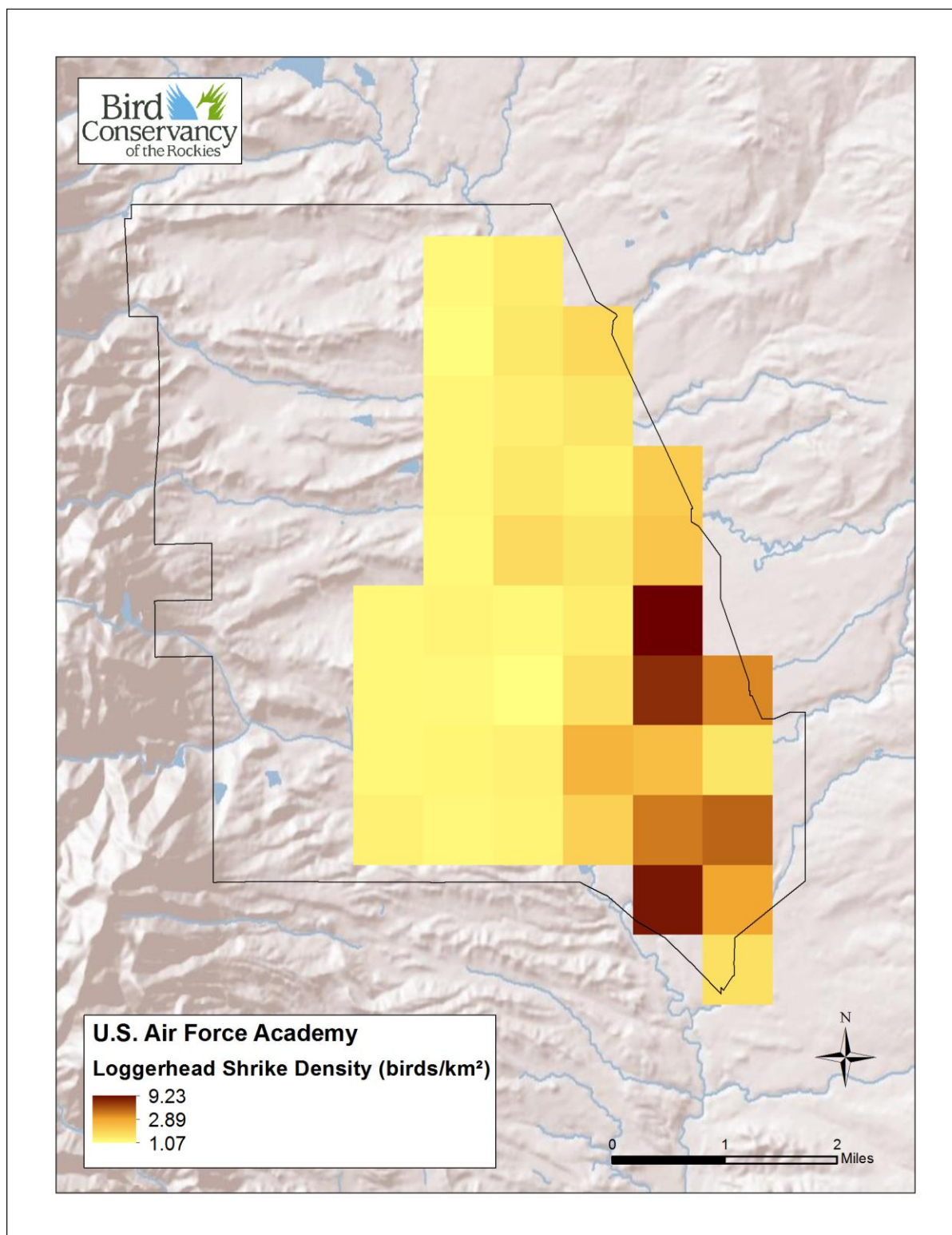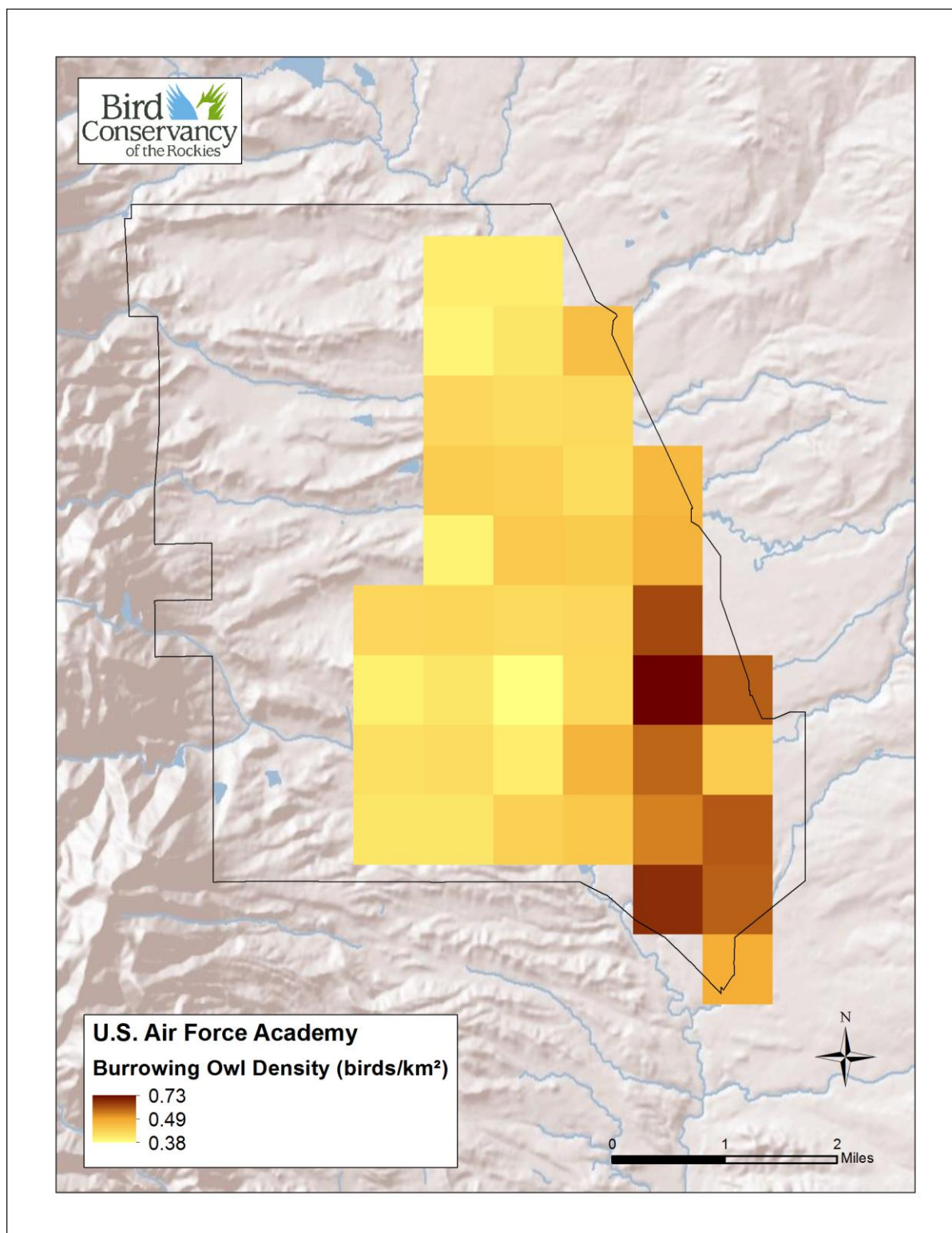
Figure K4. Predicted distribution of Loggerhead Shrike on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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Figure K5. Predicted distribution