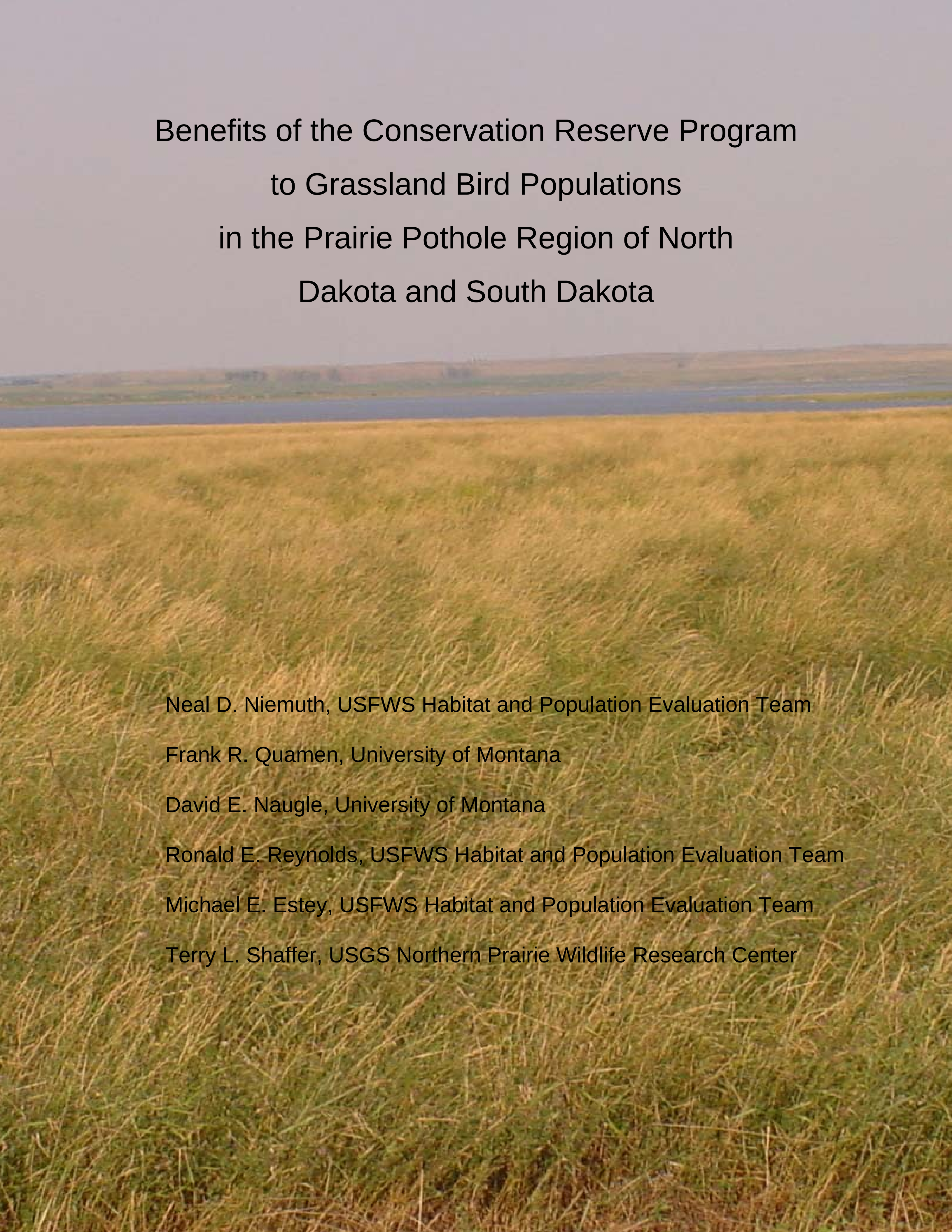

Benefits of the Conservation Reserve Program to Grassland Bird Populations in the Prairie Pothole Region of North Dakota and South Dakota

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ABSTRACT

The Conservation Reserve Program (CRP) of the 1985 Food Security Act is generally considered to provide substantial benefits to grassland wildlife species, but these benefits are often poorly known. Numerous local studies have documented benefits of the CRP to grassland birds, but few studies have sampled birds over a sufficiently broad spatial extent to make reliable inferences concerning regional benefits of the CRP to grassland birds. We assessed the response of grassland birds to the CRP in the Prairie Pothole Region (PPR) of North Dakota and South Dakota. We used different datasets, methodologies, and time periods, which strengthened our ability to make inferences about the response of grassland birds to the CRP. In the first part of the assessment, we used spatial models to estimate the distribution and number of grassland birds across the PPR of North Dakota and South Dakota in 1995 and 1997, respectively. Next, we used an independent dataset to calculate sample-based population estimates for Sedge Wren, Grasshopper Sparrow, Dickcissel, Bobolink, and Western Meadowlark in both North Dakota and South Dakota. We then quantified benefits of the CRP to grassland birds by simulating potential changes in bird numbers in both datasets if CRP grasslands were converted to cropland in the PPR of North Dakota and South Dakota.

Our analyses suggest that termination of the CRP would result in population declines ranging from 2% to 52%, depending on species, of populations of the target species in the PPR of North Dakota and South Dakota. Our spatial models predicted that conversion of CRP grasslands to cropland in the PPR of the two states would result in the combined loss of >900,000 individuals of the four species per state included in that analysis. Our sample-based extrapolations predicted that conversion of CRP grasslands to cropland in the same area would result in the combined loss of >1.8 million individuals of the five passerine species included in

that analysis. Species such as Sedge Wren and Bobolink, which used dense grasslands such as those found in CRP grasslands, showed the greatest proportional population declines under simulated loss of CRP grassland. Proportional population declines were smaller for species such as Western Meadowlark, which were found in a greater variety of grassland types and structures across the landscape. Predicted proportional declines in bird populations in response to loss of CRP were consistent regardless of time period or analytical method, as indicated by a strong correlation (r = 0.80) between results for seven species/region combinations that were common to the spatial modeling and extrapolation analyses.

Our findings reinforce the importance of the CRP to abundance of grassland birds in the northern Great Plains, and indicate that termination of the CRP would have strong negative effects on many species of grassland birds in the region. Our findings also indicate that benefits of the CRP to grassland birds were influenced by the location of the CRP grassland, composition of the surrounding landscape, and the conservation practice applied in a CRP field. Spatially explicit models provide a biologically sound mechanism for linking bird populations to landscapes, and can be used to guide conservation planning and increase the benefits of programs such as the CRP.

INTRODUCTION

The Conservation Reserve Program (CRP) of the 1985 Food Security Act (Public Law 99-198) has been shown to provide substantial benefits to grassland birds in the Prairie Pothole Region (PPR) of the United States. Lands enrolled in the CRP provide habitat for a variety of grassland bird species, typically at higher densities than adjacent croplands (Johnson and Schwartz 1993, Reynolds et al. 1994, Johnson and Igl 1995, Best et al. 1997, Herkert 1998). In addition to providing habitat that harbors high densities of birds, CRP grasslands also provide secure nesting cover for many species of grassland-nesting birds (Best et al. 1997, Koford 1999, Reynolds et al. 2001). However, with the exception of gamebirds (i.e., Nielson et al. 2006, Reynolds et al. 2006), most studies examining grassland bird use of CRP have taken place at local scales, and lack sample size, landscape context, and spatial extent sufficient to make reliable inferences concerning benefits of the CRP to grassland birds over broad regions. Knowing the effect of the CRP on grassland bird populations in the PPR may be particularly important because the number of grassland bird species is greatest in the northern Great Plains (Peterjohn and Sauer 1999) and grassland birds have a larger proportion of species that are decreasing than any other bird group in North America (Askins 1993, Peterjohn and Sauer 1999). We used two datasets and different analytical methods to assess the effect of the CRP on grassland bird populations across the PPR of North Dakota and South Dakota.

In the first part of our assessment, we used data from the North American Breeding Bird Survey (BBS), an annual, continent-wide survey that is the primary source of information regarding populations of many North American bird species (Bystrak 1981). We demonstrate how georeferenced BBS data can be used in conjunction with landcover information and statistical models to link birds to specific landscapes and estimate the distribution and size of bird populations. We then demonstrate how these populations might change in response to conversion of CRP grasslands to cropland in the PPR of North Dakota and/or South Dakota. We focused on the BBS as it is a comprehensive, annual survey with the ability to provide consistent data over the long term.

This portion of our assessment had four main objectives: (1) identify and estimate parameters for factors, especially landscape characteristics, associated with the number of individuals of target grassland bird species detected at BBS stops; (2) use parameter estimates to create spatially explicit models showing predicted number of individuals of target species across the PPR portions of North Dakota or South Dakota; (3) estimate size of regional populations of target species, following adjustments presented in the North American Landbird Conservation Plan (Rich et al. 2004, Rosenberg and Blancher 2005); and (4) estimate size of regional populations of target species following simulated conversion of CRP grasslands to cropland in the PPR portions of North Dakota and South Dakota.

For the second part (validation analysis) of our assessment, we used point-count data as part of an on-going study of grassland birds throughout the PPR to validate findings of the BBS-based spatial analysis. We extrapolated findings from 2,805 survey points to estimate grassland bird populations across the PPR of North Dakota and South Dakota, then demonstrated how these populations might change in response to conversion of CRP grasslands to cropland. This second portion of our assessment had three main objectives: (1) estimate density of target species of grassland birds, by landcover type, across the study region; (2) apply estimated densities to area of each landcover type to estimate regional population size; and (3) estimate size of regional populations of target species following simulated conversion of CRP grasslands to cropland in the PPR of North Dakota and South Dakota. Both analyses were designed to assess the effect of

CRP on grassland bird populations, not predict future CRP enrollment, and assume that all CRP grasslands revert to cropland.

All species included in the analyses with the exception of Sedge Wren (scientific names for all species are presented in Table 1) showed significant population declines at the state and/or national level from 1966 to 2005 (Sauer et al. 2005; Table 1). The U.S. Fish and Wildlife Service has identified Northern Harrier and Grasshopper Sparrow as birds of Conservation Concern in Bird Conservation Region 11 (the Prairie Pothole Region; USFWS 2002). In addition, Partners in Flight has identified Grasshopper Sparrow and Dickcissel as species of continental importance for the U.S. and Canada (Rich et al. 2004).

Table 1. Population trends (and associated P-values) for 1966-2005 from Breeding Bird Survey data for North Dakota, South Dakota, and the United States (Sauer et al. 2005) for grassland birds included in analyses. Scientific names follow common names in parentheses.

Species	North Dakota	South Dakota	United States
Northern Harrier (*Circus cyaneus*)	1.5 (0.09)	-3.4 (0.22)	-1.7 (0.04)
Sedge Wren (*Cistothorus platensis*)	5.7 (<0.01)	8.5 (0.01)	1.8 (<0.01)
Grasshopper Sparrow (*Ammodramus savannarum*)	-3.7 (0.01)	-4.7 (<0.01)	-3.7 (<0.01)
Dickcissel (*Spiza americana*)	-5.8 (0.01)	-2.1 (0.17)	-0.2 (0.86)
Bobolink (*Dolichonyx oryzivorus*)	3.0 (0.01)	2.3 (0.38)	-0.8 (0.01)
Western Meadowlark (*Sturnella neglecta*)	-0.5 (0.39)	0.1 (0.77)	-0.9 (<0.01)

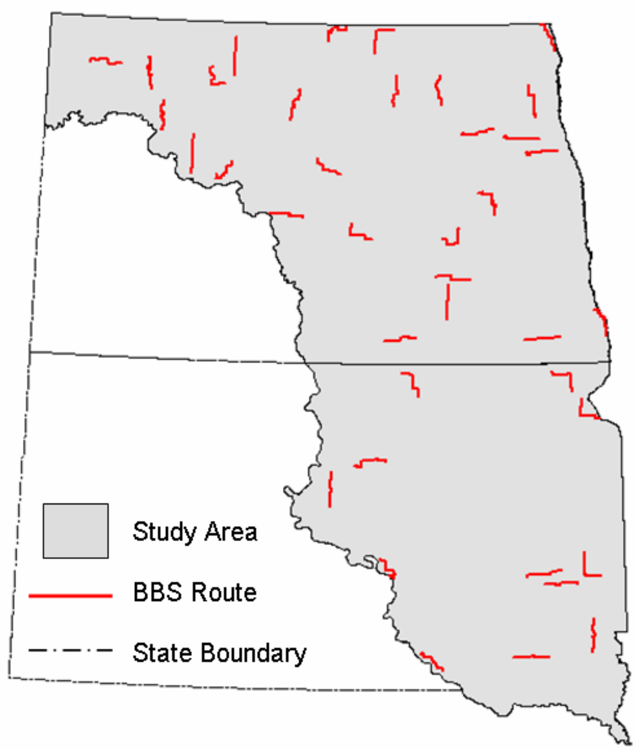
METHODS

BBS/HABITAT MODELING

Study Area

The study area was that portion of North Dakota and South Dakota east or north of the Missouri River, approximating the Prairie Pothole Region, or Bird Conservation Region 11 portion, of each state (Figure 1). The study area covers approximately 86,500 square miles. The landscape surface was formed by glacial action and is characterized by numerous depressional wetlands and prairie flora (Bluemle 1991). The climate is cool and dry, and soils are typically heavy (Winter 1989). Agriculture was the primary land use during the study period, with cropland dominating in the eastern portion of the study area, and the amount of grassland generally increasing farther west. We developed separate models for each state/PPR combination rather than the study area as a whole. This enabled us to make better use of BBS data, as the number of routes surveyed varied among years and states, and allowed us to directly compare our population estimates with those developed under the North American Landbird Conservation Plan (Rich et al. 2004, Rosenberg and Blancher 2005), which were based on the same geographic areas.

Figure 1. Location of study areas and BBS routes in North Dakota and South Dakota that were sampled in 1995 or 1997 and included in analyses. Bird-landscape relationships were only modeled north and east of the Missouri River, approximating the Prairie Pothole Region of the two states.



BBS Data

We acquired BBS data and landcover information that coincided with regional enrollment of land in the CRP, which may substantially influence grassland bird populations (Reynolds et al. 1994, Johnson and Igl 1995, O'Connor et al. 1999, Herkert 1998). We obtained 1995 and 1997 BBS data for 39 routes within our study area (Figure 1) from the United States Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA. Each 40-km route contained 50 stops, or survey points, 0.81 km apart; details of route placement and sampling were described by Bystrak (1981). We acquired digitized survey routes from the National Atlas of the United States (http://nationalatlas.gov) as an ArcView shapefile

(Environmental Systems Research Institute, Redlands, California, USA). We calculated locations for 50 stops on each BBS route by creating a point at the start node of each digitized route and every 0.81 km thereafter to the end of the route; directionality of routes was determined using to and from nodes within the shapefile and verified or corrected using BBS route maps (Keith Pardieck, USGS, personal communication). Because bird populations and number of BBS routes surveyed varied among years, we evaluated BBS data from each year to determine suitability for modeling. We developed spatial models for four species (Northern Harrier, Sedge Wren, Grasshopper Sparrow, and Western Meadowlark) in North Dakota using 1995 data and four species (Sedge Wren, Grasshopper Sparrow, Dickcissel, and Western Meadowlark) in South Dakota using 1997 data.

Landcover Data

Landcover data were derived from Thematic Mapper satellite images (30-m resolution) acquired from May 1992 through September 1996. Landcover and BBS data were acquired to coincide with a high, stable period of CRP enrollment in the region (Reynolds et al. 2001). Individual images were classified, resampled to 2.02-ha minimum mapping unit, and combined into a single grid (Table 2). User's accuracy for all images exceeded 80% (USFWS, unpublished data). Satellite imagery was used to identify undisturbed grassland that included lands enrolled in the CRP, but we could not distinguish undisturbed grassland planted as part of the CRP from other undisturbed grassland present in the landscape.

