NORTH DAKOTA GAME AND FISH DEPARTMENT

Final Report

Marsh Bird Distribution in Relation to Landscape Composition in North Dakota

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Influence of Landscape Features on Wetland Use and Distribution of Marsh Birds in North Dakota

Final Project Report

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1. Introduction

The North Dakota landscape is characterized by high wetland basin density with pronounced inter-annual variation in abundance and distribution of wetland habitats. The dynamic nature of water conditions on this landscape results in high use of available wetland habitats by breeding birds. The value of prairie wetlands as breeding habitat for waterfowl is well documented, and the region is recognized as the core breeding area for many North American duck species. Prairie wetlands are used as breeding sites by numerous other species of marsh birds, including rails, grebes, phalaropes, and bitterns. Despite the abundance of non-waterfowl species known to breed in prairie wetlands, relatively little is known about factors that influence use of wetlands in North Dakota by these species as related to landscape attributes.

Many human-induced changes have dramatically altered the character of this landscape, including extensive wetland drainage and conversion of wetlands and native prairies to cropland. These changes have had serious consequences for wildlife that rely on prairie wetland and upland habitats. Initiatives such as the Conservation Reserve Program (CRP) have partially mitigated for habitat losses by providing incentives for wetland restoration and establishment of permanent grass cover on private lands. Benefits of CRP and other grassland conservation efforts for waterfowl and grassland songbirds have been documented, but the extent to which these programs influence wetland use by marsh-breeding birds is largely unknown. Because several marsh species nest in upland sites, the demonstrated benefits of grassland conservation programs for waterfowl and songbirds should extend to these species as well. However, form of the relationship between grassland cover and marsh bird wetland use is largely unknown. To the extent that these programs are factors in use of wetlands by marsh birds, they could be used as management tools to enhance populations of marsh-breeding species of concern.

A few studies have demonstrated that landscape characteristics can influence wetland use by marsh-breeding birds (Naugle et al. 2000, Fairbairn and Dinsmore 2001, Johnson et al. 2003). However, these studies have focused primarily on visually estimated wetland habitat characteristics (Fairbairn and Dinsmore 2001, Johnson et al. 2003) and landscape metrics estimated from coarse-resolution satellite imagery (Naugle et al. 2002, Johnson et al. 2003). Niemuth and Solberg (2003) demonstrated that density and distribution of 6 waterbird species in North Dakota, as indexed by the Breeding Bird Survey, was strongly correlated with wetland abundance. However, secretive or rare waterbird species (e.g. yellow rail) are detected infrequently on BBS routes, requiring an additional source of data to model their responses to landscape conditions. Although these studies are useful in predicting relationships between bird abundance and landscape variables, none provides models describing relationships between marsh bird wetland use and landscape metrics in North Dakota.

The North Dakota Game and Fish Department developed a draft list of Bird Species of Concern to focus its efforts in developing its statewide Comprehensive Wildlife Conservation Strategy (Hagen et al. 2005). This list includes many species that breed in prairie marshes and adjacent uplands, including American bittern, black tern, pied-billed grebe, Virginia rail, Wilson's phalarope, and yellow rail. Additionally, the Northern Prairie and Parkland Waterbird Conservation Plan (Beyersbergen et al. 2004) and the Northern Plains/Prairie Potholes Regional Shorebird Conservation Plan identify several species of marsh and shore birds that are known to breed in North Dakota and that are of moderate to high regional conservation priority. Collectively, these species represent a suite of taxa for which the Game and Fish Department desires additional information on distribution and wetland use, and which are of management concern within both the state and the prairie/parkland region. Previous studies have provided some distributional data on these species, which can be compiled to reveal broad patterns in their distribution in North Dakota. For example, preliminary GAP data indicate probable and known locations of each species in 635-km^2 hexagons (Figure 1). These data have descriptive value and may be useful for modeling responses of marsh birds to landscape composition on a coarse scale. However, GAP's representation of distributional patterns includes multiple studies conducted over several years with varying objectives, methods, and study areas. In contrast, this study is designed to obtain concurrent data on marsh bird wetland use and landscape composition at a scale that is meaningful in a habitat management context, while furthering knowledge of distributional patterns for these species.

2. Objectives

This study was designed to evaluate use of wetlands by a suite of non-game marsh-breeding birds in North Dakota, and relate use of wetlands to habitat characteristics within the surveyed wetlands as well as wetland and upland habitat characteristics in the surrounding landscape. The study's specific objectives are to:

1) *Relate presence/absence and abundance of marsh birds in North Dakota to habitat characteristics of surveyed wetlands, including percent coverage by emergent vegetation, percentage of the wetland basin containing water, and wetland type.*
2) *Relate presence/absence and abundance of marsh birds in North Dakota to cropland area, grassland area, acreage of CRP, land protection status, and other upland habitat variables in the adjacent landscape;*
3) *Relate presence/absence and abundance of marsh birds in North Dakota to wetland acreage, percent of wetland basins holding water, and other wetland habitat variables in the adjacent landscape; and,*

4) *Provide baseline data on distribution of marsh birds in eastern and northern North Dakota.*

3. Methods

A. Distribution of Study Sites

We initially designed this study for the portion of North Dakota lying east and north of the Missouri River. This area encompasses the Prairie Pothole Region (PPR), which holds an extremely high abundance of wetlands, and it can be divided into 3 ecoregions (Missouri Coteau, Drift Prairie, and Red River Valley; Figure 2). We initially excluded the Northwestern Great Plains (North Dakota west of the Missouri River) because wetland abundance is relatively low in this area, and use of the region by marsh birds was not expected to be as high as in the PPR. However, surveys of wetlands west of the Missouri River in South Dakota have revealed land-use influences on abundance of marsh birds (May et al. 2002). Consequently, we expanded our sampling to include the Northwestern Great Plains in 2006. We collected data in the 3 PPR ecoregions during 2004-2006 and in the Northwestern Great Plains in 2006-2007.

We conducted our sampling on 4-square-mile (2-mile x 2-mile) sites, with new sites being selected each year. Our goal was to distribute sampling effort among ecoregions in approximate proportion to their area, and within ecoregions equally among 4 landcover strata (high vs. low grassland acreage and high vs. low wetland acreage; Naugle et al. 2000). We sought a minimum of 4 sites per landcover stratum in each ecoregion, and estimated that sampling 96 sites per year would be achievable. Proportional areas of the PPR ecoregions are approximately 1:2:3 (Red River Valley, Missouri Coteau, and Drift Prairie, respectively). Thus, we selected 16 sites in the Red River Valley, 32 in the Missouri Coteau, and 48 in the Drift Prairie. We excluded the Turtle Mountains region of north-central North Dakota because it has substantially different terrain and vegetation from other parts of North Dakota. We also avoided U.S. Fish and Wildlife Service 4-square-mile waterfowl breeding pair survey areas so that potential conflicts with private land access were minimized. We selected 48 sites/year for the Northwestern Great Plains when this ecoregion was added in 2006. Each year we selected 10-20 additional sites, distributed equally among the ecoregions being sampled, in case favorable weather conditions allowed additional data collection.

B. Study Site Selection

We consulted with the U.S. Fish and Wildlife Service's Habitat and Population Evaluation Team (HAPET) regarding distribution of cover types in North Dakota. They developed a 16-mi^2 grid covering the state, and assigned each cell to 1 of the 4 strata. Grassland cover estimates were derived from a 2001 HAPET landcover map, and wetland acreage estimates from National Wetland Inventory (NWI) data. Median values of grassland acreage and wetland acreage were derived within each ecoregion, and cell classification was based on whether the cell's value of each was above or below the median. This stratification generated a sample of study sites that was representative of upland and wetland habitat types throughout North Dakota.

Each field season, we randomly selected approximately 200 sections in each ecoregion, and assigned them random sequential numbers. We worked from the beginning of the list, including sections for sampling until the ecoregion's quota had been met for each stratum. We then examined each selected section's position within the 16-mi^2 landcover grid cell, and randomly selected 1 of the possible 4-mi^2 sites it encompassed. We excluded sections and 4-mi^2 sites that overlapped sites sampled in previous years.

We used publicly available data (plat books and/or county tax records) to determine ownership for each parcel of land in the selected sites. During late winter, we sent a written access request to each landowner. We retained only those lands for which we obtained written access permission in the final sample. We used NWI data to map wetland basins within the accessible lands, and randomly selected 6 basins (2 temporary, 2 seasonal, and 2 semipermanent) for bird surveys.