of Vesper Sparrow on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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Figure K6. Predicted distribution of Burrowing Owl on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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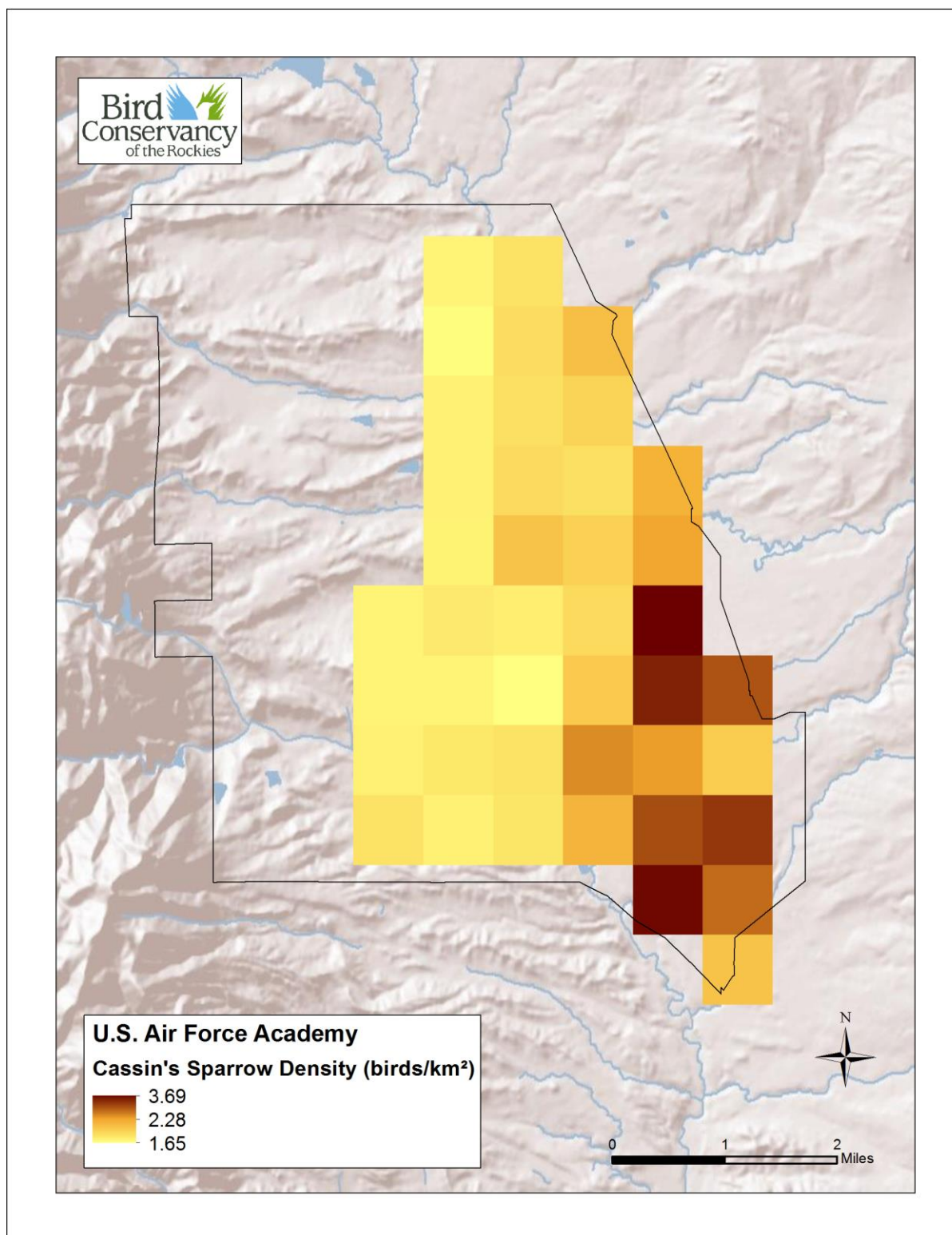
Figure K7. Predicted distribution of Cassin's Sparrow on the U.S. Air Force Academy, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values. Installation areas within BCR 16 are not included in predictions.