Table 2. Candidate predictor variables used to model number of Grasshopper Sparrows detected at BBS stops in North Dakota and South Dakota. All landcover variables were calculated for three sizes of buffers around BBS stops on GIS layers.

Landscape Variable	Description
Undisturbed Grass (%)	Mix of cool-season grass and forb species planted on previously cropped land (e.g., CRP lands); generally undisturbed but may be hayed or grazed intermittently.
Grassland (%)	Mix of native grass, forb, or scattered low shrub species on untilled prairie; typically grazed or hayed annually.
Hayland (%)	Mix of alfalfa and cool-season grass species hayed once or twice annually.
Cropland (%)	Tilled and planted with small grains or row crops that are harvested annually; includes fallow fields.
Forest (%)	Area of forest cover within each buffer.
Patches (*n*)	Number of disjunct habitat patches within each buffer.
Temporary	Area of wetland basins[a] in which surface water is present for brief periods during the growing season, but the water table is otherwise well below the soil surface.
Seasonal	Area of wetland basins[a] in which surface water is present for extended periods, especially early in the growing season, but is absent by the end of the season in most years.
Northing	UTM[b] coordinate indicating north-south position. Also included as quadratic term.
Easting	UTM coordinate indicating east-west position. Also included as quadratic term.
Observer	Identifier for each observer, coded as 0/1 categorical variable.
Stop Number	Number (1-50) of stop within each route.

[a]Derived from National Wetlands Inventory data

[b]Universal Transverse Mercator

Because many bird species are influenced by the landscape beyond the area included by traditional bird survey methods (e.g. point-count circles; Howell et al. 2000, Bakker et al. 2002), we sampled habitat at three scales using circular moving window analysis, which summarizes data within a "window" of a selected size around each cell in a GIS data layer. Landscape data were in raster format and the area within each moving window was 48, 191, and 452 ha, respectively, for circles with radii approximating 400, 800, and 1200 m. We analyzed spatial data using the Arc/Info GRID module (Environmental Systems Research Institute, Redlands, California, USA).

Stop-Level BBS Data

Analyzing BBS data at the stop level allows inferences to be made at a much finer spatial resolution than using BBS data at the route level. However, developing predictive models from stop-level BBS data is complicated by the presence of spatial autocorrelation, which can lead to overestimation of the precision of parameter estimates (Legendre 1993) and obscure ecological patterns (Carroll and Pearson 2000). We addressed several forms of spatial structure and nuisance factors in stop-level BBS data. First, BBS stops are nested within routes, and varying ability of observers (see Sauer et al. 1994, Diefenbach et al. 2003) on different routes may result in spatial patterns in detection. Therefore, we included observer identity (Table 2) to incorporate differences in observer ability in our models. Second, detection of some species of birds varies substantially during the daily survey period (Robbins 1981), which begins 0.5 hour before sunrise and typically lasts 4 to 4.5 hours (Bystrak 1981). Thus, birds that are most vocal early in the day are more likely to be found on stops at the beginning of a route than at stops toward the end of a route. We included stop numbers to provide an index to time relative to sunrise (Table 2), which enabled incorporation of time-related differences in detection in predictive models; this corresponds to the time-of-day correction used by Rosenberg and Blancher (2005). Third, bird distribution across large geographic extents may follow gradients as a consequence of trends in climate and landcover (see O'Connor et al. 1999, Thogmartin et al. 2006a). Consequently, adjacent stops, which were 0.81 km apart, were more likely to have similar landcover and avifauna than stops farther apart. We included easting and northing Universal Transverse Mercator (UTM) coordinates as linear and quadratic terms (Table 2) to model broad-scale gradients in bird distribution as trend surface variables (Haining 1990, Legendre 1993). Given the northwest-to-southeast configuration of the Missouri Coteau in the state, we also included an easting*northing interaction term.

Model Development

We used regression models appropriate to the numerical distribution of number of individuals of each species detected at BBS stops. Northern Harriers were rarely observed at BBS stops, and when they were detected, typically only one individual was observed. Therefore, we modeled probability of detecting Northern Harrier using logistic regression, which models a binary (0,1) response. The other species of grassland birds we evaluated often had multiple individuals present at a stop, so we modeled their presence using Poisson regression, which requires non-negative count data following a Poisson distribution.

We assumed that the probability of detecting Northern Harrier at BBS stops could be described as a function of predictor variables according to the model

$$\hat{Y} = \exp(\hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \ldots + \hat{\beta}_k X_k) / (1 + \exp(\hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \ldots + \hat{\beta}_k X_k))$$

where $\hat{Y}$ is the predicted probability of detection; X_i are predictor variables incorporating landscape, location, time-of-day, and observer effects (Table 2); and $\hat{\beta}_i$ are coefficients estimated using logistic regression.

We assumed that numbers of Sedge Wren, Grasshopper Sparrow, Dickcissel, and Western Meadowlark detected at BBS stops could be described as a function of predictor variables according to the model

$$\hat{Y} = \exp(\hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \ldots + \hat{\beta}_k X_k)$$

where $\hat{Y}$ is the predicted number of birds; X_i are predictor variables incorporating landscape, location, time-of-day, and observer effects (Table 2); and $\hat{\beta}_i$ are coefficients estimated using Poisson regression. For all species we developed a set of candidate models at each of the three scales and then used information-theoretic methods to evaluate how well models were supported by the data at each scale (Burnham and Anderson 1998). We developed biologically based candidate models for each species, generally hypothesizing that target species would be positively associated with grassland, undisturbed grassland, and hay; negatively associated with forest cover and landscape fragmentation; and infrequently found in crop fields (Bock et al. 1999, Helzer and Jelinski 1999, O'Connor et al. 1999, Ribic and Sample 2001, Bakker et al. 2002, Niemuth et al. 2005). Because Sedge Wrens often are associated with moist soil areas and wetland margins (Herkert et al. 2001), we also included area of temporary and seasonal wetlands in candidate models for Sedge Wren. Many species of grassland birds use cropland at low densities (Johnson and Igl 1995, Best et al. 1997). Because we wanted to simulate the effects of converting undisturbed grass to cropland, which required a parameter estimate for the cropland variable, we included the amount of cropland in the landscape surrounding BBS stops in models, even if model improvement was minimal. We hypothesized that detection would decline as stops progressed along each route because of time-related declines in bird activity (Robbins 1981).

When developing models, we first included habitat, trend surface, and stop number variables and then further assessed models as observer terms were added. We included observer identity as a categorical variable in an exploratory manner in the absence of *a priori* information about the ability of specific observers. However, including the identity of every observer in models would have greatly increased the number of predictor variables as well as redundancy among variables. We addressed these problems in an *ad hoc* manner by assessing individual observer effects and only including in models the identities of observers with materially superior or inferior abilities that explained additional variation in the dataset, treating the remaining "average" observers as the reference category. Most observers surveyed routes in a limited portion of the study area, resulting in strong collinearity between observer and trend surface variables and potential shifts in parameter estimates for trend surface variables. We examined model output in map form to ensure that inclusion of individual observers in models did not materially shift predicted distribution from that observed in the model best describing grassland bird detection or numbers in the absence of observer effects.

Because of limited *a priori* information and the desire to avoid spurious correlations associated with numerous explanatory variables, we only evaluated main effects of linear relationships, with the exception of the trend surface variables described above. We calculated Akaike's Information Criterion (AIC), corrected for overdispersion (QAIC) as necessary, and used QAIC differences (Δ_i) to compare models (Burnham and Anderson 1998). For each species, we selected the model with the lowest QAIC to use as the basis for simulation. We assessed Poisson models for overdispersion based on goodness-of-fit of the global model, adjusting all calculations for overdispersion and a large number of predictor variables (QAICc) and adjusting variance estimates as appropriate (Burnham and Anderson 1998). Analyses were performed using Number Cruncher Statistical System (Hintze 2004).

Development of Spatially Explicit Population Estimate

Spatial models linking number of birds detected at BBS stops to landscapes provided the foundation for population estimates. For each species, we created data layers and maps showing predicted probability of detection or number of birds throughout the study region by incorporating corresponding GIS layers into the appropriate regression equation using estimated regression coefficients. Observer and time-of-day variables were included in model development to remove nuisance effects and were not incorporated into spatial models. We then simulated conversion of undisturbed grassland to cropland in the landscape by replacing the coefficient estimate for undisturbed grassland in the regression equation with the coefficient estimate for cropland. For Northern Harrier, model output consisted of GIS cells representing the probability of detecting a Northern Harrier at a BBS stop, which we reclassified into 20 bins at 0.01 intervals (maximum probability = 0.2). We then resampled grid cells to a resolution of 50 ha, approximating the area within a circle with a 400-m radius, which was the detection distance assumed by Rosenberg and Blancher (2005) in their estimation of Northern Harrier population size. We then estimated the number of Northern Harriers present by summing probabilities for cells, using the midpoint of each 0.01 interval as the value summed. Again following the methodology of Rosenberg and Blancher (2005), this number was doubled to correct for unobserved birds. For the other species, model output consisted of GIS cells representing the number of individuals predicted to be present (again in the absence of observer and time-of-day effects) at a BBS stop, which we reclassified into 0.1 intervals. To avoid unwarranted extrapolations, we capped the maximum number of individuals predicted at each point at the maximum number of individuals detected for each species in the study region that year. The number of bins varied accordingly and ranged from 30 to 150, depending on maximum number of individuals observed (range 3 to 15). For the Sedge Wren model we resampled grid cells to a resolution of 5.0 ha, approximating the area of a circle with a 125-m radius which was the detection distance assumed by Rosenberg and Blancher (2005) in their estimation of regional population sizes. Again following methodology of Rosenberg and Blancher (2005), we resampled grid cells to a resolution of 12.6 ha, approximating the area within a circle with a 200-m radius, for Dickcissel and Grasshopper Sparrow models; and 50 ha, approximating the area within a circle with a 400-m radius, for Western Meadowlark. Estimated numbers of birds were doubled to correct for unobserved birds (Rosenberg and Blancher 2005). We acknowledge that final population estimates are strongly influenced by detection distances and adjustments for unobserved birds (see Thogmartin et al. 2006b), but Rosenberg and Blancher's (2005) adjustments are testable and biologically reasonable. In addition, use of Rosenberg and Blancher's (2005) adjustments ensures consistency and simplifies comparisons of results.

Model Evaluation

The primary goal of model development was identification of biologically sound models to be used as the basis for simulation. We ensured that models were biologically plausible by limiting candidate models to only include variables that addressed known biological relationships and potential biases in the data (i.e., time-of-day and observer effects). We report area under the Receiver Operating Characteristics (ROC) curve value for the logistic regression model to indicate how well the model discriminated between used and available stops (Hosmer and Lemeshow 2000) and R^2 values for Poisson regression models to indicate how much variation was explained by individual models.

We evaluated spatial dependencies in the data and the ability of models to account for spatial dependencies by creating Moran's *I* correlograms, which evaluate spatial dependence at increasing distances between points (Moran 1950, Legendre and Legendre 1998). Values of Moran's *I* range from -1 to 1 indicating greater levels of negative and positive spatial autocorrelation, respectively. As an example of how spatial dependencies were treated, we created correlograms for the amount of grassland and undisturbed grass in the North Dakota landscape, the number of Grasshopper Sparrows detected in 1995, and Pearson's residuals for regression models predicting number of Grasshopper Sparrows with habitat variables only and a model that also incorporated observer effect, stop number, and stop location. We used program PASSAGE (Rosenberg 2003) to calculate Moran's *I* at one-kilometer intervals out to a maximum distance of 10 km.

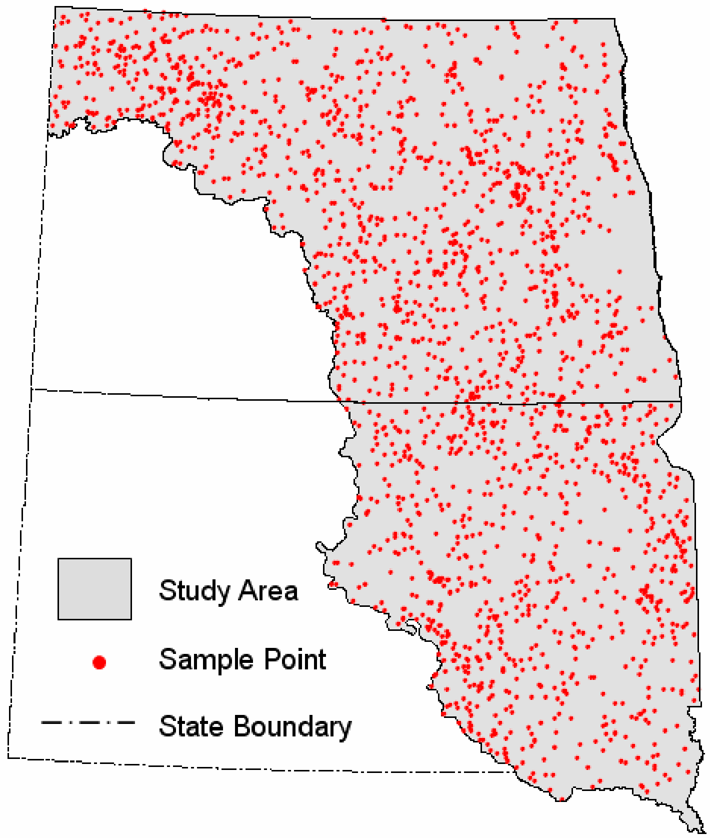
Finally, we compared our population estimates to estimates for the same regions (P. J. Blancher and K. V. Rosenberg, unpublished data) developed under the North American Landbird Conservation Plan (NALCP; Rich et al. 2004) following the protocol developed by Rosenberg and Blancher (2005). These estimates also are based on data from the BBS using an extrapolation process reviewed by Thogmartin et al. (2006b); the 1990s timeframe used by Rosenberg and Blancher (2005) to estimate landbird populations coincided with landcover and bird data used in this analysis.

VALIDATION ANALYSIS

Study Area and Selection of Sample Sites

Point count data were collected as part of a study of the response of grassland birds to landscape characteristics in the Prairie Pothole Region being conducted at the University of Montana. We used landcover data described above to stratify the sample by landcover type and amount of grass in the surrounding landscape. We randomly selected point count locations (Figure 2) from grassland, undisturbed grassland, hayfield, and cropland strata; location of actual CRP fields was unknown at time of sample allocation. Preliminary data indicated that bird numbers in cropland had lower variance than bird numbers in grasslands; therefore, cropland received lower sampling effort relative to its abundance in the landscape.

Figure 2. Location of North Dakota and South Dakota study areas and 2,805 grassland bird sample points in North Dakota and South Dakota. Grassland birds were only sampled north and east of the Missouri River, approximating the Prairie Pothole Region of the two states.