C. Target Species

We established a suite of 16 focal species, including marsh and shore birds identified as being of high conservation priority by the North Dakota Game & Fish Department (Hagen et al. 2005), most of which are also ranked as high priorities in regional waterbird (NAWCP 2003) or shorebird plans (Beyersbergen et al. 2004) (Table 1). We included sora due to its secretive nature and a lack of information on factors influencing its wetland use in North Dakota, although it is not identified as a species of concern in the state or region. We also included 4 species of prairie-nesting shorebirds (Wilson's phalarope, marbled godwit, willet, and American avocet). Although these species are predominantly upland nesters, they roost and forage in prairie wetlands and were likely to be encountered during marsh surveys. The study was designed with regard to collecting data on the 16 target species, but also presented opportunities to collect data on other species. For example, several other species of conservation interest to the North Dakota Game & Fish Department were also encountered in the surveyed wetlands. We trained technicians in identification of all birds likely to be encountered, and recorded data for these species as well. We included in our analyses 6 additional North Dakota species of conservation priority (upland sandpiper, grasshopper sparrow, lark bunting, northern pintail, redhead, and bobolink), and 6 commonly occurring species likely to be of management interest (American coot, lesser scaup, common snipe, killdeer, common yellowthroat, and marsh wren).

D. Wetland Surveys

The focal species can be grouped according to the most likely means of detection: secretive species that are most likely to be detected during auditory surveys (bitterns and rails), and species that are most likely to be detected visually (grebes, pelican, black tern, and the 4 wading birds). We adapted procedures from Naugle et al. (2000), Fairbairn and Dinsmore (2001), and Conway (2003), including components that targeted the visual and auditory species separately. First, we selected a vantage point that provided good visibility and minimized disturbance of birds. From that point, we conducted a visual and call-playback survey. The survey started with 5 minutes of silence, during which we recorded all species seen or heard. This was followed by 5 1-minute intervals, each including a 30-second call broadcast (least bittern, yellow rail, sora, Virginia rail, and American bittern; Johnson and Dinsmore 1986) followed by a 30-second silent period (c.f. Naugle et al. 1999, 2000, Conway 2003). We did not conduct call-playback surveys for wetlands containing no suitable habitat for secretive species (e.g., cropped wetlands with no vegetation). For wetlands bordered by an emergent vegetation zone, we conducted a fixed-area survey by walking a 100-m segment through the vegetation and recording all species seen or heard within the segment.

We conducted wetland surveys from mid-May to mid-July, restricting surveys to dawn (0.5 h before – 2.0 h after sunrise) and dusk (2.0 h before – 0.5 h after sunset) to maximize detection probability for secretive species (Conway 2003). We completed data collection on all wetlands within a site before moving to the next site. We started by visiting each of the randomly selected wetlands, conducting surveys on each regardless of whether the basin contained water. If any of these basins were dry, we attempted to identify additional wetlands of the same class so that a minimum of 6 wetlands containing water were surveyed at each site. This was not feasible in all cases when water conditions were especially poor. In situations where access was limited (e.g., due to lack of landowner permission), we conducted visual and/or auditory surveys from nearby roads, but did not conduct fixed-area surveys. On some sites, we conducted surveys on additional wetlands opportunistically encountered after our sampling goals had been met.

We recorded the pattern wetland of vegetation (Stewart and Kantrud 1971), percent full of the wetland basin, presence of trees, and dominant management practice (e.g., cropped, grazed, burned, none) for each wetland basin. We visually estimated percent cover of 10 landcover categories (Grassland, CRP, Hayland, Cropland, Woodland, Shrubland, Wetland, Right-of-Way, Barren Land, and Odd Area) within a 0.25-mile radius around each wetland, and also recorded the dominant management practice for this area. We recorded GPS coordinates for the survey point location and the start and end point of the emergent vegetation transect.

E. Aerial Photography

We used aerial photography to collect landscape composition data for each site. Flights occurred during mid-May, and were timed to maximize contrast between cropland and grassland. We conducted 1-3 flights per year to ensure that imagery was obtained for each study site. We used a large-format (9” x 9”) camera mounted in a Partenavia P-68 Observer (U.S. Fish and Wildlife Service, Ft. Snelling, MN) that was flown at approximately 10,000 feet MSL. This altitude provide a scale of approximately 1:15,000, at which a 9” x 9” image captures an entire 2 mile x 2 mile site. We used Kodak 1443 color infrared film, which was developed to color positive by HAS Images (Dayton, OH).

4. Data Analysis

A. Field Data Preparation

To ensure accuracy of data entry, we used double-entry procedures for all field data. We provided blank database templates to two independent technicians, grouping data sheets into manageable units (50 – 100 data sheets) for entry. Both technicians entered all of the data, and we used spreadsheet comparison software (Excel Compare 2.0.3.; Formula Software, Inc.) to identify discrepancies between pairs of spreadsheets. These discrepancies reflected a data entry error by one of the technicians. Any cells flagged by this procedure as differing between pairs were checked against the original data cards. We completed multiple iterations of comparison and error-checking for each dataset until no additional errors were identified.

B. Spatial Data Preparation

We scanned color-inferred imagery (600 dpi; RGB composite), auto corrected, sharpened, and saved images in a TIF format. We used ESRI® ArcGIS to geo-reference and interpret imagery within our 4-square-mile sites. We used field observations and manual image interpretation to classify imagery at a scale of 1:4,000, using 0.04 ha as a minimum mapping unit. We classified the entire area of our sites into the following classes: grass (including native grass cover, CRP, and hay and pasture land); crop; water (visible open water); woodland (trees and shrubs, including shelterbelts); road; barren (land devoid of vegetation, but not tilled croplands) and odd areas (e.g., rock piles, farm yards, towns, oil infrastructure, etc.). In the imagery for Northwestern Great Plains we noticed areas of very high reflectance in the infrared band, relative to the rest of the image, indicating abundant green vegetation. These areas were often associated with riparian areas and appeared to be moist soil or wet meadow areas, so we classified them as unclassified wet areas. Lastly, we calculated the area of all classified polygons and because study sites sometimes varied in actual area, we calculated the percent cover for each class within study sites.

We also utilized converged basin National Wetland Inventory (NWI) data (Johnson and Higgins 1997) to generate variables to represent the landscape within our 4-square-mile sites. However, converged basin NWI data was not available for the entire Northwestern Great Plains region, so we limited the NWI summaries to regions east of the Missouri River. For each site, we calculated the sum of the area of wetlands and the percent of the wetlands that were either seasonal or temporary regimes (landscape percent seasonal and temporary [LST]).

C. Analytical Procedures

In the following models, we used information theoretic multimodel inference (Burnham and Anderson 2002) to determine the importance of each parameter in explaining the response variable. However, we only modeled focal species that occurred at least 30 times within the scope of each analysis (see Tables 2 and 3). We modified a macro by Shaffer (2002) to rank and weight our candidate models using Akaike's Information Criterion (AIC), and calculate model averaged parameter estimates, unconditional standard errors, and 95% confidence limits. We used 95% confidence limits to evaluate the importance of each parameter. For example, if the confidence limit did not include zero or another level of a class we viewed that parameter as important. We report all important differences among levels of class variables in odds ratios (for logistic regressions) or percent change (for Poisson generalized linear models) and all important covariate parameter estimates and 95% confidence limits.

We used the data from the visual survey only to determine if several species occurred at each wetland; however, for species that are more secretive or if detection was generally improved by the call-play survey we used a combination of the visual survey and the call-play survey (see Tables 4-7). For these species, we only included wetlands where the both the visual survey and the call-play survey was conducted, and scored the species as present if it was detected in either survey. However, the call-play surveys were not conducted at all wetlands, so models that used this data had reduced sample size.

1. Wetland Models (Objectives 1 and 3)

The proportion of the area surrounding a wetland in a various cover class is compositional, and by definition correlated; however, the strongest correlations generally exist between grassland and cropland in the North Dakota landscape. To avoid problems associated with correlation among our explanatory variables we only included 3 of the 7 classifications in our models (proportions of grass [grassland, CRP, pasture, and hayland], wood [woodland and shrubland], and wetland).

We examined factors at or in the immediate surrounding area of a wetland that were important in predicting the probability that a given wetland would be used by one of our focal species with separate logistic regressions for each species (binomial distribution, logit link function; PROC GENMOD; SAS Institute 2002). We selected 8 variables of *a priori* interest and generated a list of 20 candidate models that would be competed for each species (see Tables 8-11). We also examined factors at the wetland or in the immediate surrounding area that were important in predicting the species richness at the wetland with a generalized linear model (Poisson distribution, log link function; PROC GENMOD; SAS Institute 2002).