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Appendix L. Predicted density distribution maps for priority species on Camp Guernsey**.**
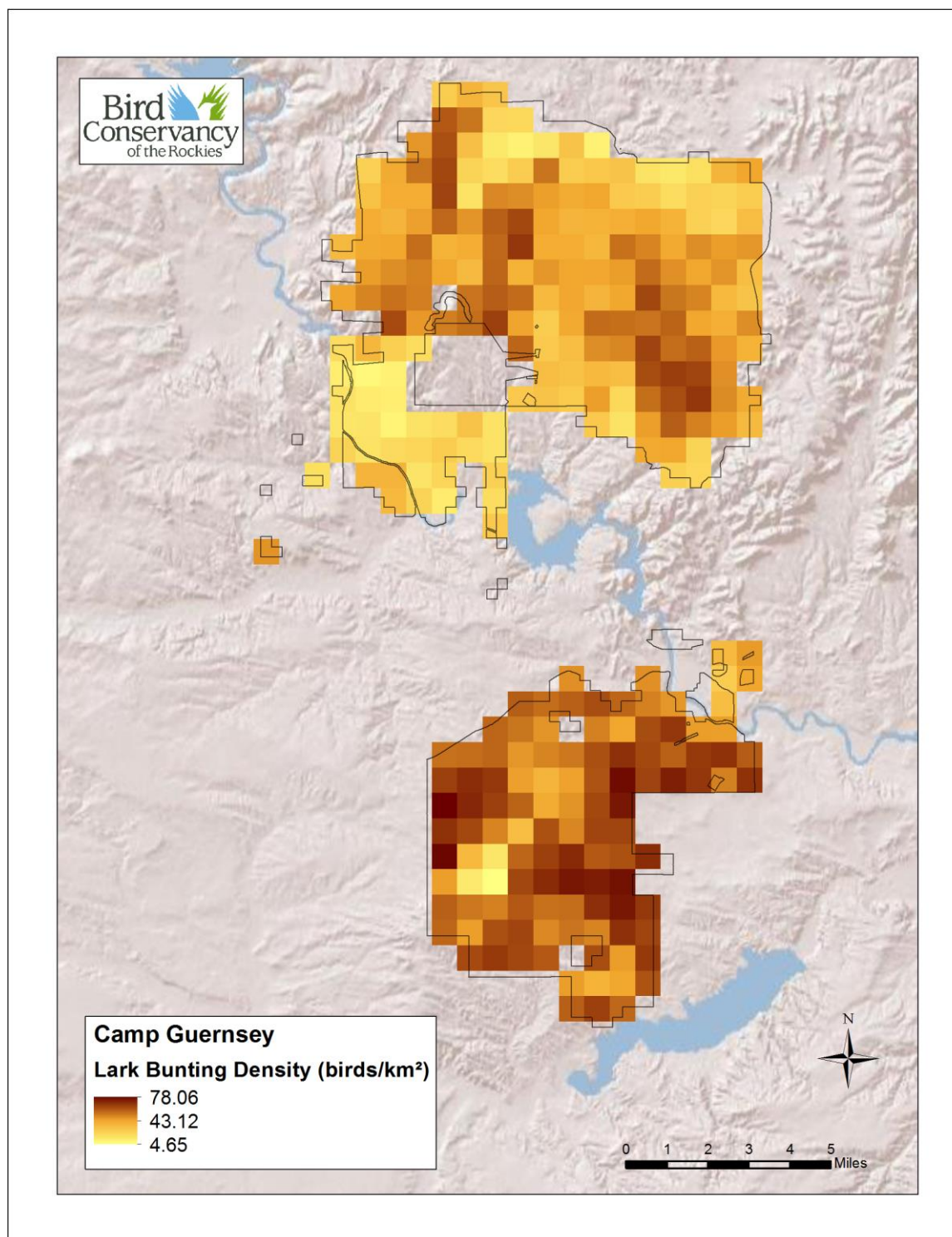
Figure L1. Predicted distribution of Lark Bunting on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