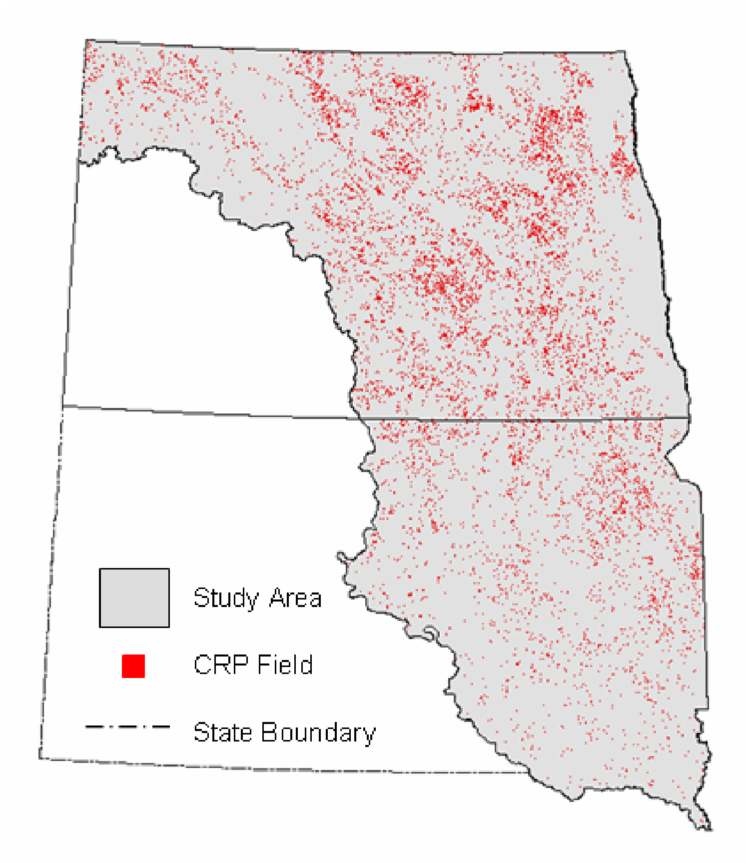
Field Methodology

Grassland birds were surveyed for 10 minutes within a 100-m fixed radius at all point count locations. Surveys were conducted from sunrise to 5 hours after sunrise 25 May-4 July of 2003, 2004, and 2005. Birds within point counts were recorded by sex when possible; individual bird movements were noted during surveys to avoid double counting. Time elapsed from the beginning of point count to detection was recorded, as well as the estimated distance of the observer to the detection. Each census point was surveyed once with a new sample of grasslands selected annually to obtain a large sample over an extensive geographic region. Habitat within point count circles sometimes consisted of >1 cover type; percent cover of each type within point count circles was visually estimated in the field. All survey points within years were located >2 km apart to minimize spatial autocorrelation. We estimated changes in population size in response to reversion of CRP grasslands to cropland for five species (Sedge Wren, Grasshopper Sparrow, Dickcissel, Bobolink, and Western Meadowlark) in the PPR of both North Dakota and South Dakota.

Analysis

We used digital CLU data provided by the Farm Service Agency in 2006 (Figure 3) to identify which of our sample points were located in fields under CRP contracts as opposed to undisturbed grass present for agricultural or conservation purposes. Number of individuals of each species in each point count was weighted by the proportion of each habitat type in the point count circle. We then calculated the mean number of individuals of target species detected per survey point in CRP, grassland, hay, cropland, and undisturbed grassland other than CRP for North Dakota and South Dakota. Mean number of male birds per point count was converted to mean number of birds per acre for each stratum; this number was then doubled to account for unobserved females assumed to be present. Densities were then applied to the area of each habitat type in each state to estimate population size. Area of CRP in the study region was derived from digital common land unit (CLU) data provided by the FSA; we used updated landcover data based on 2002-2003 satellite imagery to estimate area of cropland, hay, grassland, and undisturbed grass other than CRP. CRP acreage was assigned to a CRP grassland category unless the conservation practice (CP type) listed in the GIS database indicated that it should be assigned to the forest or crop categories, (i.e., CRP tree plantings or food plots, respectively). CLU data indicated that boundaries of CRP fields typically did not include large, deep wetlands; we considered area of small wetlands, which typically had temporary or seasonal water regimes, within CRP treatments as CRP grassland because of the structural similarity of emergent vegetation to grassland and use of wetlands by grassland birds such as Sedge Wren. Urban areas, deep wetlands outside of CRP fields, and forest cover classes, which encompassed ~12% of the region, were assumed to contain trivial numbers of grassland birds and were not included in analysis.

Figure 3. Distribution of CRP fields in North Dakota and South Dakota study region from Farm Service Agency Common Land Unit data.



We analyzed point count data for Sedge Wren, Grasshopper Sparrow, Dickcissel, Bobolink, and Western Meadowlark in both the North Dakota and South Dakota PPR. We multiplied density of each species per landcover type by area of each landcover type to obtain population estimates for each stratum. These products were then summed to obtain a population estimate for each species in the PPR of each state. We simulated the loss of CRP fields in the study areas by adding the area of CRP grassland to the cropland category and re-calculating population size of each species. The difference between population estimates with and without CRP thereby provided an indication of the contribution of the CRP to each species of grassland bird in the study areas. This difference was divided by the estimated population size for the study region to provide an estimate of the percent of each study region's population that would be lost if the CRP were terminated. We used Pearson product-moment correlation to assess similarity of results (i.e., percent of population lost with simulated termination of CRP) for the seven species/state combinations common to this and the analysis using BBS data. Our analyses assume a strict additive effect of CRP grasslands on species included in analysis.

RESULTS

BBS/HABITAT MODELING

In North Dakota, 27 North Dakota BBS routes in our study region were sampled by 14 observers in both 1995 and 1997, with the number of routes per observer ranging from 1 (n = 9) to 5 (n = 2). In South Dakota, seven routes were sampled by four observers in 1995 with number of routes per observer ranging from 1 (n = 2) to 3 (n = 1). In 1997, 12 South Dakota routes were sampled in our study region with number of routes per observer ranging from 1 (n = 8) to 2 (n = 2). Given the relatively small number of routes that were sampled in 1995, we used 1997 data for the South Dakota portion of the analysis, augmenting the analysis with data from the four North Dakota routes closest to the South Dakota border, thus providing a sample of 16 routes.

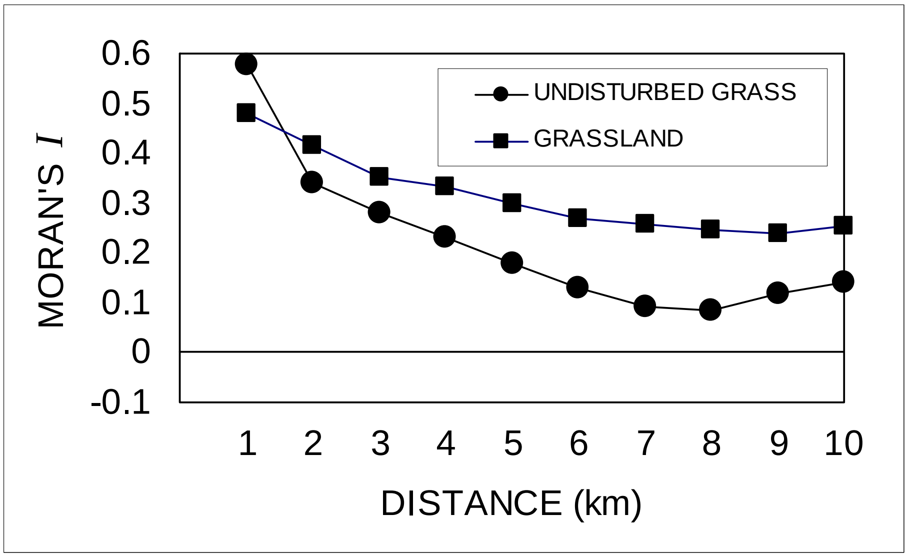
Landscapes surrounding BBS stops varied considerably in type and distribution of landcover (Table 3). Classification of satellite imagery indicated 1,759,163 acres of undisturbed grassland in North Dakota and 835,949 acres in South Dakota. The amount of grassland and undisturbed grass surrounding BBS stops in 1995 North Dakota data showed strong positive spatial autocorrelation (Figure 4A); bird numbers showed similar autocorrelation, as illustrated by the number of Grasshopper Sparrows detected (Figure 4B).

Table 3. Mean, minimum, maximum, and standard deviation of values of landcover variables measured within 800 m of 1,350 BBS stops used in analysis of 1995 North Dakota BBS data and 800 stops used in analysis of 1997 South Dakota BBS data.

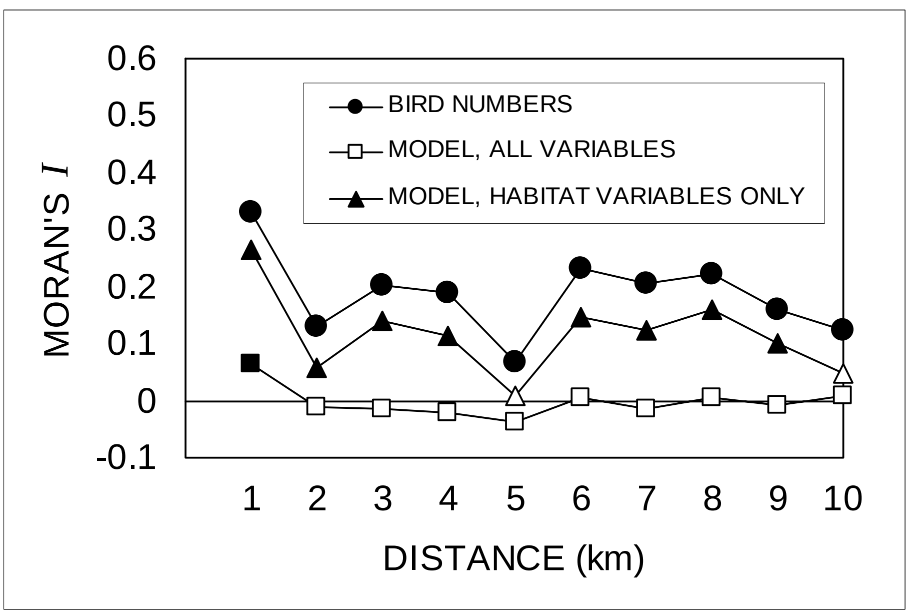
	North Dakota				South Dakota			
Landscape Variable	Mean	Min.	Max.	SD	Mean	Min.	Max.	SD
Undisturbed Grass (%)	4.9	0	91	9.9	3.5	0	57	7.0
Grassland (%)	20.0	0	99	23.6	23.8	0	99	25.6
Hayland (%)	0.9	0	24	2.6	3.5	0	40	5.7
Cropland (%)	61.8	0	100	31.2	56.1	0	100	29.1
Forest (%)	1.7	0	55	6.5	0.5	0	10	1.2
Patches (*n*)	39.3	1	163	24.3	42.8	1	127	23.8

Figure 4. (A) Moran's *I* correlograms for amount of grassland and undisturbed grass within 400 m of 1,350 North Dakota BBS stops used in analysis of 1995 BBS data. (B) Moran's *I* correlograms for number of Grasshopper Sparrows detected at BBS stops in 1995, residuals from best 1995 model including habitat variables only, and model including habitat, trend surface, observer, and time of day variables. Filled symbols denote statistically significant ($P < 0.05$) positive spatial autocorrelation.

A



B



The number of individuals detected at BBS stops was correlated with observer ability, time of day, and geographic location, as well as habitat. Observer ability and time of day were treated as nuisance effects and were not incorporated into spatial models of distribution and density (Table 4). Top models fit well for most species, with ROC value for the Northern Harrier model of 0.69 and R^2 values for models predicting number of individuals of other species ranging from 0.26 to 0.57 (Table 4). Goodness-of-fit tests for global models suggested the need for quasi-likelihood adjustments, with variance inflation factor ($\hat{c}$; Burnham and Anderson 1998) estimates ranging from 1.0 to 2.0; estimates of standard errors for regression coefficients in Poisson models were adjusted as appropriate. Models predicting presence or number of birds at stops fit best using landscape data from the 400-m moving window for Grasshopper Sparrow and Sedge Wren; models for Northern Harrier, Dickcissel, and Western Meadowlark fit best using data from the 800-m moving window.

Table 4. Variables and coefficient estimates (standard error) for models best predicting probability of detection or number of grassland birds in the PPR portion of North Dakota in 1995 and South Dakota in 1997. Variables defined in Table 2.

State	Species	Model	R^2
ND	Northern Harrier	-4.04 (2.04) + 0.011 (0.02) CROPLAND + 0.033 (0.02) UND. GRASS – 2.216E-9 (1.3E-6) EAST + 0.0243 (0.02) GRASSLAND – 0.134 (0.13) FOREST	68.8*
ND	Sedge Wren	-1579.6 (549.5) – 0.018 CROPLAND (0.005) + 0.023 (0.008) UND. GRASS + 3.60E-5 (1.3E-5) EAST – 3.8427E-11 (1.4E-12) $EAST^2$ + 5.941E-4 (2.1E-4) NORTH – 5.615E-11 (2.0E-12) $NORTH^2$ + 0.043 (0.03) SEASONAL – 0.087 (0.06) FOREST	31.9
ND	Grasshopper Sparrow	-4052.9 (805.2) + 0.00084 (0.007) CROPLAND + 0.039 (0.008) UND. GRASS + 3.0E-4 (1.8E-4) EAST – 1.88E-11 (1.4E-12) $EAST^2$ – 5.4E-11 (3.3E-12) EAST*NORTH + 0.015 (0.007) GRASSLAND + 1.515E-3 NORTH (2.9E-4) – 1.417E-10 (2.7E-12) $NORTH^2$ – 0.044 (0.02) PATCHES	39.7
ND	Western Meadowlark	27.4 (2.0) + 0.0028 (0.0029) CROPLAND + 0.016 (0.004) UND. GRASS + 6.388E-6 (1.9E-7) EAST – 1.559E-11 (2.3E-13) $EAST^2$ + 0.0081 (0.003) GRASSLAND – 5.018E-6 (3.7E-9) NORTH – 0.077 (0.013) FOREST	57.4
SD	Sedge Wren	-1508.3 (725.0) – 0.008 (0.01) CROPLAND + 0.05 (0.01) UND. GRASS + 6.396E-5 (6.7E-5) EAST – 4.1932E-11 (5.9E-12) $EAST^2$ + 0.020 (0.01) GRASSLAND + 5.915E-4 (2.9E-4) NORTH – 5.901E-11 (2.9E-12) $NORTH^2$ + 0.074 (0.03) SEASONAL	32.2
SD	Dickcissel	-414.6 (335.4) + 0.008 (0.008) CROPLAND + 0.04 (0.015) UND. GRASS – 4.59E-5 (2.1E-5) EAST + 3.339E-11 (1.9E-12) $EAST^2$ + 0.01 (0.008) GRASSLAND + 0.03 (0.01) HAY + 1.919E-4 (1.4E-4) * NORTH – 2.136E-11 (1.4E-12) $NORTH^2$	53.0

SD	Grasshopper Sparrow	12.3 (4.5) + 0.022 (0.01) CROPLAND + 0.035 (0.01) UND. GRASS – 8.186E-6 (1.1E-7) EAST + 0.033 (0.01) GRASSLAND + 0.042 (0.01) HAY – 2.349E-6 (7.7E-8) NORTH	26.0
SD	Western Meadowlark	372.2 (65.9) + 0.005 (0.003) CROPLAND + 0.016 (0.005) UND. GRASS + 6.98E-5 (1.6E-6) EAST – 1.516E-11 (3.2E-13) EAST*NORTH + 0.016 (0.003) GRASSLAND + 0.017 (0.005) HAY – 1.547E-4 (2.6E-6) NORTH + 1.6165E-11 (2.5E-13) $NORTH^2$	48.6

*Value reported for Northern Harrier model is area under curve of Receiver Operating Characteristics (ROC) plot.

Inclusion of trend surface, observer effect, and time-of-day terms improved model fit and reduced positive spatial autocorrelation in model residuals, as illustrated by the model for Grasshopper Sparrow (Figure 4B). Spatial patterns in predicted number of grassland birds as a function of habitat features are readily discernable on state and county maps showing estimated number of individuals (Figures A1-A16 in Appendix 1). Predicted numbers of all species included in analysis decreased following simulated conversion of undisturbed grassland to cropland in the landscape (Table 5, Figures A1-A16). Digital data showing locations of CRP fields was not available for the mid 1990s time period represented in this analysis. However, distribution of grassland birds associated with undisturbed grassland often coincided with locations of CRP fields identified using digital data provided by the FSA in 2006 (Figure 5).

Figure 5. Predicted number of Grasshopper Sparrows in civil townships located in Ward (top) and Mc Lean (bottom) counties, North Dakota, in the presence (left) and absence (right) of undisturbed grassland. White lines indicate boundaries of CRP fields; black lines indicate section lines at 1.6-km intervals.