The following variables were specified as nominal class variables when they occurred in candidate models: region (R; including: Red River Valley, Drift Prairie, Missouri Coteau, and Northwestern Great Plains), wetland cover (WC; vegetation cover in the wetland ranging from 1 to 4, with 1 being a closed marsh and 4 being mostly open water), trees (WT; whether the wetland basin contained trees or not), and wetland manipulation (WM; whether the wetland was unmanipulated, cropped, or other [e.g., burned, hayed, or grazed]). The following variables were modeled as continuous covariates: percent of the wetland basin full of water (WF; we included a quadratic term because we believed this variable would not be linearly related to probability of occurrence for several of our focal species), and percent of the surrounding area in grass (SAG), woodland (SAW), and other wetlands (SWE).

For species that did not occur or were very rare in a given region (under 3 detections), we excluded all the data from those regions to ensure that the calculation of parameter estimates and standard errors would be stable and that all models would converge. The regions included for modeling and the samples size for each species are included in Table 2. American bittern occurred infrequently in all regions except the Drift Prairie, so we combined all other regions into one region, allowing for inference between Drift Prairie and other parts of North Dakota (Table 2). Lark bunting occurred only in the northwestern Great Plains, so region was removed from all lark bunting candidate models. Grebes occurred infrequently in wetlands of cover class 1 and 2, so we combined cover classes 1 and 2 as well as 3 and 4 to ensure that models would converge.

2. Landscape Models (Objective 2)

We conducted separate analyses for northwestern Great Plains region because converged basin NWI data were not available for this region. However, this approach limited the number of focal species with adequate numbers of occurrences that we could model in either the northwestern Great Plains or for the area east of the Missouri River (see Table 3).

We examined large landscape-scale factors that were important in predicting the probability that a given 4-square-mile site would be used by one of our focal species using separate logistic regressions for each species (binomial distribution, logit link function; PROC GENMOD; SAS Institute 2002). For these models we specified the number of wetlands within a site as the trials and the number of detections within a site as the events. We then included the events over the trials and the response variable, ensuring that the experimental unit of these analyses was the 4-square-mile site and that the proper error term was calculated. We also examined large landscape-scale factors that were important in predicting the species richness within the 4-square-mile site using a generalized linear model (Poisson distribution, log link function; PROC GENMOD; SAS Institute 2002).

For areas east of the Missouri River we examined 6 variables and examined 20 *a priori* candidate models (Tables 12-15). We calculated the percent wetness (LWET) of the 4-square-mile site by dividing the sum of the water classified from imagery (LWW) by the sum of the wetland area from converged basin NWI data. However, we also included LWW into candidate models, but we did not let LWW occur in the same models as LWET because these variables are partially correlated, rather our approach competed similar *a priori* candidate models that contained either LWET or LWW. Similar to our models at the wetland scale, we included the percent of the landscape that was classified from imagery as grass (LG) and woodland (LWO). We characterized the class of wetlands within the 4-squre-mile sites by including the percent of the wetlands that were seasonal or temporary (LST). Lastly, we only included region as a blocking term, because we examined the region effect in our wetland scale models. We examined 4 parameters (LWW, LWO, LG, and unclassified wet areas [UCW]) in the northwestern Great Plains and competed all possible main effect models (16; Table 15).

3. Distribution (Objective 4)

We evaluated distribution of each target species by calculating the proportion of wetlands surveyed at which the species was detected in each site. We mapped these data by species and examined the maps visually to describe regional trends in distribution.

5. Results

A. Sites Surveyed

Four of our focal species (American white pelican, American avocet, least bittern, and yellow rail) occurred too infrequently for us to model the factors that influenced their wetland use. However, we summarized the characteristics of the wetlands where they were observed. The wetlands where American white pelicans were observed were, on average, 87% ± 8 SE full, and 93% of the wetlands where they were observed had cover classes of 3 or 4. Ninety-three percent of the wetlands were treeless, 60% were unmanipulated, and none were cropped. American avocet were primarily observed in the Drift Prairie (72% of our observations; Appendix A). The wetlands where American avocet were observed were, on average, 93% ± 8 SE full; 82% of the wetlands where they were observed had cover classes of 3 or 4 and were treeless. Least bittern also were primarily observed in the Drift Prairie (86% of our observations; Appendix A). The wetlands where least bittern were observed were, on average, 118% ± 9 SE full; 86% of the wetlands where they were observed had cover classes of 1 or 2 and were treeless. Similarly, 86% of least bittern observations were on unmanipulated wetlands and none were on cropped wetlands. At least 20% of the surrounding landscape was covered by other wetlands in 71% of the wetlands where least bittern were observed. Yellow rail were primarily observed in the Drift Prairie (88% of our observations; Appendix A). The wetlands where yellow rails were observed were, on average, 117% ± 13 SE full; 63% of the wetlands where they were observed had cover classes of 3 and 75% were treeless. Similarly, 63% of least bittern observations were on unmanipulated wetlands and none were on cropped wetlands.

B. Wetland Models

Black Terns

Black terns were 11.0 and 7.6 times more likely to occur at wetlands in the Drift Prairie and Missouri Coteau, respectively, than on those in the Red River Valley (Appendix A), they were at least 3 times more likely to occur at wetlands with cover classes of 2 or 3 than those of classes 1 or 4, and they were 2.7 times more likely to occur on unmanipulated wetlands than those that had been cropped. The probability that black terns would occur at a wetland was positively correlated with the percent of the landscape covered by other wetlands (X = 0.331, 95% CL: 0.194 – 0.469) and the percent of the wetland basin full of water (X = 0.01, 95% CL: 0.003 – 0.018).

Shorebirds

Upland sandpiper, marbled godwit, and Wilson's phalarope were at least 4.0, 4.3, and 2.4 times, respectively, more likely to occur at wetlands in the northwestern Great Plains than those of the Drift Prairie or the Missouri Coteau (Appendix A). However, region was not important in explaining the occurrence of killdeer, willet, and common snipe. Wetland cover class appeared not to be important in explaining occurrence of shorebird species, except for killdeer which were 3.9, 1.7, and 1.8 times more likely to occur at wetlands with cover class of 4 than those of 1, 2, and 3, respectively. Killdeer were over 2.1 times more likely to occur at wetlands that were manipulated by cropping or other manipulations (e.g., haying, grazing, burning) than those that were unmanipulated. Marbled godwit were over 3.7 times more likely to occur at wetlands that were cropped than those that were unmanipulated or otherwise manipulated. Wilson's phalarope were 8.7 times more likely to occur at wetlands without trees than those that had trees within the basin. The probability that killdeer would occur at a wetland was negatively correlated with the percent of the landscape covered by woodlands (X = -0.236, 95% CL: -0.375 – -0.096). The probabilities that common snipe and killdeer would occur at a wetland were positively correlated with the percent of the landscape covered by other wetlands (X = 0.28, 95% CL: 0.111 – 0.450; X = 0.199, 95% CL: 0.107 – 0.291; respectively). The probabilities that killdeer and willet would occur at a wetland were negatively correlated with the percent of the landscape covered by grass (X = -0.061, 95% CL: -0.119 – -0.003; X = -0.16, 95% CL: -0.292 – -0.028; respectively). The probability that Wilson's phalarope would occur at a wetland was positively correlated with the percent of the wetland basin full of water (X = 0.045, 95% CL: 0.013 – 0.077). The probability that willet would occur at a wetland was positively correlated with the percent of the wetland basin full of water up to 130%, then it was weakly negatively correlated thereafter (X = 0.042, 95% CL: 0.022 – 0.061; X^2 = -0.0002, 95% CL: -0.0003 – -0.00004).

Ducks and Grebes

Grebes, northern pintails, and redheads occurred too infrequently in the Red River Valley for this region to be included in our models; the same was true for grebes in the northwestern Great Plains (Table 2). Redheads were 2.6 times more likely to occur at wetlands in the Drift Prairie than those of the Missouri Coteau (Appendix A). Redheads were most likely to occur at wetlands with cover class of 3, these wetlands were 11.2 times more likely to have redheads than those of cover class 1. Similarly, grebes were 3.9 times more likely to occur at wetlands of cover class 3 or 4 than those of cover class 1 or 2. Grebes were 8.1 and 5.4 times more likely to occur at wetlands that were unmanipulated than those that were cropped or otherwise manipulated, respectively. The probability that redheads occured at a wetland was positively correlated with the percent of the wetland basin full of water (X = 0.023, 95% CL: 0.007 – 0.038). The probabilities that northern pintails and grebes occured at wetlands were positively correlated with the percent of the wetland basin full of water up to 110 and 140%, then they were weakly negatively correlated thereafter (X = 0.08, 95% CL: 0.029 – 0.131, X^2 = -0.0004, 95% CL: -0.0007 – -0.00005; X = 0.104, 95% CL: 0.022 – 0.186; X^2 = -0.0004, 95% CL: -0.0007 – -0.00005; respectively).