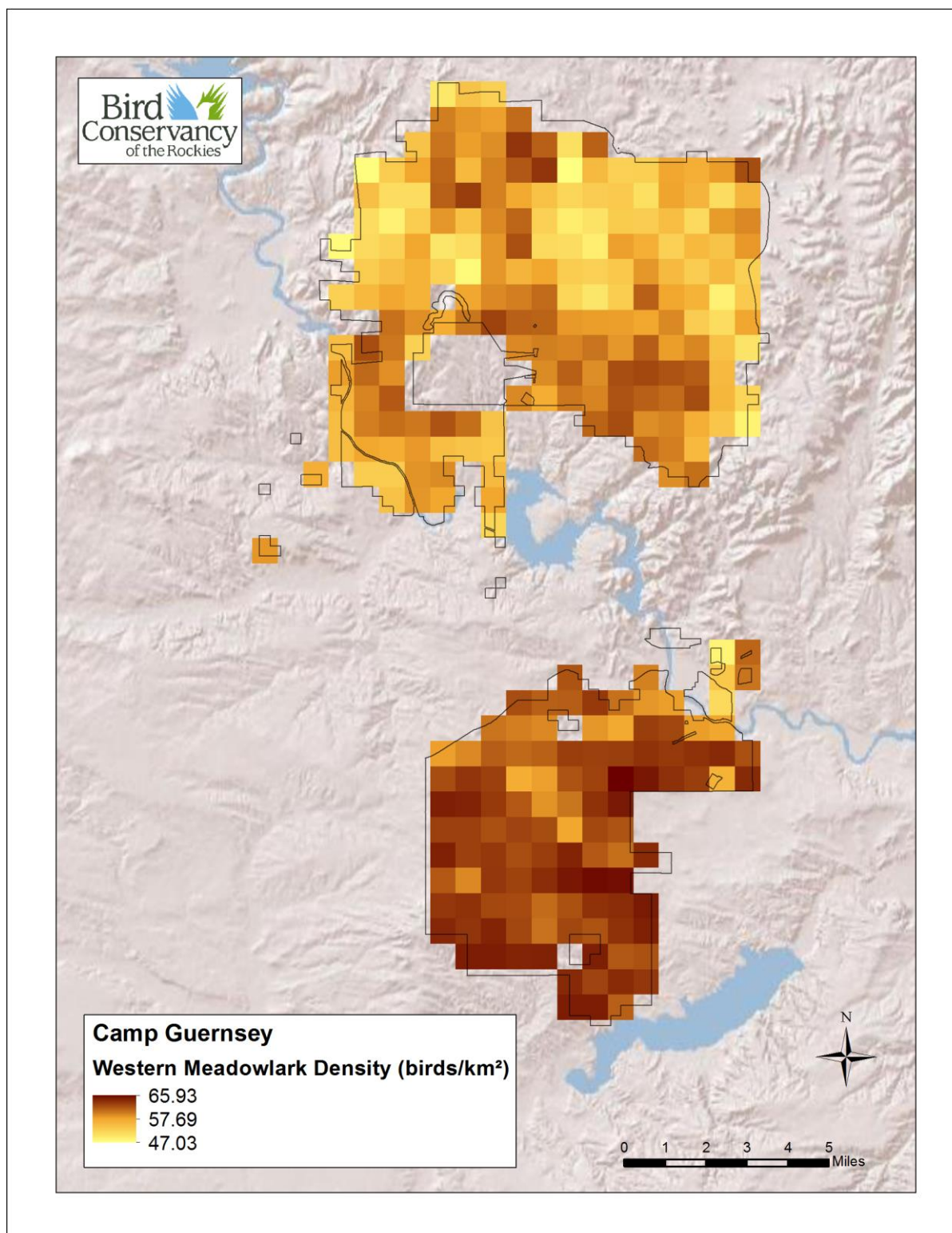
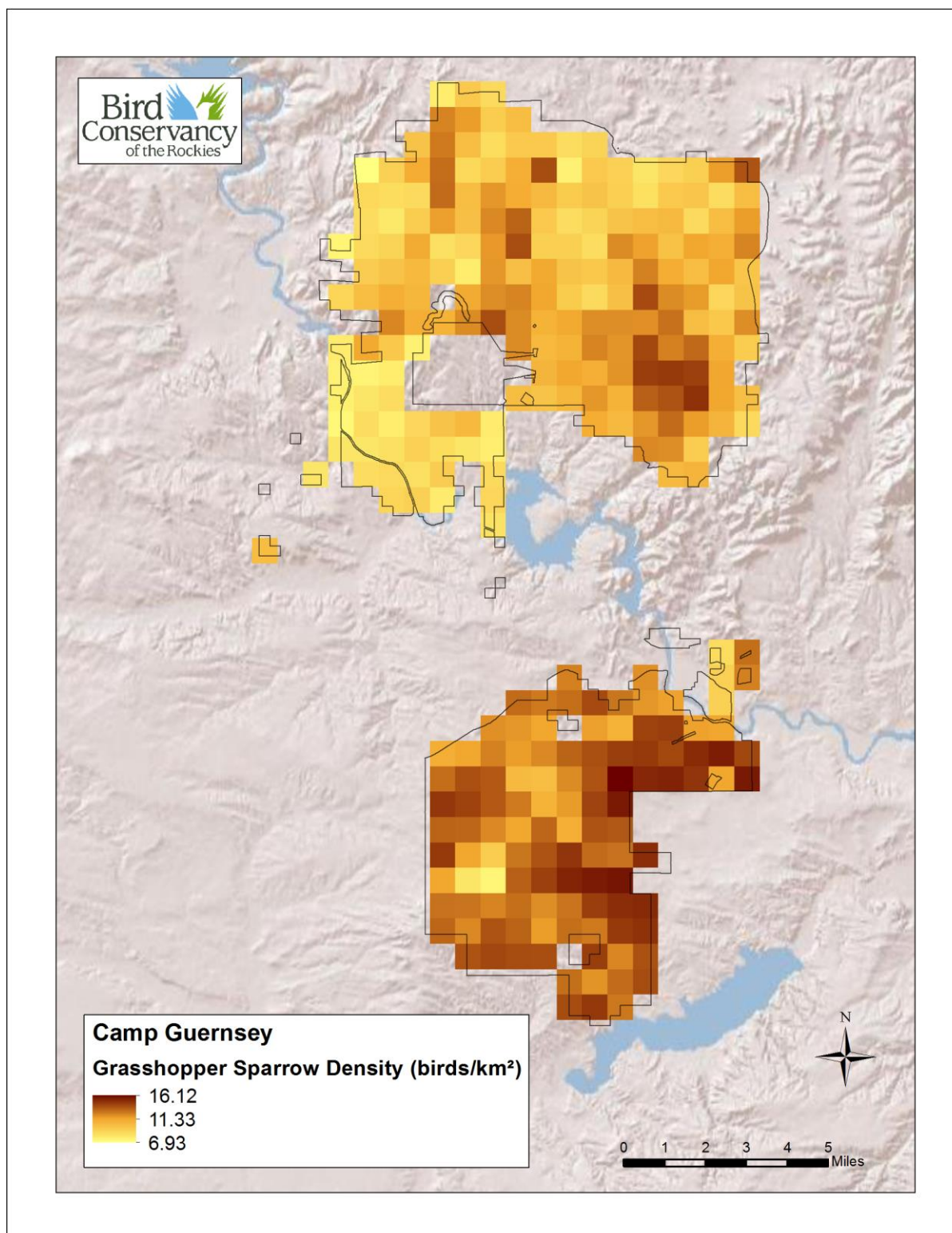Bird Conservancy of the Rockies
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Figure L2. Predicted distribution of Western Meadowlark on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