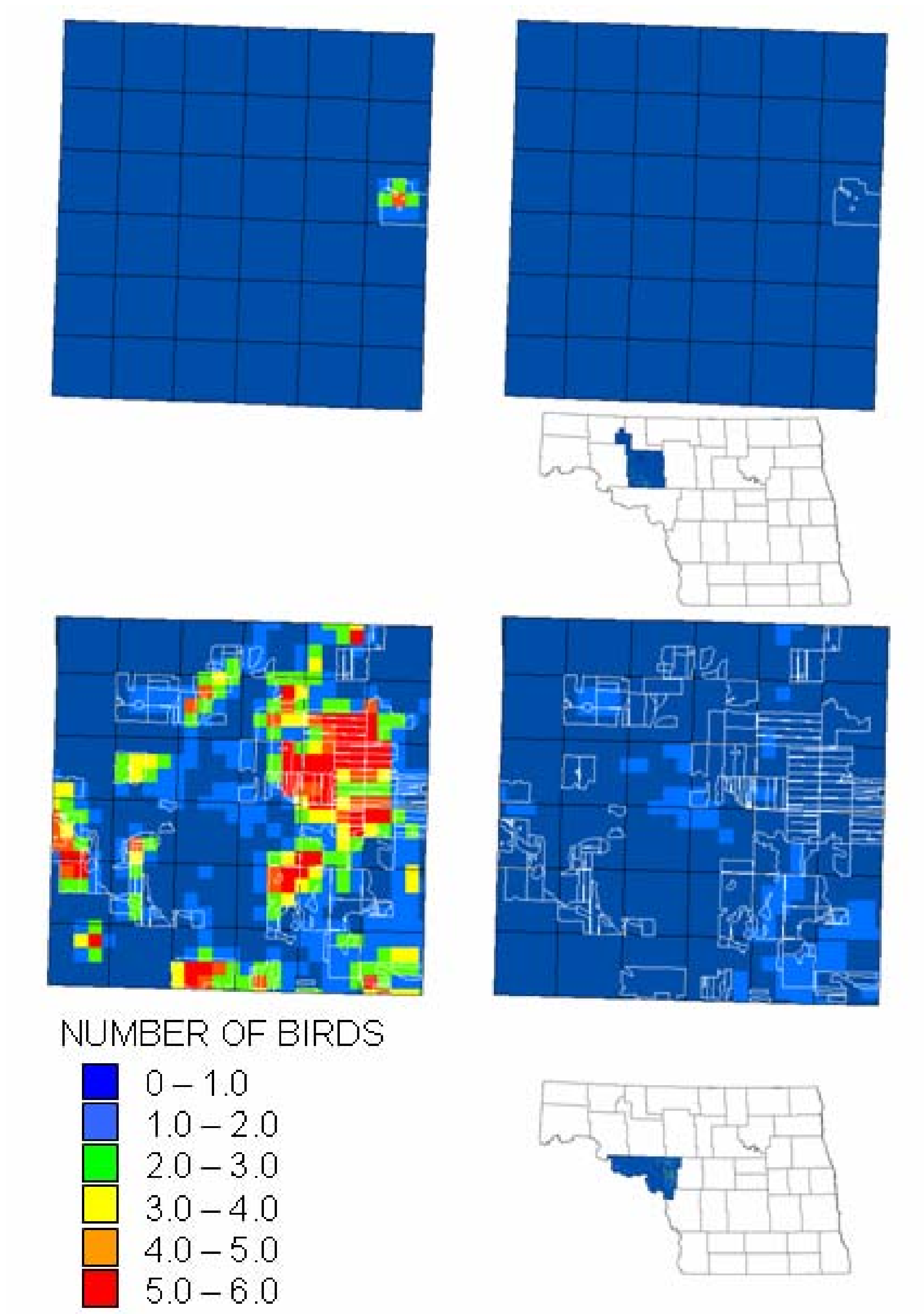


Table 5. Population estimates for grassland birds in the Prairie Pothole portions of North Dakota and South Dakota, modeled population estimates following simulated conversion of undisturbed grassland to cropland in the landscape, and differences (absolute and percent) between estimates.

State	Species	Year	Modeled estimate	Estimate after loss of CRP	Difference in estimate	Difference (%)
ND	Northern Harrier	1995	16,247	14,116	-2,131	-13.1
ND	Sedge Wren	1995	1,203,872	786,040	-417,832	-34.7
ND	Grasshopper Sparrow	1995	624,274	446,183	-178,091	-28.5
ND	Western Meadowlark	1995	1,654,648	1,528,541	-126,107	-7.6
SD	Sedge Wren	1997	384,935	281,716	-103,219	-26.8
SD	Grasshopper Sparrow	1997	480,489	456,167	-24,322	-5.1
SD	Dickcissel	1997	730,427	673,426	-57,001	-7.8
SD	Western Meadowlark	1997	903,947	868,419	-35,528	-3.9

VALIDATION ANALYSIS

During the three-year study period, 2,805 point counts were conducted in the study region (Figure 2), with 276 points in CRP fields, 702 in cropland, 1,027 in grassland, 361 in hay fields, and 439 in undisturbed grassland other than CRP fields. Area of land classified as cropland, hay, grassland, undisturbed grass, and CRP grassland totaled approximately 88% in the PPR of North Dakota and South Dakota (Table 6); wetlands outside of CRP, urban areas, and forest cover classes encompassed the remaining 12% of the region. Mean number of birds detected per point count varied among landcover types and species (Table 7). Estimated numbers of all species decreased following simulated conversion of CRP to cropland in the landscape (Table 8). Our population estimates showed patterns of abundance consistent with estimates for the same regions developed using the approach of Rosenberg and Blancher (2005; Table 9). Estimated percent declines for the seven species/state combinations common to this and the BBS analysis were consistent (Table 9), with a correlation of 0.80 between values from the two analyses.

Table 6. Percent of study region in North Dakota and South Dakota classified as landcover classes for which grassland bird density was estimated.

	Percent of study region	
Landcover category	North Dakota	South Dakota
CRP grassland	8.1	4.5
Grassland	19.9	31.9
Cropland	53.7	47.0
Hay	0.7	1.9
Undisturbed grass (non-CRP)	5.7	2.7

Table 7. Mean (SE) number of grassland birds detected per point count in North Dakota and South Dakota, by landcover and program (CRP) type, 2003-2005. Highest values per species are in bold font.

	Sedge Wren		Grasshopper Sparrow		Dickcissel		Bobolink		Western Meadowlark	
Landcover/program	ND	SD	ND	SD	ND	SD	ND	SD	ND	SD
Cropland	0.012	0.012	0.033	0.026	0.000	0.014	0.093	0.066	0.027	0.116
	(0.006)	(0.008)	(0.012)	(0.010)	(0.000)	(0.006)	(0.021)	(0.024)	(0.007)	(0.022)
CRP	**0.274**	**0.541**	0.340	0.440	0.013	0.078	**1.299**	**1.214**	0.157	0.219
	(0.041)	(0.128)	(0.046)	(0.098)	(0.010)	(0.037)	(0.096)	(0.195)	(0.029)	(0.069)
Grassland	0.075	0.040	**0.500**	**0.696**	0.008	0.054	0.307	0.473	**0.357**	**0.615**
	(0.015)	(0.012)	(0.037)	(0.048)	(0.004)	(0.016)	(0.030)	(0.044)	(0.028)	(0.040)
Hay	0.053	0.075	0.340	0.296	**0.015**	**0.163**	0.650	0.505	0.239	0.381
	(0.019)	(0.031)	(0.049)	(0.065)	(0.009)	(0.054)	(0.073)	(0.103)	(0.035)	(0.067)
Undisturbed Grass	0.191	0.056	0.217	0.357	0.007	0.071	0.535	0.659	0.252	0.300
	(0.036)	(0.019)	(0.035)	(0.057)	(0.007)	(0.027)	(0.060)	(0.085)	(0.030)	(0.044)

Table 8. Population estimates for grassland birds in the Prairie Pothole portions of North Dakota and South Dakota based on 2003-2005 point-count data and changes in population estimates following simulated conversion of CRP grasslands to cropland.

State	Species	Modeled estimate	Estimate after loss of CRP	Difference in estimate	Difference (%)
ND	Sedge Wren	460,554	281,660	-179,894	-38.8
ND	Grasshopper Sparrow	1,343,117	1,133,661	-209,457	-15.6
ND	Dickcissel	26,499	17,630	-8,870	-33.5
ND	Bobolink	2,114,651	1,291,675	-822,976	-38.9
ND	Western Meadowlark	960,885	871,999	-88,886	-9.3
SD	Sedge Wren	269,553	129,412	-140,141	-52.0
SD	Grasshopper Sparrow	1,573,972	1,464,257	-109,715	-7.0
SD	Dickcissel	188,920	171,9977	-16,923	-9.0
SD	Bobolink	1,544,021	1,239,832	-304,190	-19.7
SD	Western Meadowlark	1,610,589	1,583,165	-27,424	-1.7

Table 9. Population estimates for grassland birds in the Prairie Pothole portions of North Dakota and South Dakota from BBS-based spatial model and 2003-2005 independent data, population estimate based on Rosenberg and Blancher (2005) approach, and estimated percent changes in population size following simulated conversion of CRP grasslands to cropland. Correlation between predicted percent declines in bird populations for species/region combinations common to both analyses (final two columns) was 0.80.

State	Species	Estimate from spatial model	Estimate from independent data	Rosenberg and Blancher estimate	Difference (%) after CRP loss	
					Spatial model	Independent data
ND	Northern Harrier	16,247	--	18,000	-13.1	--
ND	Sedge Wren	1,203,872	460,554	759,347	-34.7	-38.8
ND	Grasshopper Sparrow	624,274	1,343,117	775,170	-28.5	-15.6
ND	Dickcissel	--	26,499	37,921	--	-33.5
ND	Bobolink	--	2,114,651	1,285,150	--	-38.9
ND	Western Meadowlark	1,654,648	960,885	1,129,438	-7.6	-9.3
SD	Sedge Wren	384,935	269,553	783,992	-26.8	-52.0
SD	Grasshopper Sparrow	480,489	1,573,972	547,017	-5.1	-7.0
SD	Dickcissel	730,427	188,920	741,105	-7.8	-9.0
SD	Bobolink	--	1,544,021	510,972	--	-19.7
SD	Western Meadowlark	903,947	1,610,589	677,513	-3.9	-1.7

DISCUSSION

BBS/HABITAT MODELING

The variables included in our models, as well as the direction and magnitude of their estimated coefficients, agree well between states and generally agree with findings of other studies of landscape-level habitat selection by grassland birds (Bock et al. 1999, Helzer and Jelinski 1999, O'Connor et al. 1999, Ribic and Sample 2001, Bakker et al. 2002, Thogmartin et al. 2006b). Our population estimates were similar to those developed independently by Rosenberg and Blancher (2005), which is due in part to both procedures using BBS data and following the same adjustments. But beyond similarity of numbers, our results demonstrate the utility of using spatially explicit models to evaluate a conservation program, as the landscape relationships incorporated into the models provide a mechanism for examining effects of conversion of CRP grasslands to cropland.

Percent changes in populations estimated by our models were similar to those of Johnson and Igl (1995), who used North Dakota data to estimate statewide losses of 25.8%, 20.5%, and 5.1% for Sedge Wren, Grasshopper Sparrow, and Western Meadowlark, respectively. The differences in numbers of individuals following conversion of undisturbed grassland that we demonstrated should not be viewed as absolute, though, as environmental conditions in the Prairie Pothole Region are highly variable, and distributions, numbers of birds, and their response to habitat can change greatly from one year to the next (George et al. 1992, Igl and Johnson 1999, Niemuth and Solberg 2003, Johnson 2005). Given the different methodology used in the spatial modeling, extrapolations from the independent dataset, and extrapolations from the BBS using Rosenberg and Blancher's (2005) approach, as well as different time periods and the variation inherent to grassland bird populations in the Great Plains, our population estimates are surprisingly consistent. Johnson (2005:21) reported densities of nine species of grassland birds sampled using the same methodology in 1990-1991 and 1995-1996; density for the seven species that were present in both time periods differed between the two time periods by a mean factor of 3.6, which is a conservative reflection of changes because it does not include the two species that were absent during one time period. Estimated population sizes for the seven species/state combinations common to both our analyses differed by a mean factor of 2.4, which reflects differences in methodology and well as time periods.

Regardless of minor differences in size of populations, our analyses indicate that the CRP has substantially increased populations of several species of grassland birds in the study region. Our spatial models predicted that conversion of CRP grasslands to cropland in the PPR of the two states would result in the combined loss of >900,000 individuals of the four species included in that analysis. This number includes populations for Northern Harrier, which occur at low densities and consequently would experience a small decline in numbers with the loss of CRP relative to more abundant species. Our sample-based extrapolations, which include five passerine species, all of which were considerably more abundant than Northern Harrier, predicted that conversion of CRP grasslands to cropland in the same area would result in the combined loss of >1.8 million individuals. To put these numbers in perspective, our study area, which is in the core of North America's famed PPR "duck factory," hosts ~1.8 million breeding Mallard (*Anas platyrhynchos*) ducks (Reynolds et al. 2006). These numbers emphasize the importance of the PPR to continental grassland, waterfowl, and grassland bird conservation efforts. In addition, CRP in the PPR certainly benefits a variety of grassland birds other than waterfowl and the species we assessed. Both our analyses were limited to four or five species per state/PPR combination, and many more species would also likely experience population declines following loss of the CRP (see also Johnson and Igl 1995).

Data characteristics and modeling procedures also influenced population estimates. Our estimates of CRP acreage derived from remotely sensed data were 0.3% higher than reported enrollments for our study area in South Dakota and 22.1% lower than reported enrollments for our study area in North Dakota during the mid 1990s. The large difference in North Dakota between undisturbed grass classified using remotely sensed imagery and known acres of CRP may be the result of haying CRP fields (Johnson 2005) in that state. Consequently, benefits of the CRP to grassland birds in North Dakota are likely greater than we reported. Response to landscape characteristics and, therefore, response to conversion of CRP as measured by percent of population, was consistent among competing models with slightly different total population estimates (USFWS, unpublished data). Sample size was small and no BBS routes were present in the central portion of the South Dakota study area, but our findings were supported by results of the analysis using data from the validation sample and analysis. Finally, we may have underestimated the benefits of the CRP to our target species by capping numbers of individuals, as sites with landscape characteristics conducive to grassland birds but not sampled by the BBS may have had more individuals present than the maximum number observed on BBS routes.

VALIDATION ANALYSES

Our analyses based on the independent 2003-2005 grassland bird sampling further demonstrate the substantial impact the CRP has had on grassland birds in our study region. Population estimates developed using our two techniques and the Rosenberg and Blancher (2005) approach varied, and all had a certain amount of uncertainty as reflected in the standard errors associated with parameter and density estimates. These differences are likely attributable to different data, methods, and time periods used in the three analyses. However, in our greatest disparity between population estimates, South Dakota bobolink populations developed from our grassland bird sampling data and the Rosenberg and Blancher (2005) approach differed by a factor of three, which is well within the range of inter-annual variation observed for grassland birds in the PPR (Johnson 2005). More important, the response of grassland birds to CRP grasslands as measured by the percent of the population that would be lost with the termination of the CRP was consistent. Similarities in results of the two analyses reinforce the value of the CRP to grassland birds in the PPR of North Dakota and South Dakota.

Our results indicate that the effect of CRP on regional populations of grassland birds is affected not only by the relative density of grassland birds in CRP grasslands and crop fields, but also by how birds respond to other grassland types in the landscape. For example, Western Meadowlark, Grasshopper Sparrow, and Dickcissel, which were most abundant in native grassland or hay fields, typically exhibited the smallest percent decrease in population size following simulated conversion of CRP to cropland. Conversely, Sedge Wren and Bobolink, which were most abundant in CRP grasslands, typically showed the greatest percent decrease in regional population size following simulated conversion of CRP to cropland. Assessments of the CRP that lack information on grassland bird response to cover types other than CRP and cropland will provide less insight into regional dynamics of grassland bird populations.