Rails, Bitterns, and Coots

American bittern and American coot were 8.2 and at least 2.6 times, respectively, more likely to occur at wetlands in the Drift Prairie than those of all other regions in North Dakota (Appendix A). The highest probabilities of occurrence for American coot were in cover classes of 2 and 3; these wetlands were at least 2.6 and 6.1 times more likely to have American coot than those of classes 1 and 4, respectively. However, the highest probabilities of occurrence for sora were wetlands with cover classes 1 and 2; these wetlands were at least 10.8 times more likely to have sora then those of class 1. Sora were 2.3 times more likely to occur at wetlands that were unmanipulated than those that had been manipulated through grazing, haying, or burning. American coot were at least 4.8 times more likely to occur at unmanipulated wetlands than those that were cropped or otherwise manipulated. The probabilities that American bittern and sora would occur at a wetland were positively correlated with the percent of the landscape covered by other wetlands (X = 0.252, 95% CL: 0.059 – 0.446; X = 0.131, 95% CL: 0.021 – 0.242; respectively). The probabilities that Virginia rail, sora, and American coot occur at a wetland were positively correlated with the percent of the wetland basin full of water up to 140, 210, and 250%, then they were weakly negatively correlated thereafter (X = 0.044, 95% CL: 0.027 – 0.061, X^2 = -0.0001, 95% CL: -0.00023 – -0.00007; X = 0.035, 95% CL: 0.027 – 0.042; X^2 = -

0.00008, 95% CL: -0.00011 – -0.00006; X = 0.035, 95% CL: 0.023 – 0.048; X^2 = -0.00007, 95% CL: -0.0001 – -0.00004; respectively). The probability that American bittern occured at a wetland was positively correlated with the percent of the wetland basin full of water (X = 0.017, 95% CL: 0.003 – 0.031).

Passerines

Lark bunting only occurred in the northwestern Great Plains, and grasshopper sparrow was at least 2.1 times more likely to occur at wetlands of the northwestern Great Plains than any other region in North Dakota (Appendix A). However, marsh wren did not occur in the northwestern Great Plans, and common yellowthroat were 2.8 times more likely to occur at wetlands of the Red River Valley than those of the northwestern Great Plains (Appendix A). Region appeared unimportant in explaining the probability of occurrence for bobolink (Appendix A). Marsh wren and common yellowthroat were at least 4.4 and 1.7 times more likely to occur at wetlands that were unmanipulated than those that were cropped or otherwise manipulated. However, lark bunting were 2.9 more likely to occur on wetlands that had been manipulated by burning, haying, or grazing than those that were unmanipulated. The probability that common yellowthroat would occur at a wetland was positively correlated with the percent of the landscape covered by other wetlands (X = 0.306, 95% CL: 0.203 – 0.408). The probability that marsh wren would occur at a wetland was positively correlated with the percent of the wetland basin full of water up to 180%, then it was weakly negatively correlated thereafter (X = 0.02, 95% CL: 0.011 – 0.03, X^2 = -0.00006, 95% CL: -0.0001 – -0.00002). The probability that grasshopper sparrow would occur at a wetland was negatively correlated with the percent of the wetland basin full of water (X = -0.009, 95% CL: -0.015 – -0.003). The probabilities that bobolink, grasshopper sparrow, and marsh wren would occur at a wetland were positively correlated with the percent of the area surrounding the wetland covered in grass (X = 0.106, 95% CL: 0.013 – 0.200; X = 0.093, 95% CL: 0.007 – 0.180; X = 0.133, 95% CL: 0.031 – 0.234; respectively).

Species Richness

Species richness at wetlands was 28, 19, and 17% higher in northwestern Great Plains than that at wetlands of the Red River Valley, Drift Prairie, and Missouri Coteau, respectively (Appendix A). Species richness at wetlands was highest at wetlands with cover classes of 2, 3, or 4, and was at least 15% lower on cropped wetland than those that were unmanipulated or otherwise manipulated. Species richness at wetlands was positively influenced by both the percent of surrounding area covered by other wetlands (X = 0.069, 95% CL: 0.052 – 0.085) and the percent of the wetland basin full of water (X = 0.003, 95% CL: 0.002 – 0.004).

C. Landscape Models

Black Terns

The probability of occurrence of black terns, east of the Missouri River, was negatively correlated with the percent of the wetlands in the landscape that were seasonal or temporary (X = -0.013, 95% CL: -0.023 – -0.003) and the percent of the landscape covered with woodland (X = -0.234, 95% CL: -0.457 – -0.012).

Shorebirds

The probability of occurrence of killdeer east of the Missouri River was negatively correlated with the percent of the landscape covered by grass (X = -0.015, 95% CL: -0.023 – -0.008) and the percent of the landscape covered with woodland (X = -0.104, 95% CL: -0.196 – -0.012). However, none of the parameters we included in our models appeared important in predicting occurrence of killdeer and upland sandpiper in the northwestern Great Plains.

Similarly, none of the parameters we included in our models appeared important in predicting occurrence of upland sandpiper, common snipe, and willet in the area east of the Missouri River.

Ducks and Grebes

We only had an adequate sample of detections to model the redhead occurrence in the areas east of the Missouri River; however, none of the parameters we included in our models appeared important.

Rails, Bitterns, and Coots

The probabilities of occurrence of American bittern and Virginia rail, in the area east of the Missouri River, were negatively and positively correlated, respectively, with the percent of the landscape covered with woodlands (X = -0.462, 95% CL: -0.875 – -0.049; X = 0.054, 95% CL: 0.016 – 0.092). However, none of the parameters we included in our models appeared important for predicting occurrence of sora and American coot in the area east of the Missouri River.

Passerines

The probabilities of occurrence of common yellowthroat and grasshopper sparrow, in the area east of the Missouri River, were negatively correlated with the percent of the wetlands that were seasonal or temporary (X = -0.013, 95% CL: -0.021 – -0.006; X = -0.015, 95% CL: -0.027 – -0.003); however, none of the parameters we included in our models appeared important for predicting occurrence of grasshopper sparrow in northwestern Great Plains. The probabilities of occurrence of lark bunting and bobolink in the northwestern Great Plains were negatively and positively correlated, respectively, with the percent of the landscape covered with woodlands (X = -0.194, 95% CL: -0.346 – -0.041; X = 0.053, 95% CL: 0.003 – 0.103); lark bunting were also negatively correlated with percent cover of unclassified wet areas (X = -0.203, 95% CL: -0.324 –

-0.082). However, none of the parameters we included in our models appeared important for bobolink and marsh wren in the area east of the Missouri River.

Species Richness

The percent of the wetlands on the landscape that were either seasonal or temporary had a weak negative correlation with species richness in the area east of the Missouri River (X = -0.002, 95% CL: -0.004 – -0.0008). The amount of the landscape covered with water had a weak negative correlation with species richness in the northwestern Great Plains (X = -0.029, 95% CL: -0.052 – -0.006).

D. Distribution

Of the 23 species analyzed, 14 occurred in the Red River Valley, 22 occurred in the Drift Prairie (all but lark bunting), 20 in the Missouri Coteau (all but lark bunting, least bittern, and yellow rail), and 18 in the Northwestern Great Plains (all but American avocet, black tern, grebes, least bittern, and marsh wren) (Appendix A).