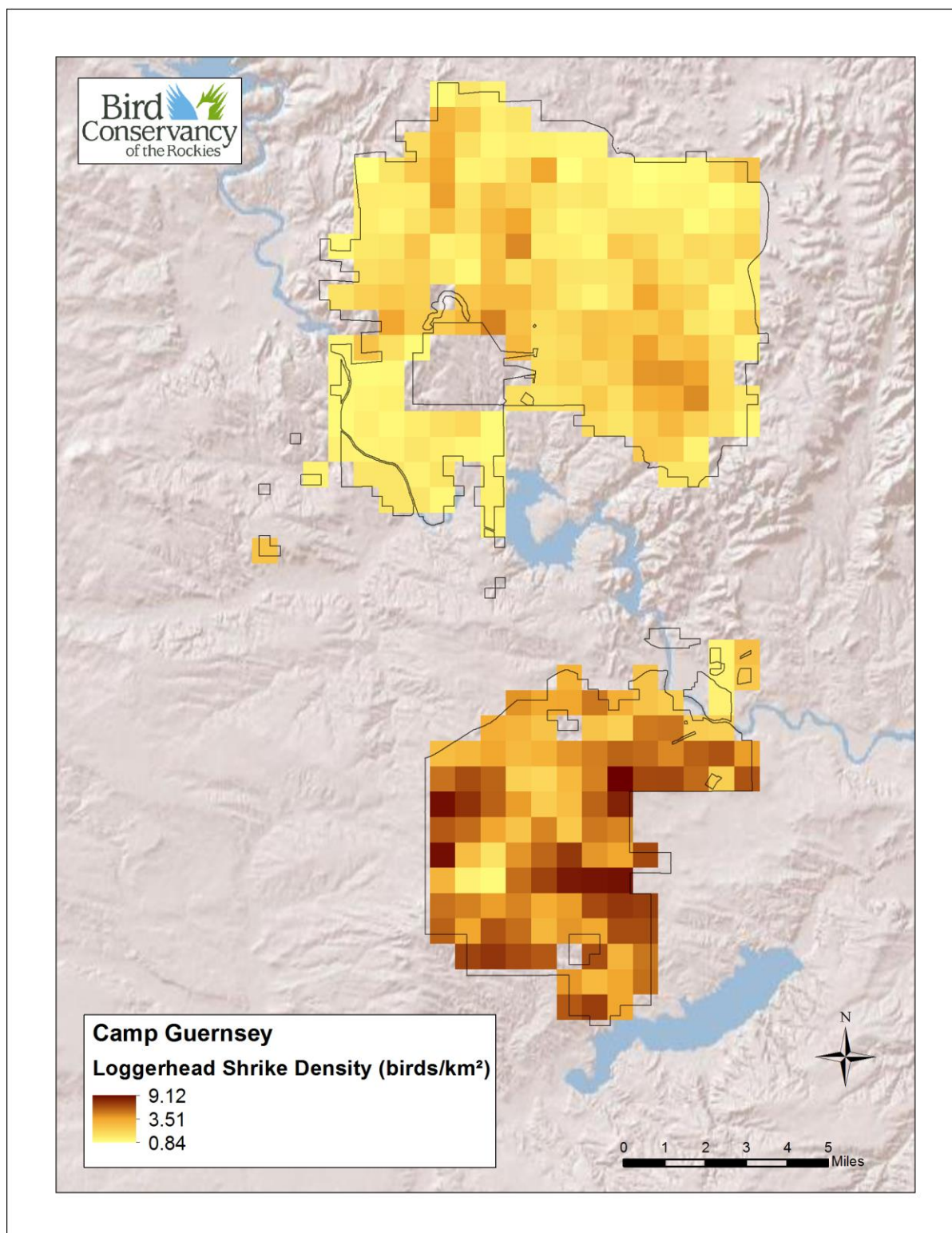
Figure L3. Predicted distribution of Grasshopper Sparrow on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.

Figure L4. Predicted distribution of Loggerhead Shrike on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