Estimates of population declines following conversion of CRP grassland to cropland could also be influenced by how birds respond to different grassland types. Our estimates of population loss are based on the implicit assumption that population changes following conversion of CRP are additive when, possibly, some birds might disperse and settle into other habitats. However, other habitats may be poorer quality if the higher selection for undisturbed grasslands and higher densities in CRP grasslands shown by some species in our analysis represents adaptive selection of habitat. Additionally, our estimates of population loss may be low, as some species of grassland birds are known to respond positively to total area of grassland in the broader landscape, and not just the area of the patch they occupy. Response to grassland type may also be influenced by annual precipitation and resulting effects on vegetation (George et al. 1992, Igl and Johnson 1999, Johnson 2005).

Our analyses suggest that grassland bird populations increased substantially when the CRP added extensive acreages of undisturbed grassland to the Prairie Pothole Region landscape. But the benefits of the CRP to grassland birds may go beyond increased numbers of individuals, as several studies have demonstrated a link between nesting success of grassland birds and size of grassland patches or the amount of grass in the surrounding landscape (Johnson and Temple 1990, Greenwood et al. 1995, Reynolds et al. 2001, Herkert et al. 2003, Stephens et al. 2005). As with all models, our results are simplifications of more complex relationships. Nevertheless, our results are consistent with and affirm the findings of previous studies of grassland birds and benefits provided to grassland birds by the CRP.

MANAGEMENT IMPLICATIONS

Continuation of the CRP is necessary to maintain the benefits that CRP grasslands in the PPR of North Dakota and South Dakota have provided for grassland birds and waterfowl. We note that Sedge Wren, which demonstrated the greatest apparent benefit from the CRP (as measured by % change in population) is the only one of the six species we examined that has not shown statistically significant population declines at the state and/or national level from 1966 to 2005 (Sauer et al. 2005). The CRP may well have been instrumental in keeping this "common bird common," in addition to benefiting many other species. However, CRP grasslands provide little benefit to species such as Sprague's Pipit (*Anthus spragueii*) and Chestnut-collared Longspur (*Calcarius ornatus*), which depend primarily on native prairie. Both of these species have experienced significant population declines (Sauer et al. 2005), and we recommend that the CRP and other agricultural programs be structured so they do not provide incentive to convert native prairie on which these and other species depend (see also Johnson 2005).

Our results indicate that the response of grassland birds to the CRP in the PPR varies among species, location, and landscape context; consideration of these factors during CRP signups may increase benefits of CRP grasslands to grassland birds. For example, grassland bird response will greatly depend on the conservation practice enacted in a CRP field. Undisturbed cover such as that found in CRP grasslands is heavily used by many species of grassland birds and is relatively uncommon in our study area. Cropland, on the other hand, is the greatest single land use in our study region, and the addition of CRP food plots, which typically contain crops grown in the surrounding landscape, provide few, if any, benefits to grassland birds. Similarly, trees are generally an artificial addition to PPR grasslands that can negatively impact grassland birds (RESULTS, above; see also Grant et al. 2004, Kelsey et al. 2006); limiting CRP tree plantings to areas where trees existed in pre-settlement times (e.g., riparian areas) would reduce negative effects of trees on grassland birds.

Insights from this study and other studies can be used to increase benefits of the CRP to grassland birds in the PPR. Spatial models can be used to target landscapes for conservation programs (e.g., Reynolds et al. 2006) and guide selection of sites for the application or avoidance of specific conservation practices (i.e., planting of grass or trees, respectively) to be enacted in CRP fields. The spatial resolution of our models was sufficiently fine (Figure 5) that effects of CRP can be assessed at the scale of individual fields, which can greatly aid planning. Used in conjunction with other information to assess costs and risks, spatial models can increase benefits and efficiency of conservation programs such as the CRP.

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APPENDIX 1. MAPS OF PREDICTED GRASSLAND BIRD DISTRIBUTIONS

Figure A1. Predicted probability of detecting Northern Harrier in the PPR portion of North Dakota in 1995 with (above) and without (below) undisturbed grassland in the landscape.

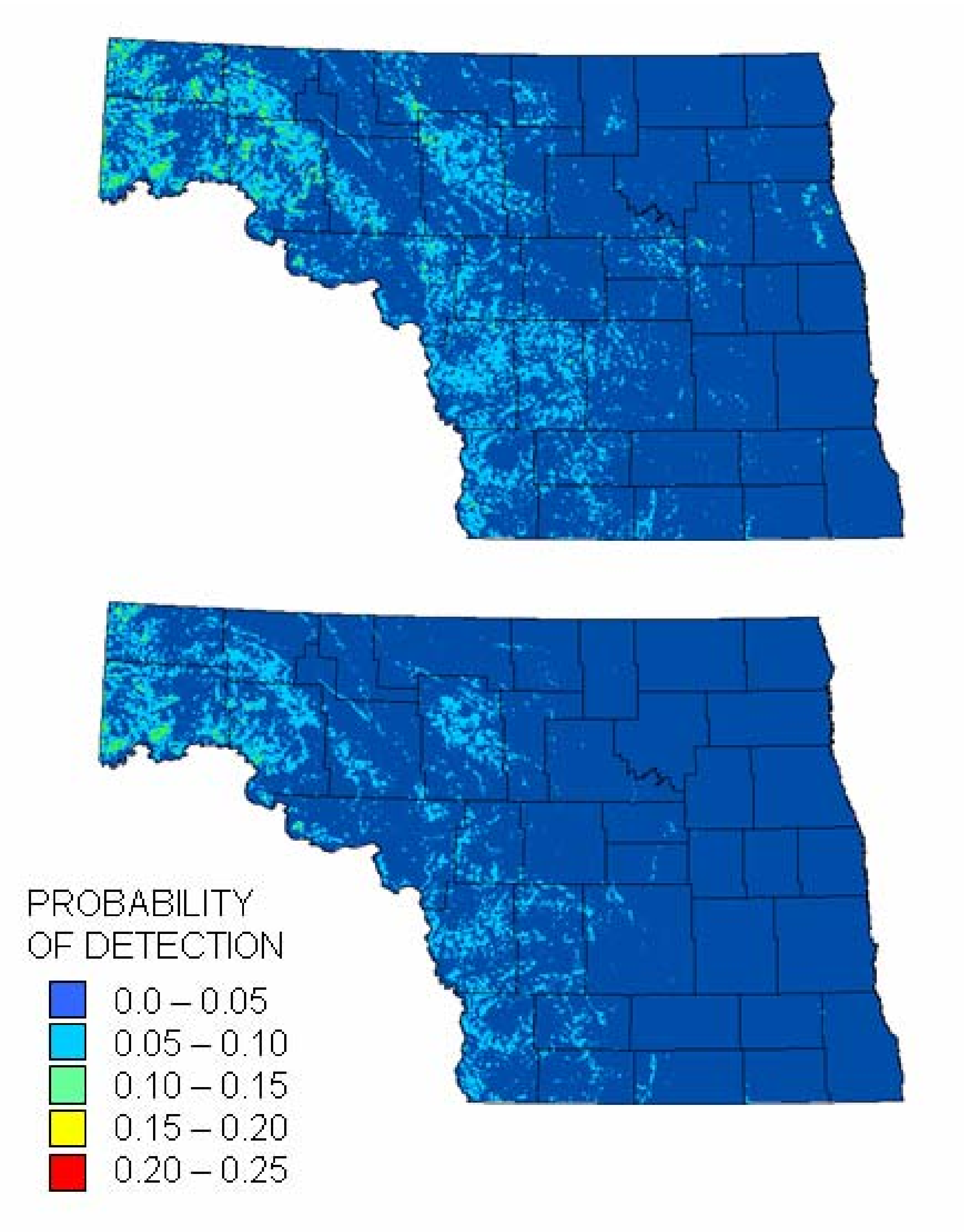

Figure A2. Predicted probability of detecting Northern Harrier in Kidder County, North Dakota in 1995 with (left) and without (right) undisturbed grassland in the landscape.

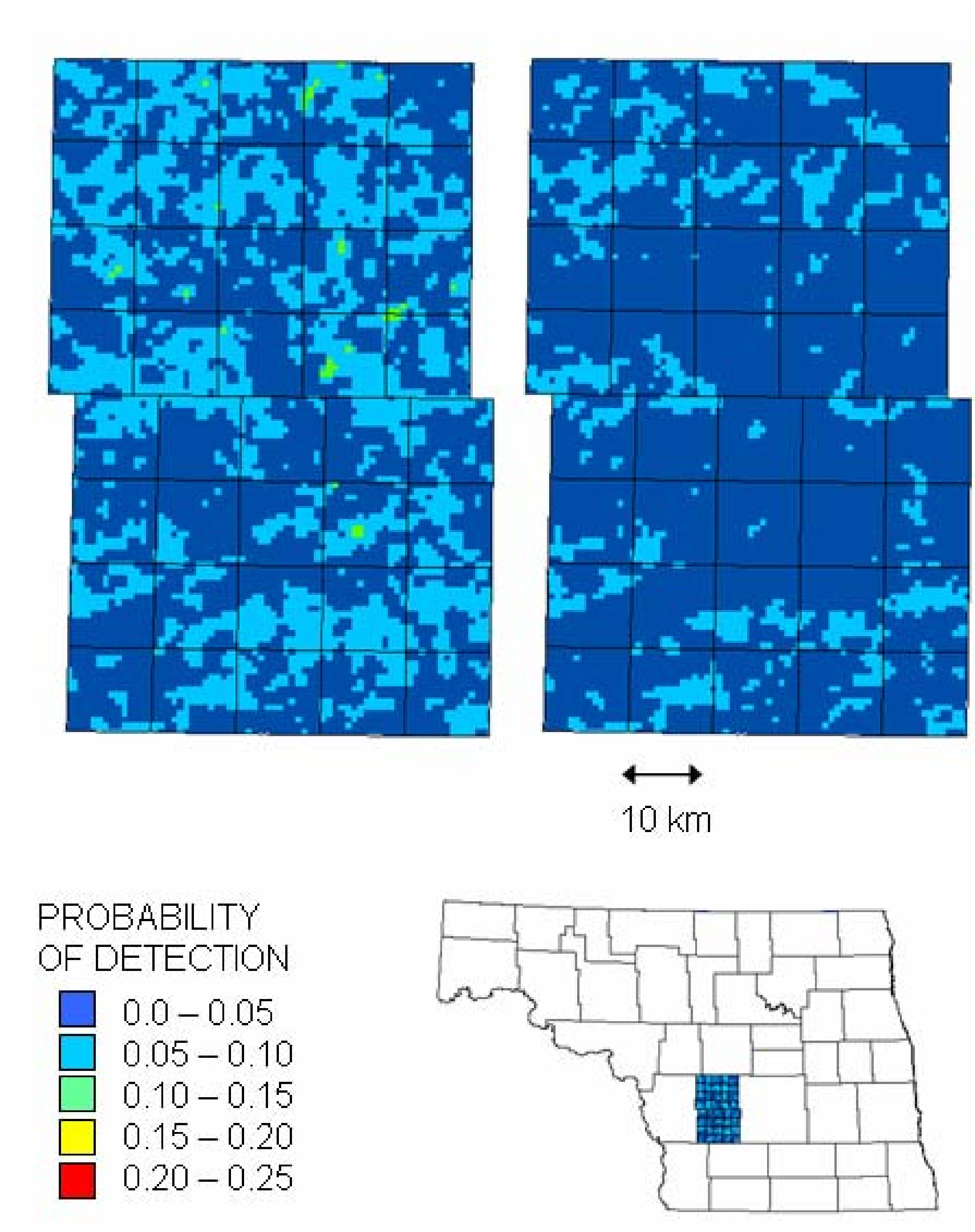

Figure A3. Number of Sedge Wrens predicted to be detected per 12.6-ha sample unit in the PPR portion of North Dakota in 1995 with (above) and without (below) undisturbed grass in the landscape.

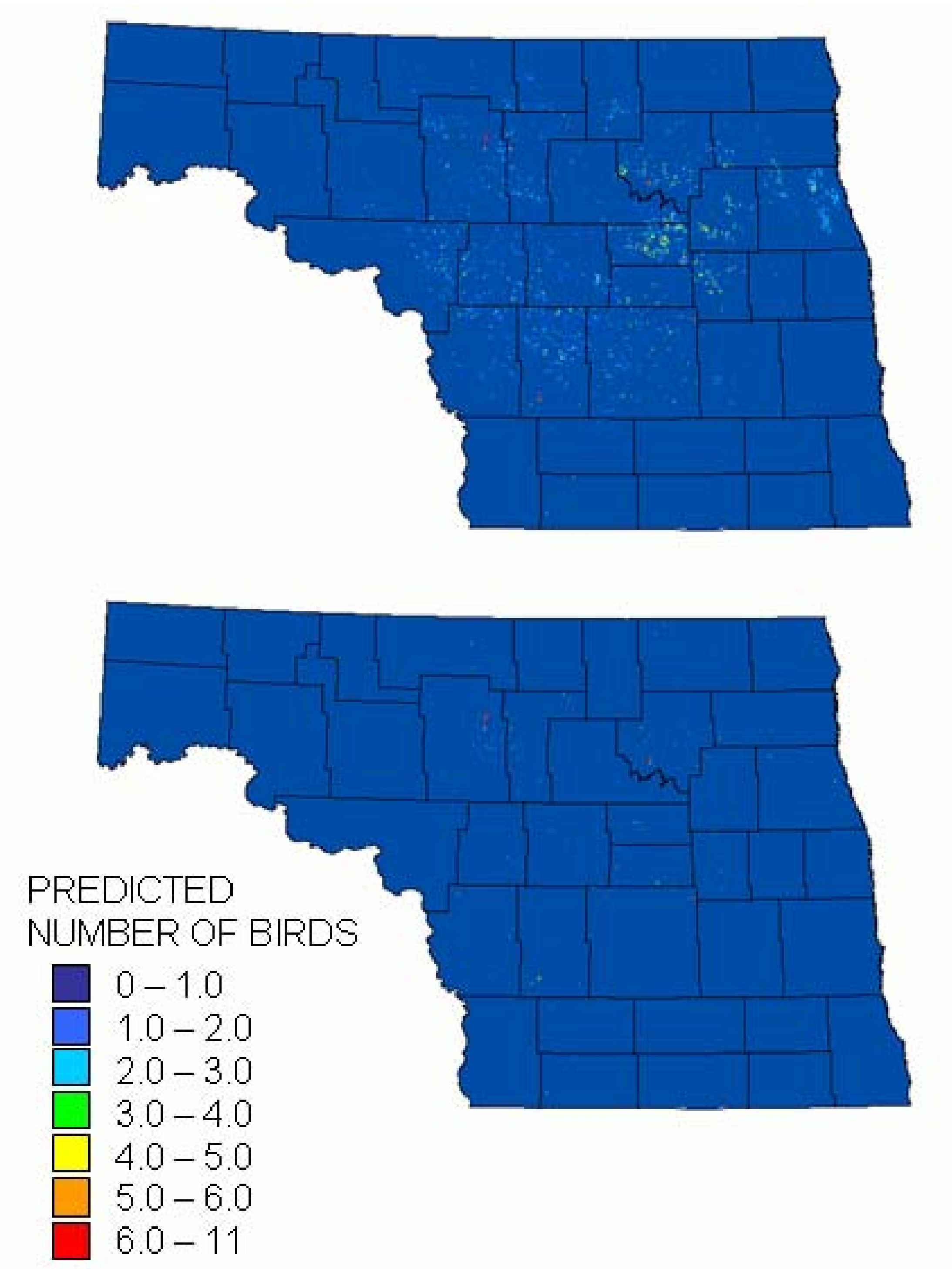

Figure A4. Number of Sedge Wrens predicted to be detected per 12.6-ha sample unit in Kidder County, North Dakota in 1995 with (left) and without (right) undisturbed grassland in the landscape.