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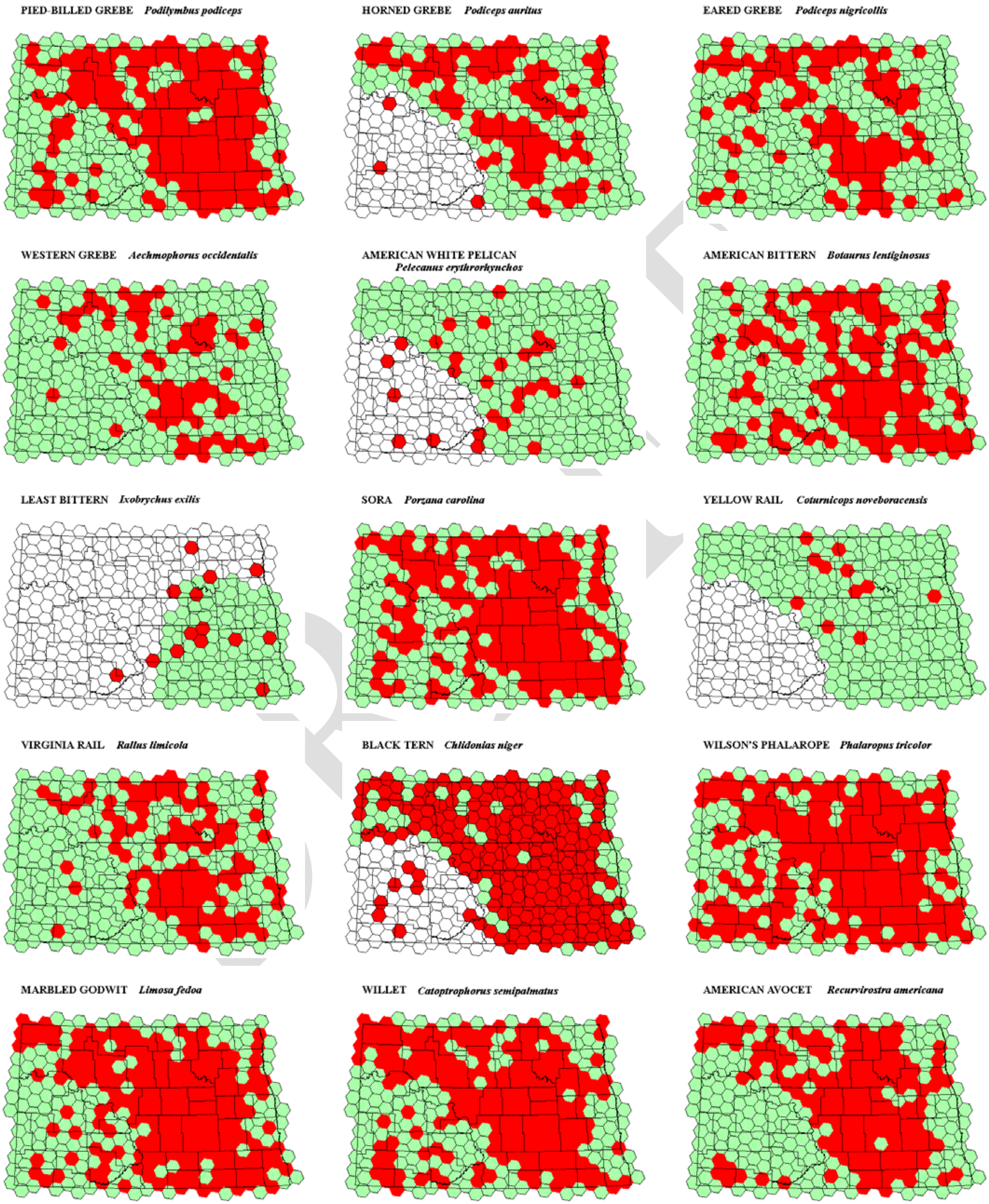


Figure 1. Distribution of target marsh bird species in 635 km^2 hexagons in North Dakota. Gray (green) hexagons represent probable locations, and black (red) hexagons contain at least 1 location record for the species. Data source: North Dakota GAP Analysis Project.

Figure 2. Ecoregions of North Dakota sampled for presence of marsh birds.

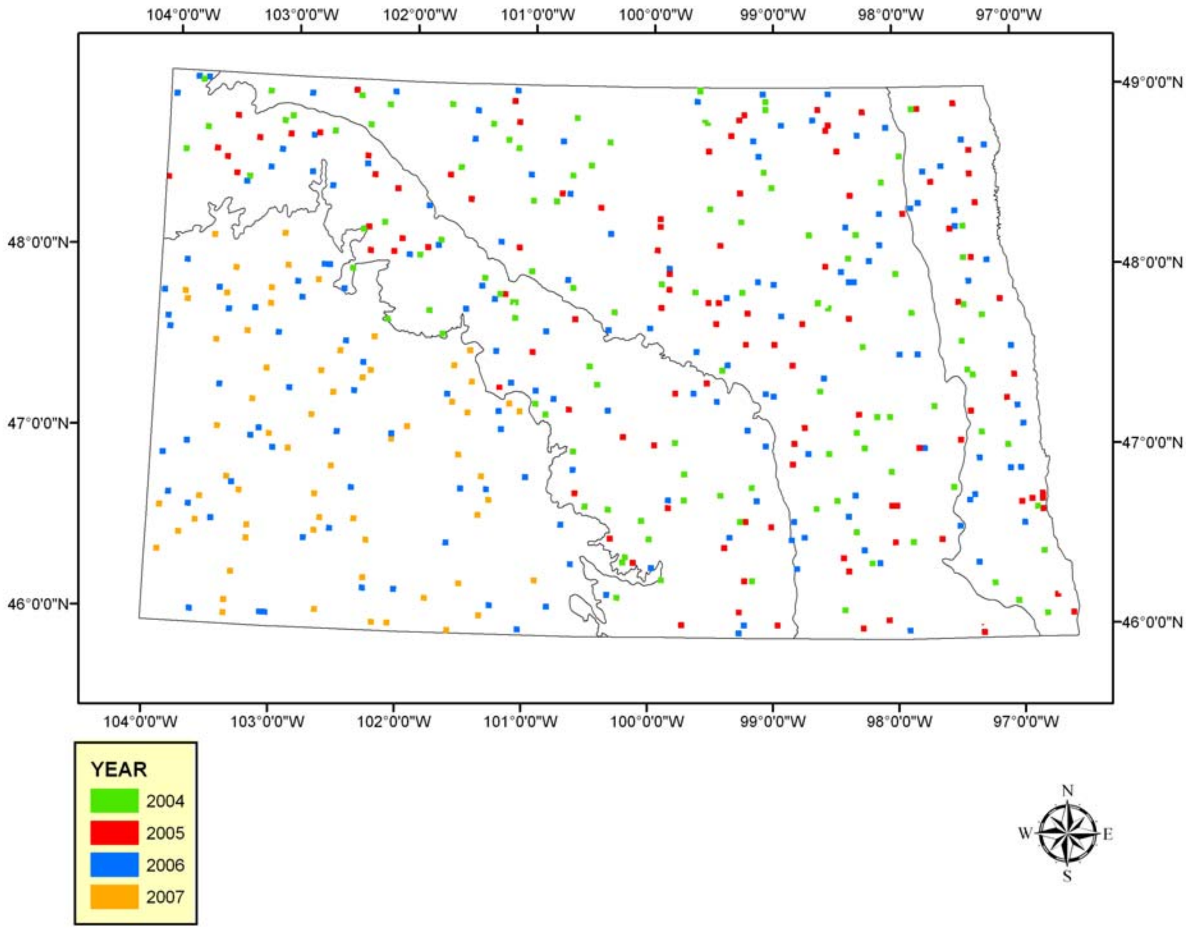


Figure 3. Distribution of 4-square-mile sites at which wetland bird surveys were conducted during 2004-2007 in North Dakota.

Table 1. Focal marsh and shore bird species of North Dakota identified as conservation priorities in state and regional conservation plans.

Species	Focal Species	ND Conservation Priority[1]	Regional Conservation Vulnerability[2]	Regional Priority Score[3]
Pied-billed Grebe	Yes	N/A	Low Risk	N/A
Horned Grebe	Yes	I	High Concern	N/A
Eared Grebe	Yes	N/A	Moderate Concern	N/A
Western Grebe	Yes	N/A	High Concern	N/A
American White Pelican	Yes	I	Moderate Concern	N/A
American Bittern	Yes	I	High Concern	N/A
Least Bittern	Yes	N/A	Moderate Concern	N/A
Sora	Yes	N/A	Low Risk	N/A
Yellow Rail	Yes	I	High Concern	N/A
King Rail	Yes	N/A	High Concern	N/A
Virginia Rail	Yes	N/A	Moderate Concern	N/A
Black Tern	Yes	I	High Concern	N/A
Wilson's Phalarope	Yes	I	N/A	4 (Species of Concern)
Marbled Godwit	Yes	I	N/A	4 (Species of Concern)
Willet	Yes	I	N/A	3
American Avocet	Yes	II	N/A	4 (Species of Concern)
Upland Sandpiper	No	I	N/A	N/A
Grasshopper Sparrow	No	I	N/A	N/A
Lark Bunting	No	I	N/A	N/A
Northern Pintail	No	II	N/A	N/A
Redhead	No	II	N/A	N/A
Bobolink	No	II	N/A	N/A
American Coot	No	N/A	N/A	N/A
Common Yellowthroat	No	N/A	N/A	N/A
Common Snipe	No	N/A	N/A	N/A
Killdeer	No	N/A	N/A	N/A
Marsh Wren	No	N/A	N/A	N/A

1 Priority species of the North Dakota Game & Fish Department's Comprehensive Wildlife Conservation Strategy (Hagen et al. 2005).

2 Regional ranking in the Prairie & Parkland Regional Waterbird Conservation Plan (NAWCP 2003).

3 Regional priority in the Northern Plains/Prairie Potholes Regional Shorebird Conservation Plan (Beyersbergen et al. 2005).