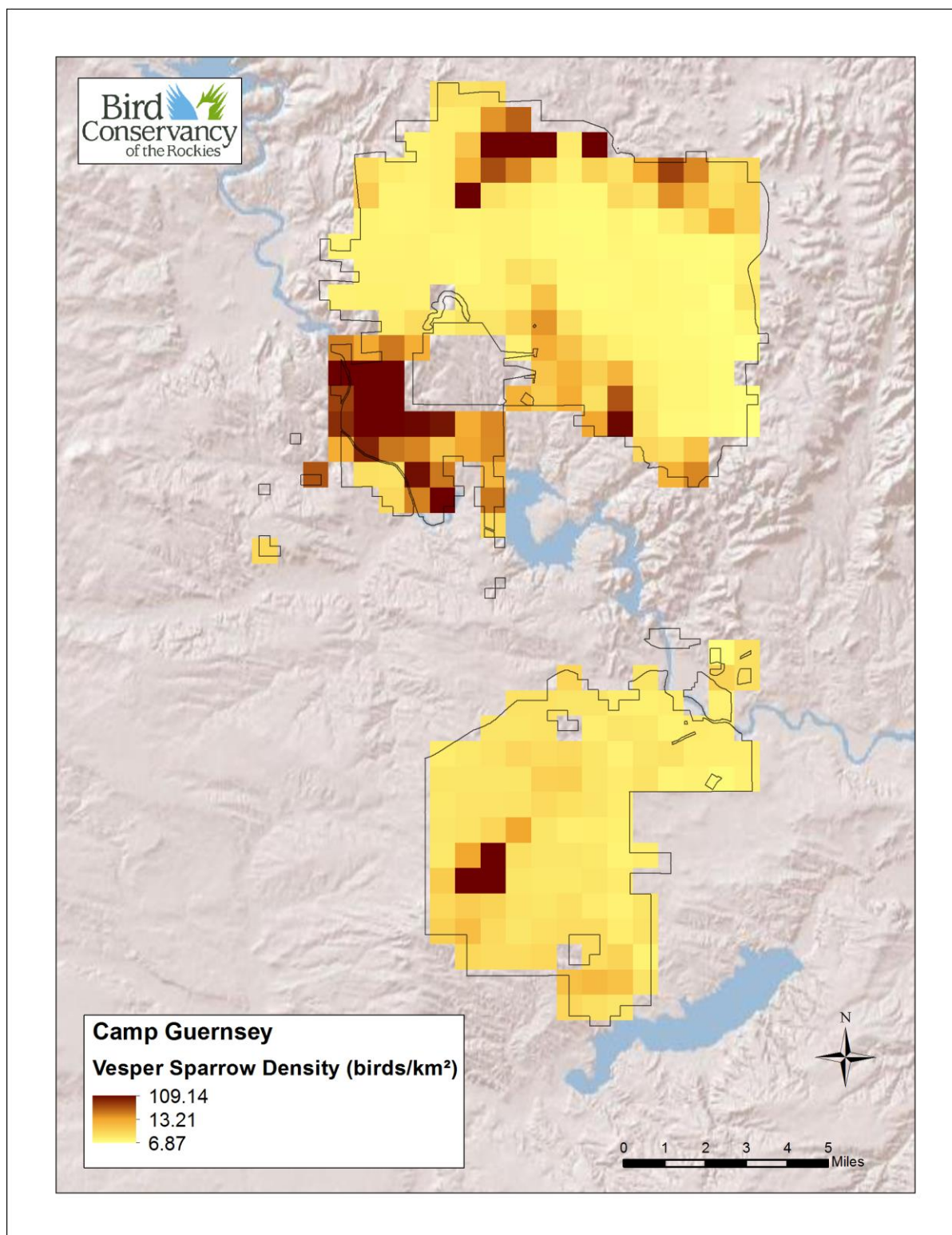
Figure L5. Predicted distribution of Vesper Sparrow on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
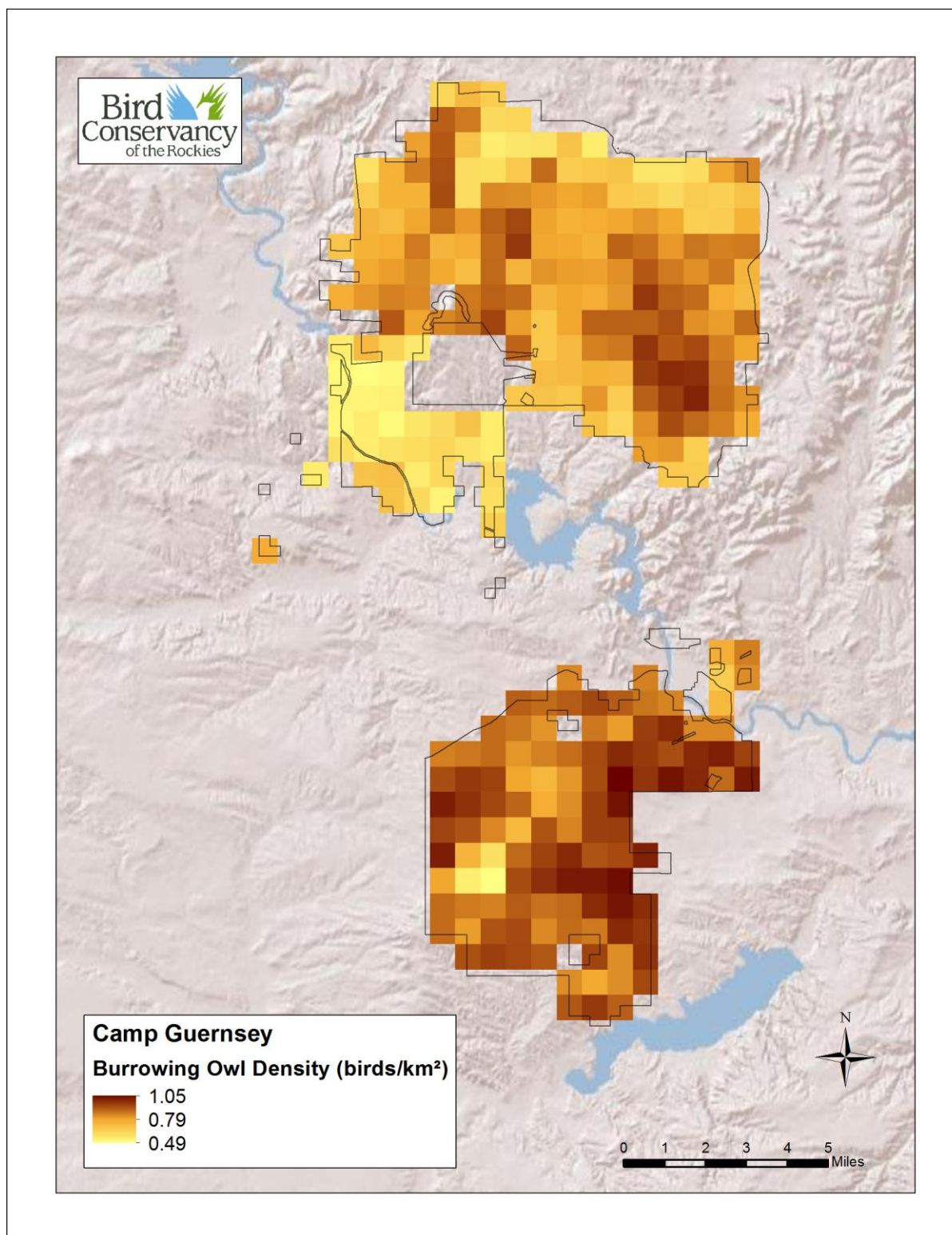
Figure L6. Predicted distribution of Burrowing Owl on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.