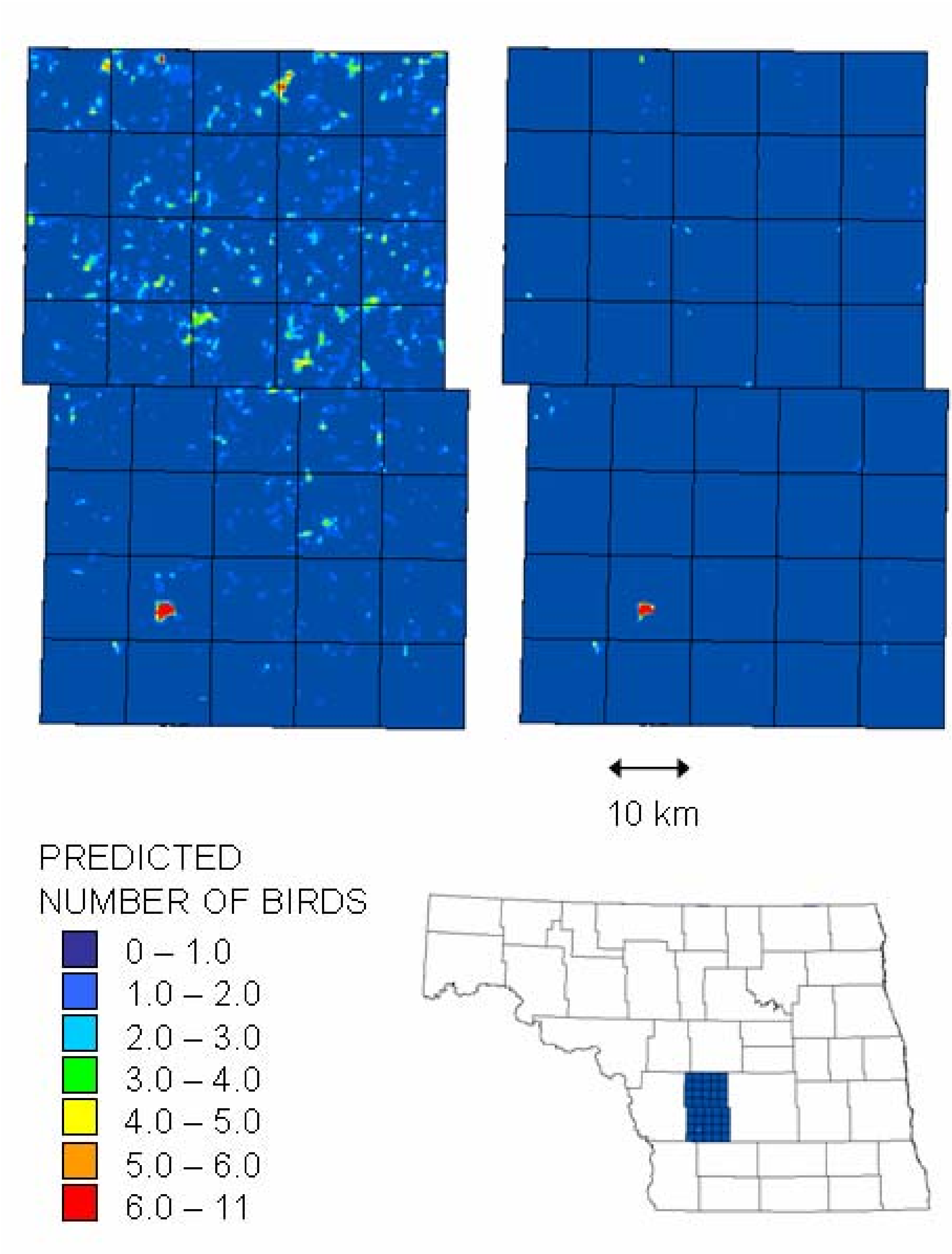

Figure A5. Number of Grasshopper Sparrows predicted to be detected per 12.6-ha sample unit in the PPR portion of North Dakota in 1995 with (above) and without (below) undisturbed grass in the landscape.

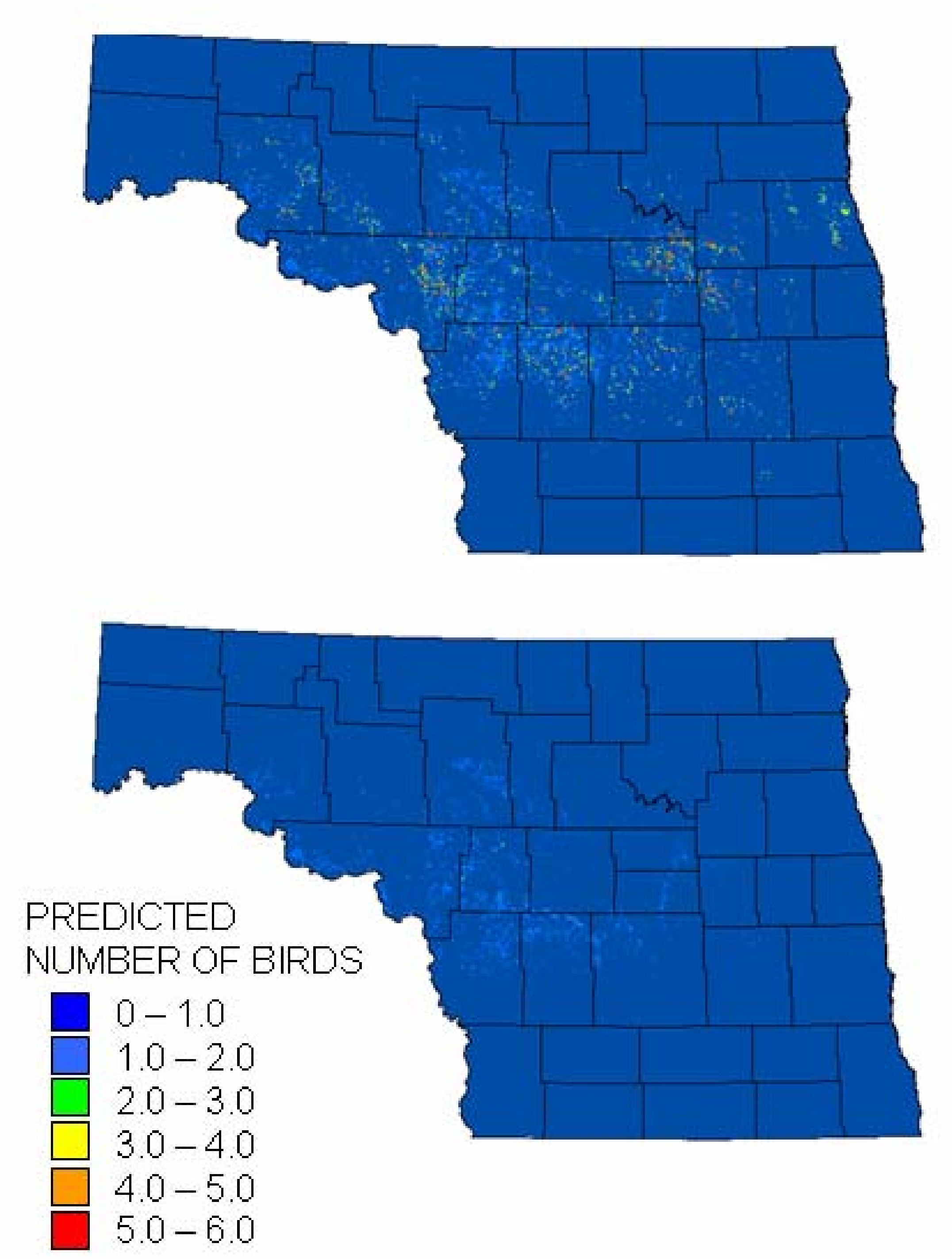

Figure A6. Number of Grasshopper Sparrows predicted to be detected per 12.6-ha sample unit in Kidder County, North Dakota in 1995 with (left) and without (right) undisturbed grass in the landscape.

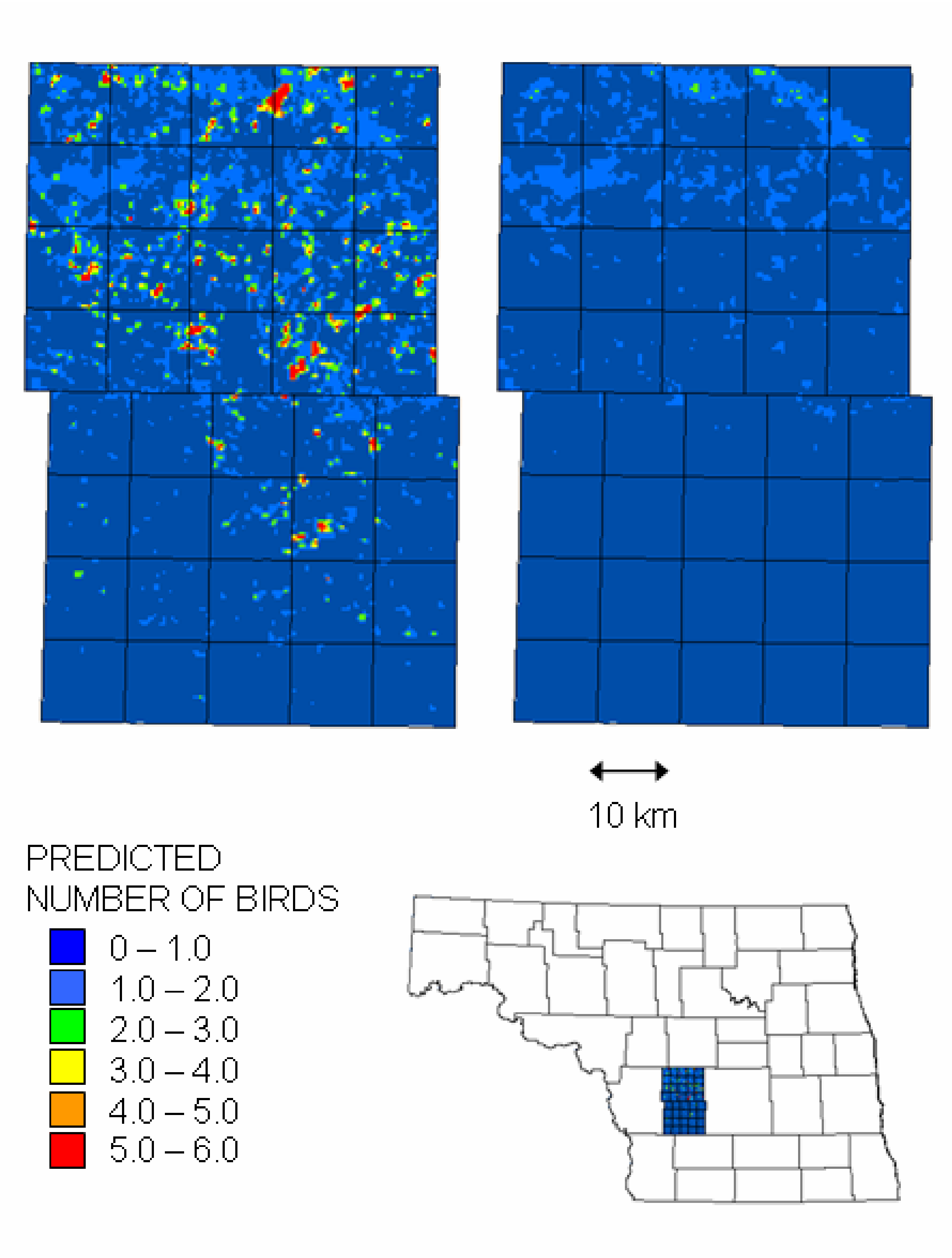

Figure A7. Number of Western Meadowlarks predicted to be detected per 50-ha sample unit in the PPR portion of North Dakota in 1995 with (above) and without (below) undisturbed grass in the landscape.

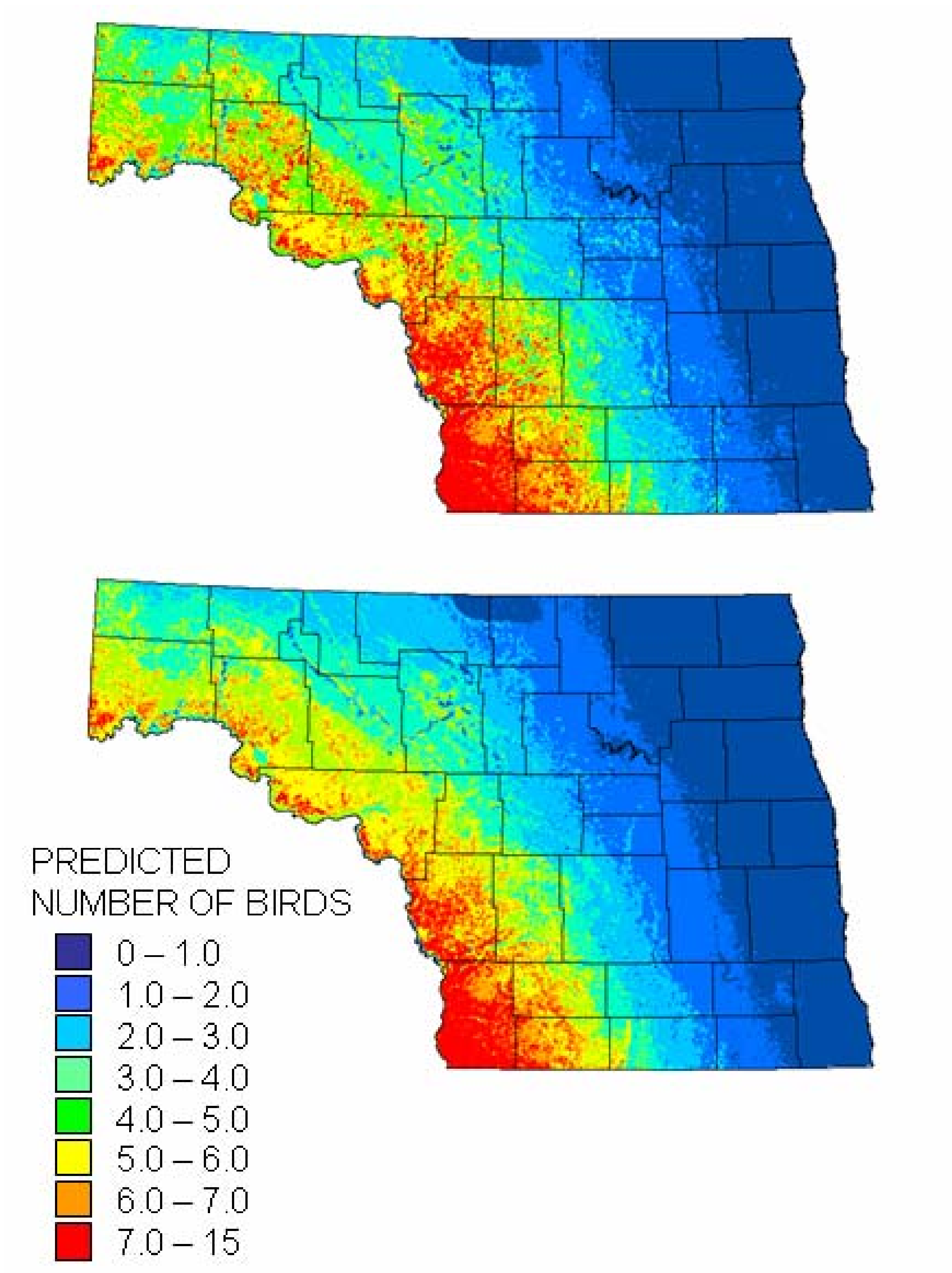

Figure A8. Number of Western Meadowlarks predicted to be detected per 50-ha sample unit in Kidder County, North Dakota in 1995 with (left) and without (right) undisturbed grass in the landscape.