Table 2. Survey type, regions, and sample sizes for focal species with adequate occurrences to model the characteristics of wetlands at or immediately surrounding wetlands that influence their wetland use in North Dakota.

Species	Survey	Regions Modeled	Occurrences	Wetlands Surveyed
black tern	V [a]	RR, DP, MC	100	1858
marbled godwit	V	DP, MC, NP	31	2183
willet	V	RR, DP, MC, NP	51	2488
Wilson's phalarope	V	DP, MC, NP	50	2183
grebe [b]	V	DP, MC	33	1553
redhead	V	DP, MC	45	1553
northern pintail	V	DP, MC, NP	36	2183
American bittern	VCP [c]	DP, OTHER [d]	47	1842
Virginia rail	VCP	RR, DP, MC	74	1321
sora	VCP	RR, DP, MC, NP	250	1842
American coot	VCP	DP, MC, NP	124	1628
upland sandpiper	VCP	DP, MC, NP	109	1628
common snipe	VCP	RR, DP, MC, NP	63	1842
killdeer	VCP	RR, DP, MC, NP	396	1842
marsh wren	VCP	RR, DP, MC	102	1321
common yellowthroat	VCP	RR, DP, MC, NP	209	1842
lark bunting	VCP	NP	58	521
bobolink	VCP	RR, DP, MC, NP	116	1842
grasshopper sparrow	VCP	RR, DP, MC, NP	166	1842

[a] Visual survey data
[b] Eared and pied-billed grebes
[c] Visual and call-play survey data
[d] RR, MC, and NP combined

Table 3. Survey type, regions, and sample sizes for focal species with adequate occurrences to model the characteristics of landscapes that influence their wetland use in North Dakota.

Species	Survey	Regions Modeled	Occurrences	Wetlands Surveyed
black tern	V [a]	DP, MC	91	1420
willet	V	DP, MC	38	1420
redhead	V	DP, MC	42	1420
American bittern	VCP [d]	DP, MC	44	1014
sora	VCP	RR, DP, MC	202	1226
Virginia rail	VCP	RR, DP, MC	69	1226
American coot	VCP	DP, MC	102	1014
upland sandpiper	VCP	RR, DP, MC	36	1226
		NP	53	388
common snipe	VCP	RR, DP, MC	45	1226
killdeer	VCP	RR, DP, MC	260	1226
		NP	82	388
marsh wren	VCP	RR, DP, MC	93	1226
common yellowthroat	VCP	RR, DP, MC	154	1226
lark bunting	VCP	NP	51	388
bobolink	VCP	RR, DP, MC	63	1226
		NP	35	388
grasshopper sparrow	VCP	RR, DP, MC	75	1226
		NP	70	388

[a] Visual survey data
[b] Eared and pied-billed grebes
[c] RR, MC, and NP combined
[d] Visual and call-play survey data

Table 4. Number of wetlands at which all bird species were detected during visual surveys (n=2560) in North Dakota, 2004-2007.

Code	Species	N(wetlands detected)
AGWT	American Green-winged Teal	11
AMAV	American Avocet	11
AMBI	American Bittern	9
AMCO	American Coot	92
AMCR	American Crow	17
AMGO	American Goldfinch	81
AMKE	American Kestrel	2
AMRE	American Redstart	2
AMRO	American Robin	66
AMWI	American Wigeon	29
AMWO	American Woodcock	1
ATSP	American Tree Sparrow	1
AWPE	American White Pelican	15
BAIS	Baird's Sparrow	2
BANS	Bank Swallow	41
BAOR	Baltimore Oriole	3
BARS	Barn Swallow	262
BASA	Baird's Sandpiper	1
BAWW	Black-and-White Warbler	1
BBMA	Black-billed Magpie	1
BCNH	Black-crowned Night-Heron	19
BEKI	Belted Kingfisher	3
BEVI	Bell's Vireo	1
BHCO	Brown-headed Cowbird	141
BHGR	Black-headed Grosbeak	2
BLJA	Blue Jay	1
BLTE	Black Tern	100
BOBO	Bobolink	102
BRBL	Brewer's Blackbird	16
BRTH	Brown Thrasher	17
BUFF	Bufflehead	1
BWTE	Blue-winged Teal	331
CAGO	Canada Goose	17
CAGU	California Gull	6
CANV	Canvasback	21
CCLO	Chestnut-collared Longspur	5
CCSP	Clay-colored Sparrow	48
CEDW	Cedar Waxwing	14
CHSP	Chipping Sparrow	5
CHSW	Chimney Swift	2
CLSW	Cliff Swallow	93
COGR	Common Grackle	198
COHA	Cooper's Hawk	4
COME	Common Merganser	1
CONI	Common Nighthawk	39

COSN	Common Snipe	35
COYE	Common Yellowthroat	71
DCCO	Double-crested Cormorant	9
DICK	Dickcissel	17
DOWO	Downy Woodpecker	6
EABL	Eastern Bluebird	1
EAGR	Eared Grebe	9
EAKI	Eastern Kingbird	267
EATO	Eastern Towhee	1
EUST	European Starling	11
FISP	Field Sparrow	12
FOSP	Fox Sparrow	2
FOTE	Forster's Tern	1
FRGU	Franklin's Gull	13
GADW	Gadwall	152
GBHE	Great Blue Heron	13
GHOW	Great Horned Owl	3
GRCA	Gray Catbird	21
GREG	Great Egret	2
GRSP	Grasshopper Sparrow	76
GRYE	Greater Yellowlegs	13
HASP	Harris's Sparrow	1
HAWO	Hairy Woodpecker	3
HESP	Henslow's Sparrow	1
HOLA	Horned Lark	27
HOME	Hooded Merganser	1
HOSP	House Sparrow	7
HOWR	House Wren	10
HUPA	Gray/Hungarian Partridge	3
KILL	Killdeer	364
LARB	Lark Bunting	46
LASP	Lark Sparrow	12
LAZB	Lazuli Bunting	4
LBDO	Long-billed Dowitcher	5
LCSP	Le Conte's Sparrow	17
LEFL	Least Flycatcher	8
LESA	Least Sandpiper	3
LESC	Lesser Scaup	29
LEYE	Lesser Yellowlegs	15
LOSH	Loggerhead Shrike	5
MAGO	Marbled Godwit	31
MALL	Mallard	322
MAWR	Marsh Wren	50
MERL	Merlin	1
MOBL	Mountain Bluebird	2
MODO	Mourning Dove	241
NOHA	Northern Harrier	13
NOPI	Northern Pintail	37
NOWA	Northern Waterthrush	1
NRWS	Northern Rough-winged Swallow	17

NSHO	Northern Shoveler	100
NSTS	Nelson's Sharp-tailed Sparrow	12
OROR	Orchard Oriole	8
PBGR	Pied-billed Grebe	25
PEFA	Peregrine Falcon	1
PIPL	Piping Plover	1
PRFA	Prairie Falcon	1
RBGR	Rose-breasted Grosbeak	1
RBGU	Ring-billed Gull	26
REDH	Redhead	46
RLHA	Rough-legged Hawk	1
RNDU	Ring-necked Duck	5
RNGR	Red-necked Grebe	1
RODO	Rock Dove	4
RPHE	Ring-necked Pheasant	65
RTHA	Red-tailed Hawk	27
RUDU	Ruddy Duck	59
RWBL	Red-winged Blackbird	1176
SAPH	Say's Phoebe	3
SAVS	Savannah Sparrow	121
SBDO	Short-billed Dowitcher	7
SEOW	Short-eared Owl	1
SESA	Semipalmated Sandpiper	3
SEWR	Sedge Wren	10
SNEG	Snowy Egret	1
SORA	Sora	10
SOSA	Solitary Sandpiper	4
SOSP	Song Sparrow	106
SPSA	Spotted Sandpiper	14
SPTO	Spotted Towhee	8
STGR	Sharp-tailed Grouse	10
SWHA	Swainson's Hawk	5
SWSP	Swamp Sparrow	17
TRES	Tree Swallow	67
TURK	Turkey	2
TUVU	Turkey Vulture	1
UNK	Unknown bird	31
UPSA	Upland Sandpiper	68
VESP	Vesper Sparrow	11
VIRA	Virginia Rail	4
WAVI	Warbling Vireo	1
WBNU	White-breasted Nuthatch	3
WEBL	Western Bluebird	1
WEKI	Western Kingbird	59
WEME	Western Meadowlark	212
WIFL	Willow Flycatcher	4
WILL	Willet	51
WIPH	Wilson's Phalarope	50
WODU	Wood Duck	17
WPWI	Whip-poor-will	2

WRSA	White-rumped Sandpiper	2
YBCH	Yellow-breasted Chat	2
YHBL	Yellow-headed Blackbird	196
YRWA	Yellow-rumped Warbler	1
YSFL	Yellow-shafted Flicker	20
YWAR	Yellow Warbler	42

Table 5. Number of wetlands at which all bird species were detected during call-playback surveys (n=1856) in North Dakota, 2004-2007.