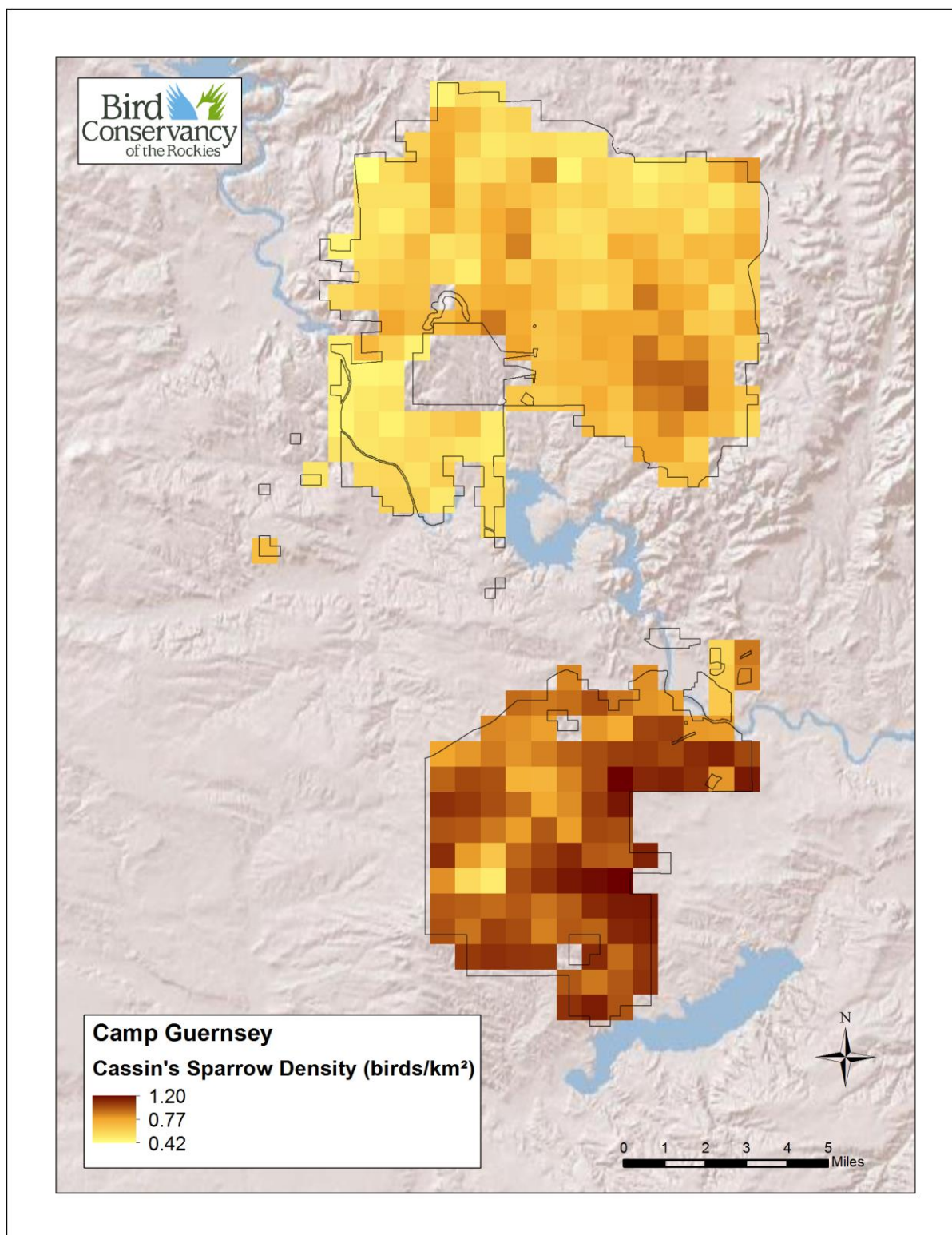
Figure L7. Predicted distribution of Cassin's Sparrow on Camp Guernsey, showing model-averaged population density (birds/km²). Legend displays maximum, minimum, and mean predicted density values.