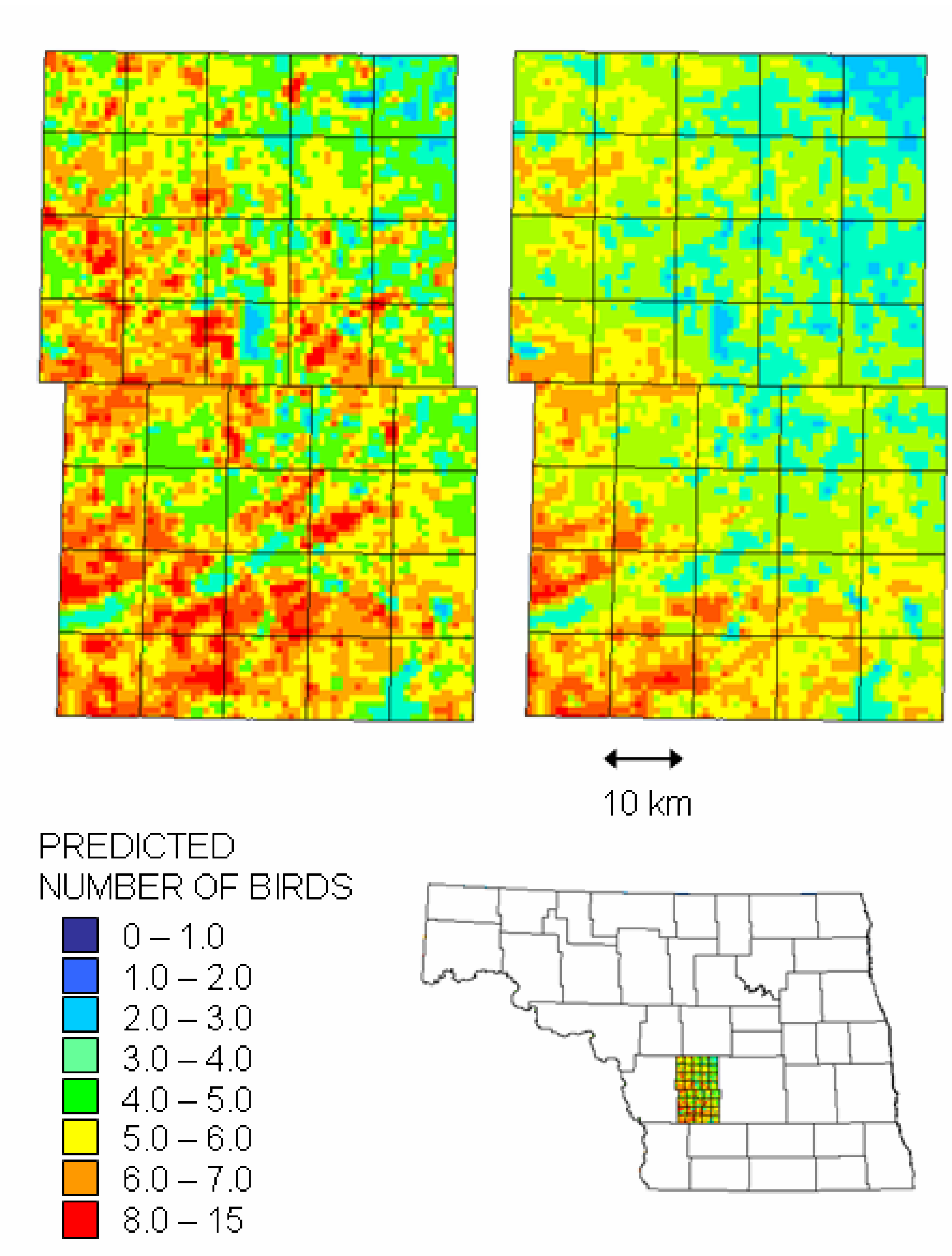

Figure A9. Number of Sedge Wrens predicted to be detected per 5-ha sample unit in the PPR portion of South Dakota in 1997 with (above) and without (below) undisturbed grass in the landscape.

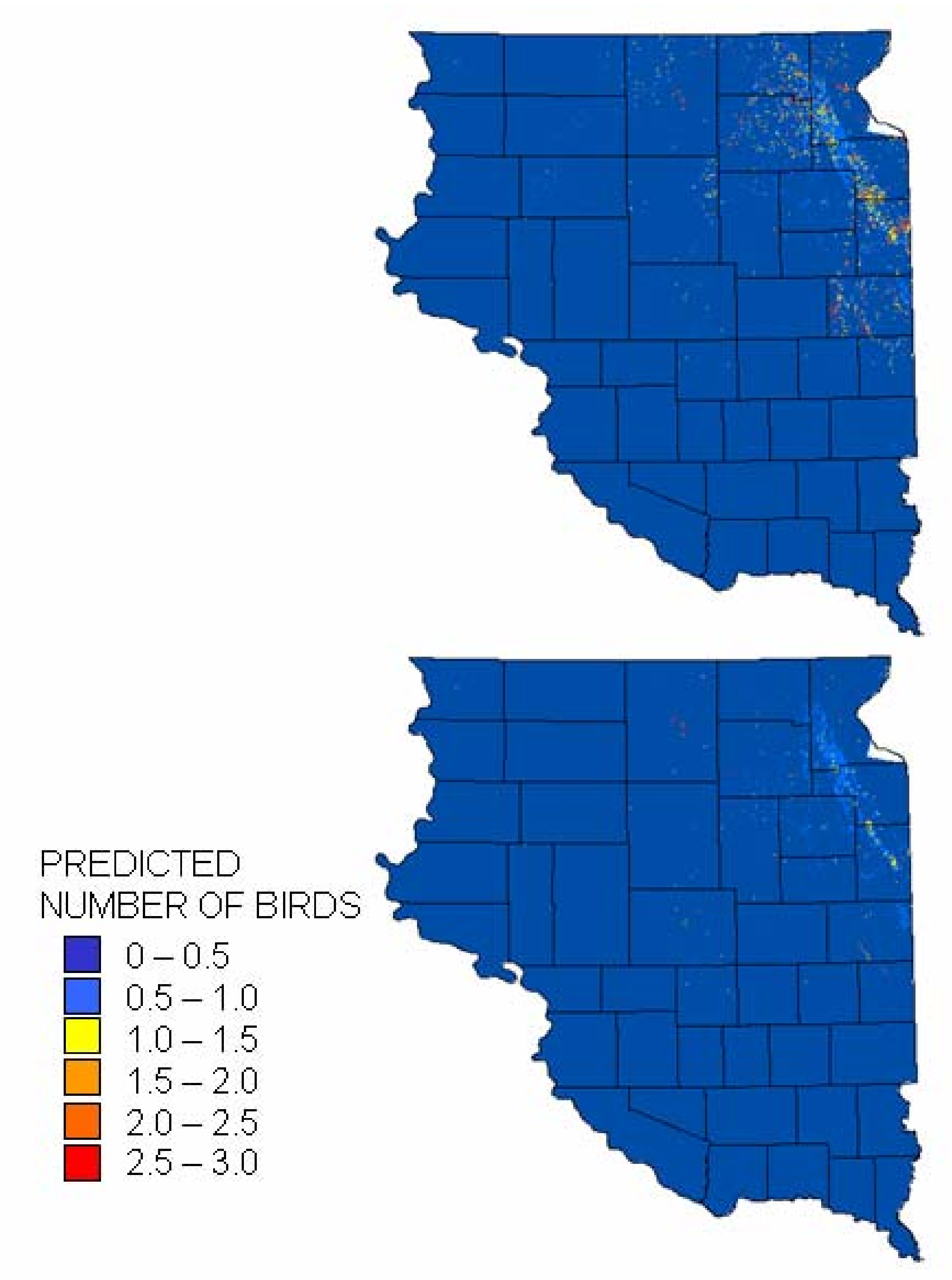

Figure A10. Number of Sedge Wrens predicted to be detected per 5-ha sample unit in Day County, South Dakota in 1997 with (left) and without (right) undisturbed grass in the landscape.

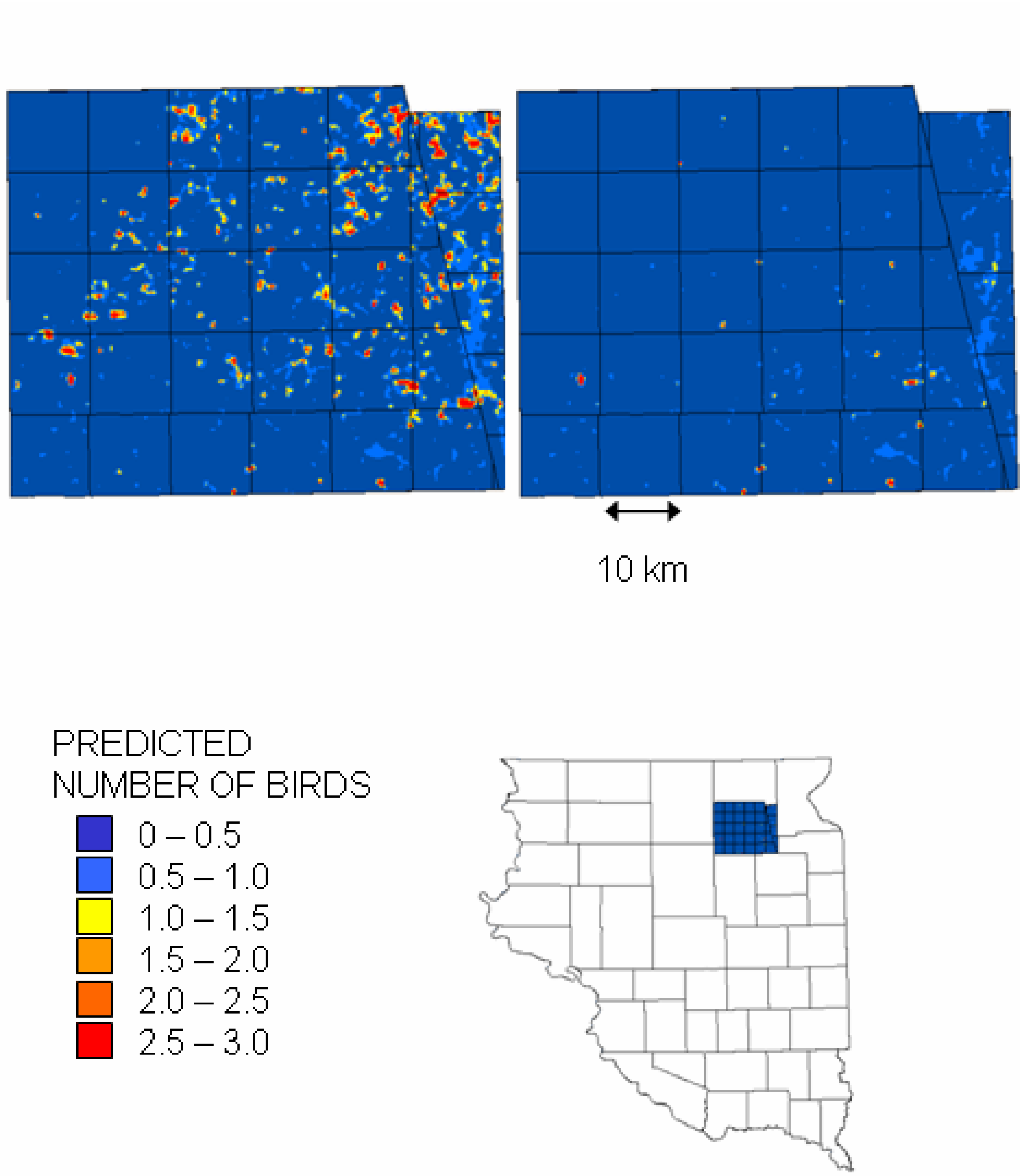

Figure A11. Number of Dickcissels predicted to be detected per 12.6-ha sample unit in the PPR portion of South Dakota in 1997 with (above) and without (below) undisturbed grass in the landscape.

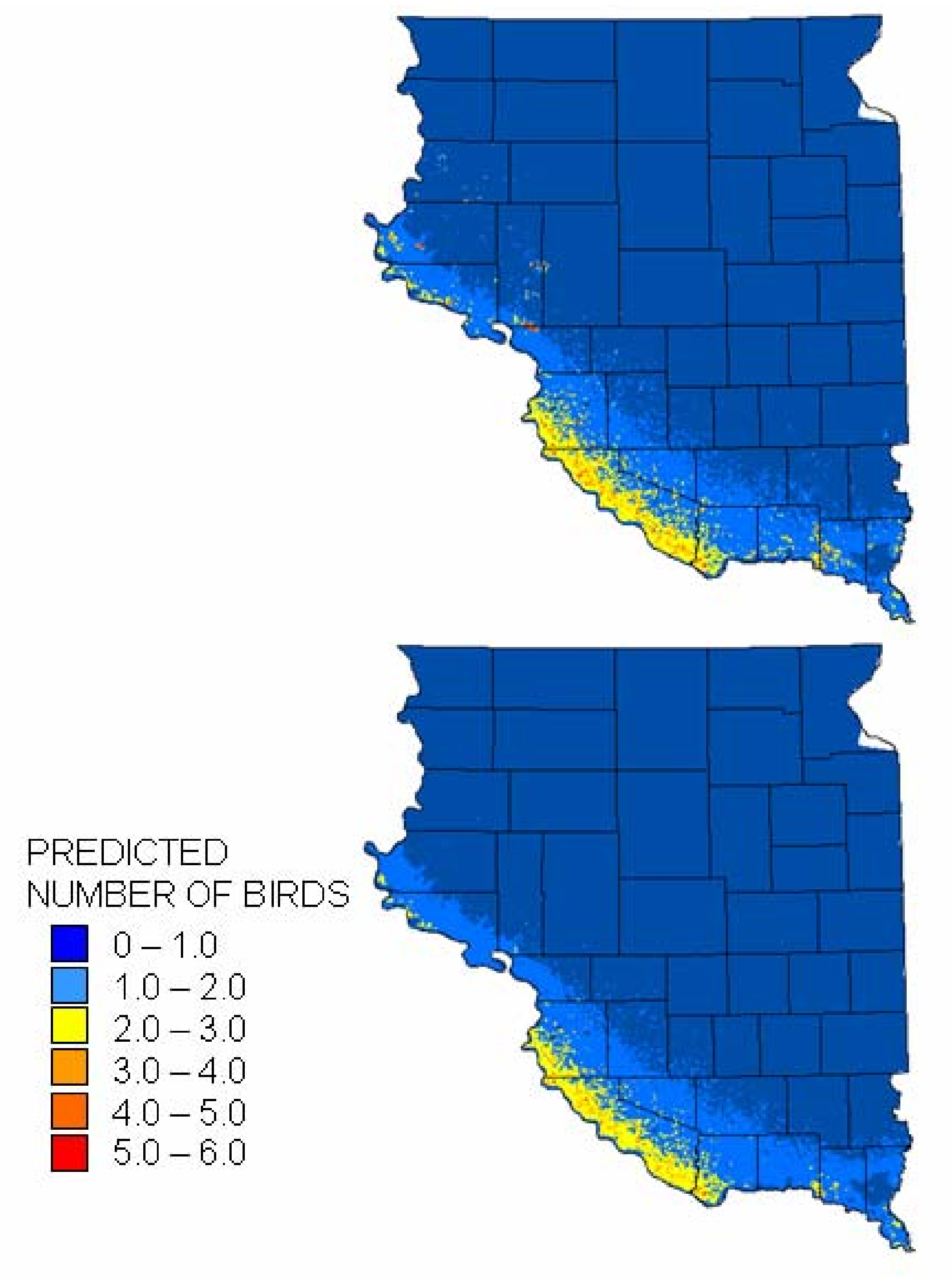

Figure A12. Number of Dickcissels predicted to be detected per 12.6-ha sample unit in Hyde County, South Dakota in 1997 with (left) and without (right) undisturbed grass in the landscape.