Code	Species	N(wetlands detected)
AMBI	American Bittern	43
AMCO	American Coot	58
AMCR	American Crow	8
AMGO	American Goldfinch	30
AMRO	American Robin	31
AMWI	American Wigeon	1
ATSP	American Tree Sparrow	1
BAIS	Baird's Sparrow	2
BARS	Barn Swallow	4
BCCH	Black-capped Chickadee	1
BCNH	Black-crowned Night-Heron	2
BEKI	Belted Kingfisher	2
BHCO	Brown-headed Cowbird	20
BLJA	Blue Jay	1
BLTE	Black Tern	4
BOBO	Bobolink	51
BRTH	Brown Thrasher	3
BWTE	Blue-winged Teal	1
CAGO	Canada Goose	3
CCSP	Clay-colored Sparrow	59
CHSP	Chipping Sparrow	1
CLSW	Cliff Swallow	1
COGR	Common Grackle	11
CONI	Common Nighthawk	13
COSN	Common Snipe	30
COYE	Common Yellowthroat	153
DICK	Dickcissel	7
EAKI	Eastern Kingbird	25
EATO	Eastern Towhee	1
FISP	Field Sparrow	38
GADW	Gadwall	1
GBHE	Great Blue Heron	2
GHOW	Great Horned Owl	1
GRCA	Gray Catbird	29
GRSP	Grasshopper Sparrow	120
HAWO	Hairy Woodpecker	1
HOLA	Horned Lark	72
HOSP	House Sparrow	1
HOWR	House Wren	5
HUPA	Gray/Hungarian Partridge	3
KILL	Killdeer	106
LARB	Lark Bunting	29
LASP	Lark Sparrow	1
LAZB	Lazuli Bunting	1
LCSP	Le Conte's Sparrow	6

LEBI	Least Bittern	7
LEFL	Least Flycatcher	2
LESC	Lesser Scaup	1
LEYE	Lesser Yellowlegs	1
MAGO	Marbled Godwit	3
MALL	Mallard	17
MAWR	Marsh Wren	63
MODO	Mourning Dove	75
NOHA	Northern Harrier	1
NOPI	Northern Pintail	1
NRWS	Northern Rough-winged Swallow	3
NSHO	Northern Shoveler	1
NSTS	Nelson's Sharp-tailed Sparrow	3
OROR	Orchard Oriole	2
OVEN	Ovenbird	1
PBGR	Pied-billed Grebe	7
RBGU	Ring-billed Gull	1
REVI	Red-eyed Vireo	1
RPHE	Ring-necked Pheasant	109
RTHA	Red-tailed Hawk	4
RUGR	Ruffed Grouse	2
RWBL	Red-winged Blackbird	209
SAVS	Savannah Sparrow	46
SEWR	Sedge Wren	18
SORA	Sora	249
SOSP	Song Sparrow	70
SPSA	Spotted Sandpiper	1
SPTO	Spotted Towhee	3
SWHA	Swainson's Hawk	1
SWSP	Swamp Sparrow	1
TRES	Tree Swallow	1
TURK	Turkey	2
UNK	Unknown bird	4
UPSA	Upland Sandpiper	66
VESP	Vesper Sparrow	8
VIRA	Virginia Rail	74
WBNU	White-breasted Nuthatch	1
WEKI	Western Kingbird	4
WEME	Western Meadowlark	204
WIFL	Willow Flycatcher	9
WILL	Willet	8
WIPH	Wilson's Phalarope	2
YBCH	Yellow-breasted Chat	2
YERA	Yellow Rail	8
YHBL	Yellow-headed Blackbird	46
YSFL	Yellow-shafted Flicker	9
YWAR	Yellow Warbler	24

Table 6. Number of wetlands at which all bird species were detected during transect surveys (n=962) in North Dakota, 2004-2007.

Code	Species	N(wetlands detected)
AGWT	American Green-winged Teal	2
AMAV	American Avocet	5
AMBI	American Bittern	1
AMCO	American Coot	14
AMGO	American Goldfinch	7
AMRO	American Robin	3
AMWI	American Wigeon	3
AWPE	American White Pelican	1
BARS	Barn Swallow	8
BCNH	Black-crowned Night-Heron	4
BHCO	Brown-headed Cowbird	4
BLTE	Black Tern	6
BOBO	Bobolink	4
BRTH	Brown Thrasher	4
BWTE	Blue-winged Teal	57
CAGO	Canada Goose	3
CAGU	California Gull	1
CANV	Canvasback	2
CCSP	Clay-colored Sparrow	6
CLSW	Cliff Swallow	1
COGR	Common Grackle	4
CONI	Common Nighthawk	2
COSN	Common Snipe	12
COYE	Common Yellowthroat	17
DICK	Dickcissel	2
EAKI	Eastern Kingbird	7
EUST	European Starling	1
FISP	Field Sparrow	1
GADW	Gadwall	23
GRCA	Gray Catbird	1
GRSP	Grasshopper Sparrow	5
GRYE	Greater Yellowlegs	2
HOLA	Horned Lark	4
HOWR	House Wren	1
HUPA	Gray/Hungarian Partridge	1
KILL	Killdeer	33
LARB	Lark Bunting	2
LASP	Lark Sparrow	2
LAZB	Lazuli Bunting	1
LCSP	Le Conte's Sparrow	2
LESA	Least Sandpiper	1
LEYE	Lesser Yellowlegs	1
MAGO	Marbled Godwit	2
MALL	Mallard	46
MAWR	Marsh Wren	30

MODO	Mourning Dove	14
NADA	Notheing found	541
NOHA	Northern Harrier	1
NOPI	Northern Pintail	6
NSHO	Northern Shoveler	6
NSTS	Nelson's Sharp-tailed Sparrow	1
OROR	Orchard Oriole	1
PBGR	Pied-billed Grebe	1
REDH	Redhead	3
RPHE	Ring-necked Pheasant	8
RUDU	Ruddy Duck	1
RWBL	Red-winged Blackbird	131
SAVS	Savannah Sparrow	9
SBDO	Short-billed Dowitcher	1
SEOW	Short-eared Owl	1
SEWR	Sedge Wren	3
SORA	Sora	24
SOSP	Song Sparrow	14
SPTO	Spotted Towhee	1
STGR	Sharp-tailed Grouse	6
SWHA	Swainson's Hawk	1
SWSP	Swamp Sparrow	2
TRES	Tree Swallow	5
UNK	Unknown Bird	5
UPSA	Upland Sandpiper	10
VESP	Vesper Sparrow	1
VIRA	Virginia Rail	9
WEKI	Western Kingbird	5
WEME	Western Meadowlark	10
WIFL	Willow Flycatcher	2
WILL	Willet	5
WIPH	Wilson's Phalarope	11
YERA	Yellow Rail	4
YHBL	Yellow-headed Blackbird	30
YSFL	Yellow-shafted Flicker	2
YWAR	Yellow Warbler	6

Table 7. Number of wetlands at which all bird species were detected during visual and call-playback surveys combined (n=1856) in North Dakota, 2004-2007.

Code	Species	N(wetlands detected)
AGWT	American Green-winged Teal	10
AMAV	American Avocet	8
AMBI	American Bittern	47
AMCO	American Coot	127
AMCR	American Crow	23
AMGO	American Goldfinch	97
AMKE	American Kestrel	2
AMRE	American Redstart	2
AMRO	American Robin	88
AMWI	American Wigeon	27
AMWO	American Woodcock	1
ATSP	American Tree Sparrow	2
AWPE	American White Pelican	14
BAIS	Baird's Sparrow	3
BANS	Bank Swallow	38
BAOR	Baltimore Oriole	3
BARS	Barn Swallow	256
BASA	Baird's Sandpiper	1
BAWW	Black-and-White Warbler	1
BBMA	Black-billed Magpie	1
BCCH	Black-capped Chickadee	1
BCNH	Black-crowned Night-Heron	19
BEKI	Belted Kingfisher	4
BEVI	Bell's Vireo	1
BHCO	Brown-headed Cowbird	135
BHGR	Black-headed Grosbeak	2
BLJA	Blue Jay	2
BLTE	Black Tern	99
BOBO	Bobolink	116
BRBL	Brewer's Blackbird	10
BRTH	Brown Thrasher	20
BUFF	Bufflehead	1
BWTE	Blue-winged Teal	300
CAGO	Canada Goose	18
CAGU	California Gull	5
CANV	Canvasback	20
CCLO	Chestnut-collared Longspur	5
CCSP	Clay-colored Sparrow	88
CEDW	Cedar Waxwing	13
CHSP	Chipping Sparrow	6
CHSW	Chimney Swift	2
CLSW	Cliff Swallow	87
COGR	Common Grackle	189
COHA	Cooper's Hawk	4