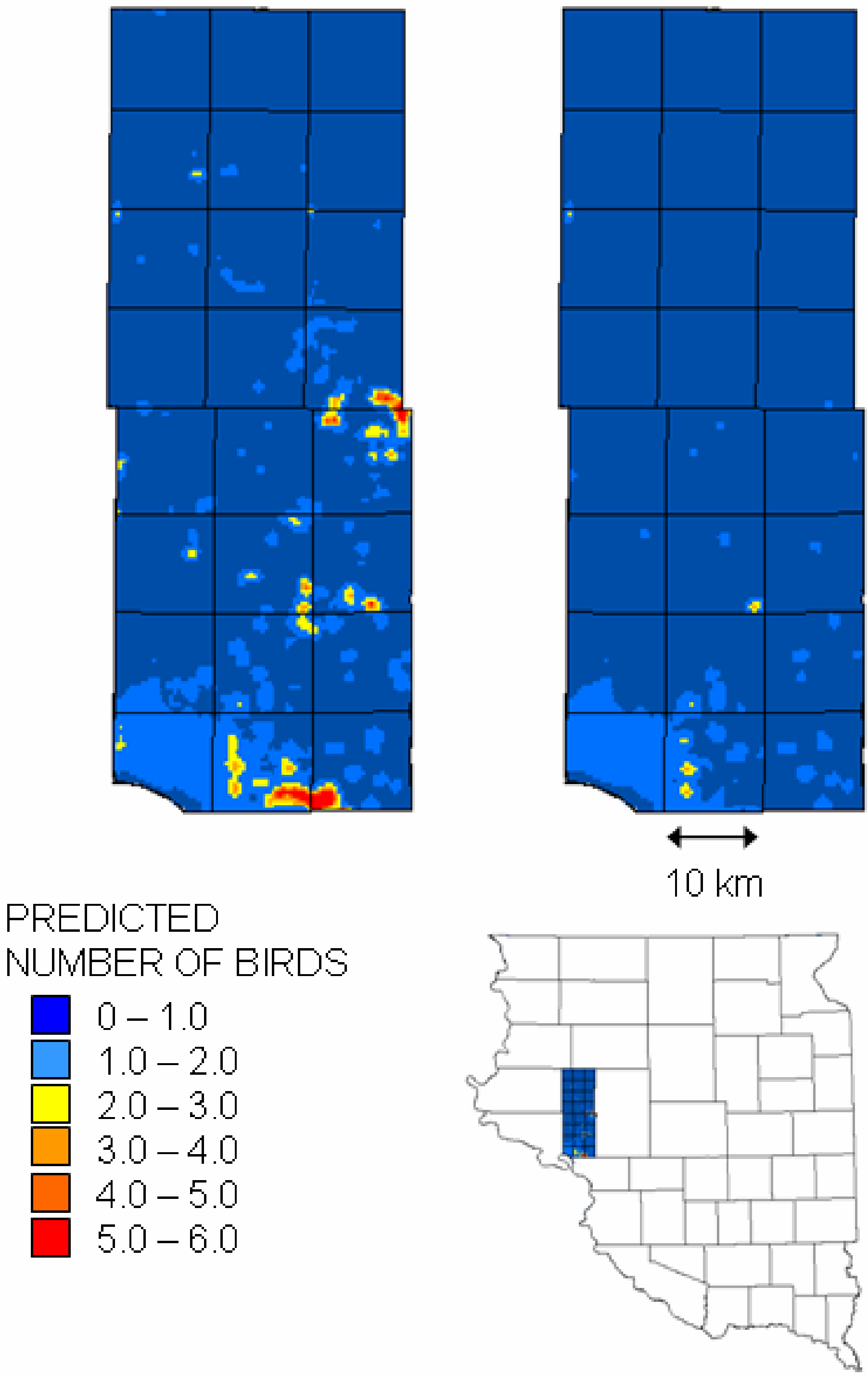

Figure A13. Number of Grasshopper Sparrows predicted to be detected per 12.6-ha sample unit in the PPR portion of South Dakota in 1997 with (above) and without (below) undisturbed grass in the landscape.

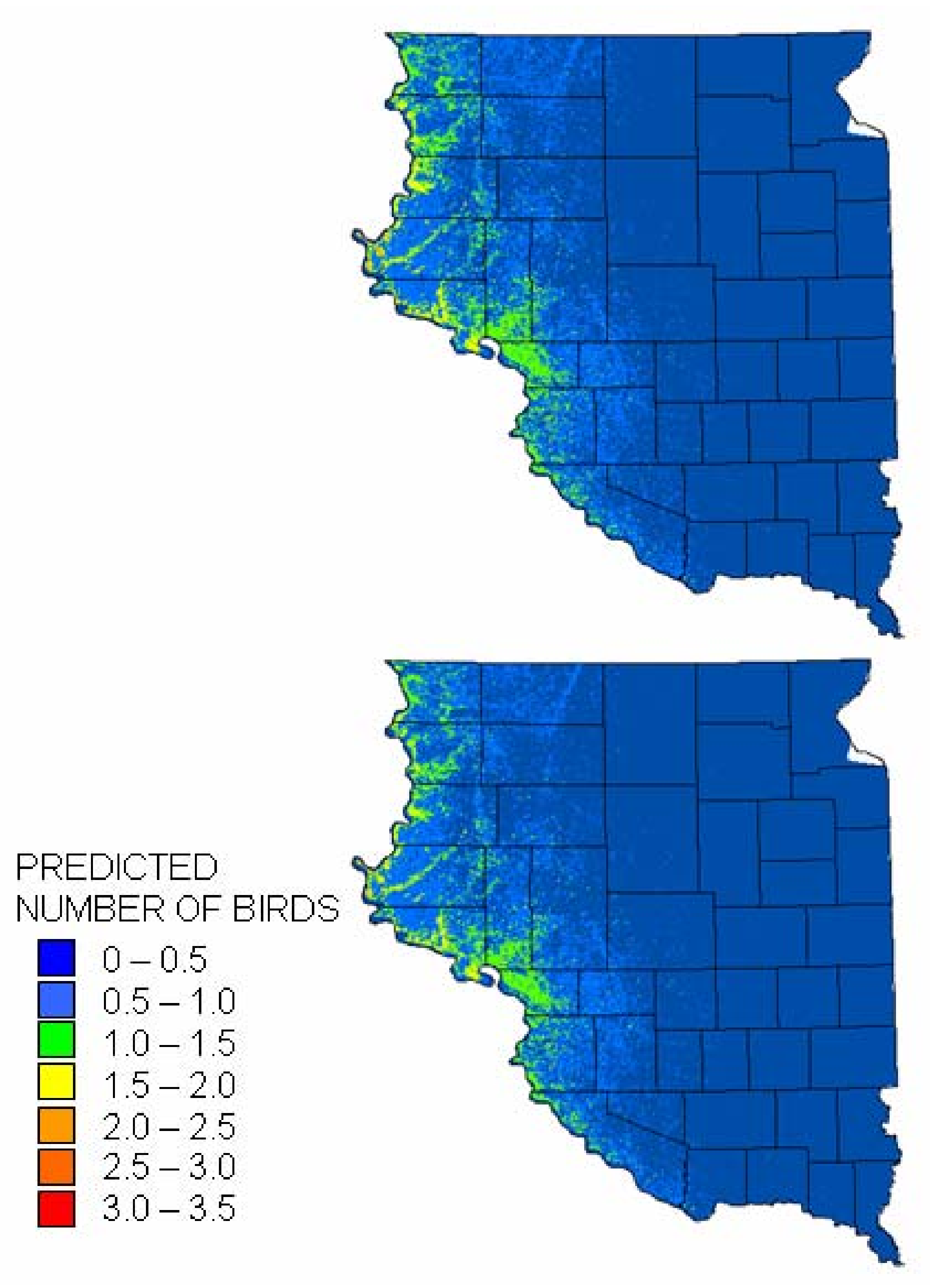

Figure A14. Number of Grasshopper Sparrows predicted to be detected per 12.6-ha sample unit in Hyde County, South Dakota in 1997 with (left) and without (right) undisturbed grass in the landscape.

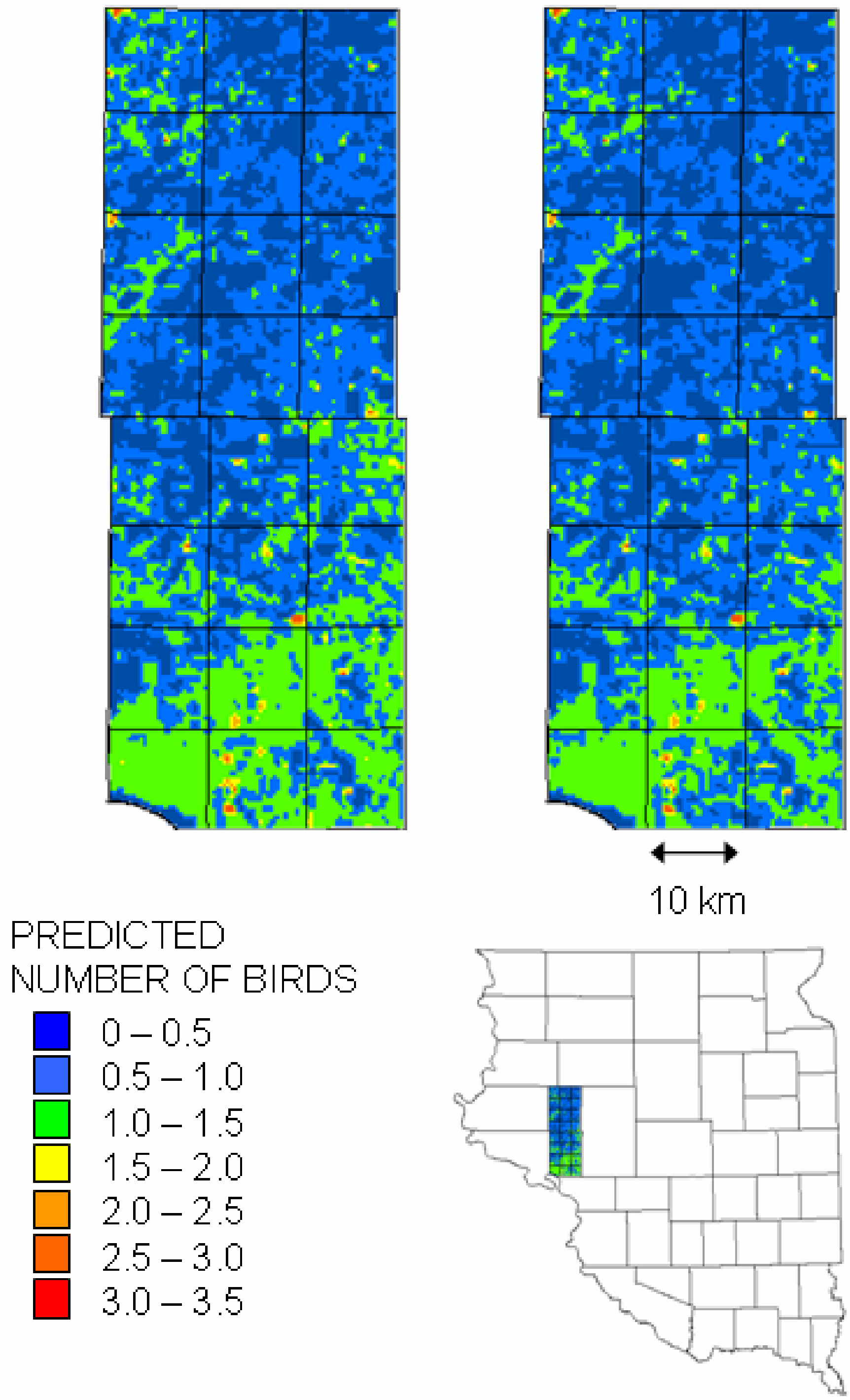

Figure A15. Number of Western Meadowlarks predicted to be detected per 50-ha sample unit in the PPR portion of South Dakota in 1997 with (above) and without (below) undisturbed grass in the landscape.

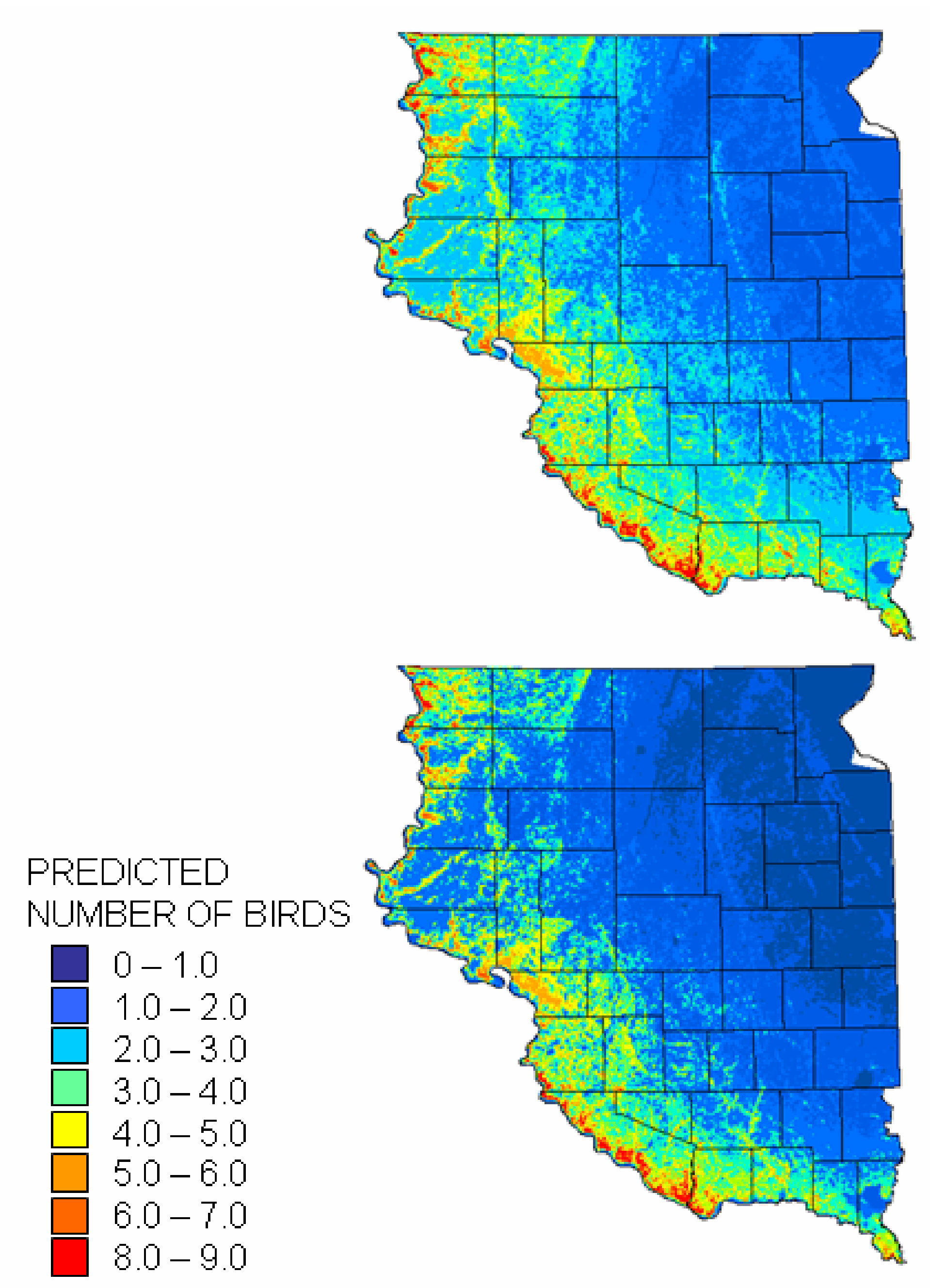

Figure A16. Number of Western Meadowlarks predicted to be detected per 50-ha sample unit in Hyde County, South Dakota in 1997 with (above) and without (below) undisturbed grass in the landscape.