COME	Common Merganser	1
CONI	Common Nighthawk	46
COSN	Common Snipe	65
COYE	Common Yellowthroat	209
DCCO	Double-crested Cormorant	8
DICK	Dickcissel	20
DOWO	Downy Woodpecker	5
EABL	Eastern Bluebird	1
EAGR	Eared Grebe	9
EAKI	Eastern Kingbird	260
EATO	Eastern Towhee	2
EUST	European Starling	11
FISP	Field Sparrow	44
FOSP	Fox Sparrow	2
FOTE	Forster's Tern	1
FRGU	Franklin's Gull	11
GADW	Gadwall	139
GBHE	Great Blue Heron	15
GHOW	Great Horned Owl	4
GRCA	Gray Catbird	46
GREG	Great Egret	1
GRSP	Grasshopper Sparrow	167
GRYE	Greater Yellowlegs	12
HASP	Harris's Sparrow	1
HAWO	Hairy Woodpecker	4
HESP	Henslow's Sparrow	1
HOLA	Horned Lark	91
HOME	Hooded Merganser	1
HOSP	House Sparrow	8
HOWR	House Wren	12
HUPA	Gray/Hungarian Partridge	6
KILL	Killdeer	399
LARB	Lark Bunting	58
LASP	Lark Sparrow	13
LAZB	Lazuli Bunting	5
LBDO	Long-billed Dowitcher	5
LCSP	Le Conte's Sparrow	19
LEBI	Least Bittern	7
LEFL	Least Flycatcher	8
LESA	Least Sandpiper	3
LESC	Lesser Scaup	27
LEYE	Lesser Yellowlegs	12
LOSH	Loggerhead Shrike	5
MAGO	Marbled Godwit	28
MALL	Mallard	308
MAWR	Marsh Wren	102
MERL	Merlin	1
MOBL	Mountain Bluebird	1
MODO	Mourning Dove	278
NOHA	Northern Harrier	11

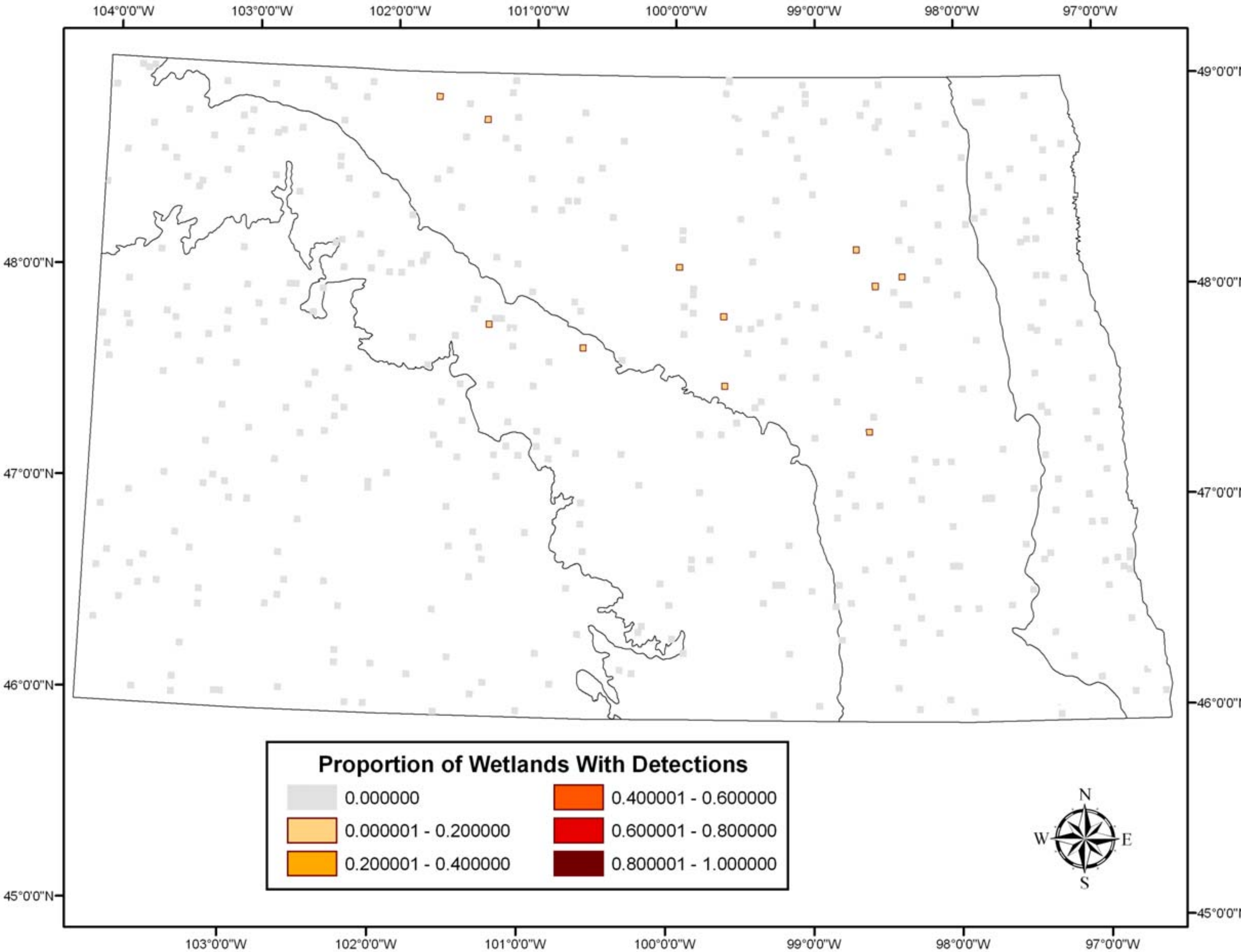
NOPI	Northern Pintail	36
NOWA	Northern Waterthrush	1
NRWS	Northern Rough-winged Swallow	20
NSHO	Northern Shoveler	92
NSTS	Nelson's Sharp-tailed Sparrow	12
OROR	Orchard Oriole	10
OVEN	Ovenbird	1
PBGR	Pied-billed Grebe	30
PEFA	Peregrine Falcon	1
PIPL	Piping Plover	1
PRFA	Prairie Falcon	1
RBGR	Rose-breasted Grosbeak	0
RBGU	Ring-billed Gull	24
REDH	Redhead	46
REVI	Red-eyed Vireo	1
RLHA	Rough-legged Hawk	1
RNDU	Ring-necked Duck	5
RNGR	Red-necked Grebe	1
RODO	Rock Dove	4
RPHE	Ring-necked Pheasant	152
RTHA	Red-tailed Hawk	28
RUDU	Ruddy Duck	56
RUGR	Ruffed Grouse	2
RWBL	Red-winged Blackbird	1151
SAPH	Say's Phoebe	3
SAVS	Savannah Sparrow	112
SBDO	Short-billed Dowitcher	7
SEOW	Short-eared Owl	1
SESA	Semipalmated Sandpiper	3
SEWR	Sedge Wren	26
SNEG	Snowy Egret	1
SORA	Sora	254
SOSA	Solitary Sandpiper	4
SOSP	Song Sparrow	151
SPSA	Spotted Sandpiper	14
SPTO	Spotted Towhee	11
STGR	Sharp-tailed Grouse	9
SWHA	Swainson's Hawk	5
SWSP	Swamp Sparrow	18
TRES	Tree Swallow	65
TURK	Turkey	4
TUVU	Turkey Vulture	1
UNK	Unknown bird	33
UPSA	Upland Sandpiper	114
VESP	Vesper Sparrow	18
VIRA	Virginia Rail	76
WAVI	Warbling Vireo	1
WBNU	White-breasted Nuthatch	4
WEBL	Western Bluebird	1
WEKI	Western Kingbird	56

WEME	Western Meadowlark	348
WIFL	Willow Flycatcher	13
WILL	Willet	51
WIPH	Wilson's Phalarope	49
WODU	Wood Duck	17
WPWI	Whip-poor-will	2
WRSA	White-rumped Sandpiper	2
YBCH	Yellow-breasted Chat	4
YERA	Yellow Rail	8
YHBL	Yellow-headed Blackbird	215
YRWA	Yellow-rumped Warbler	1
YSFL	Yellow-shafted Flicker	25
YWAR	Yellow Warbler	64

Appendix A

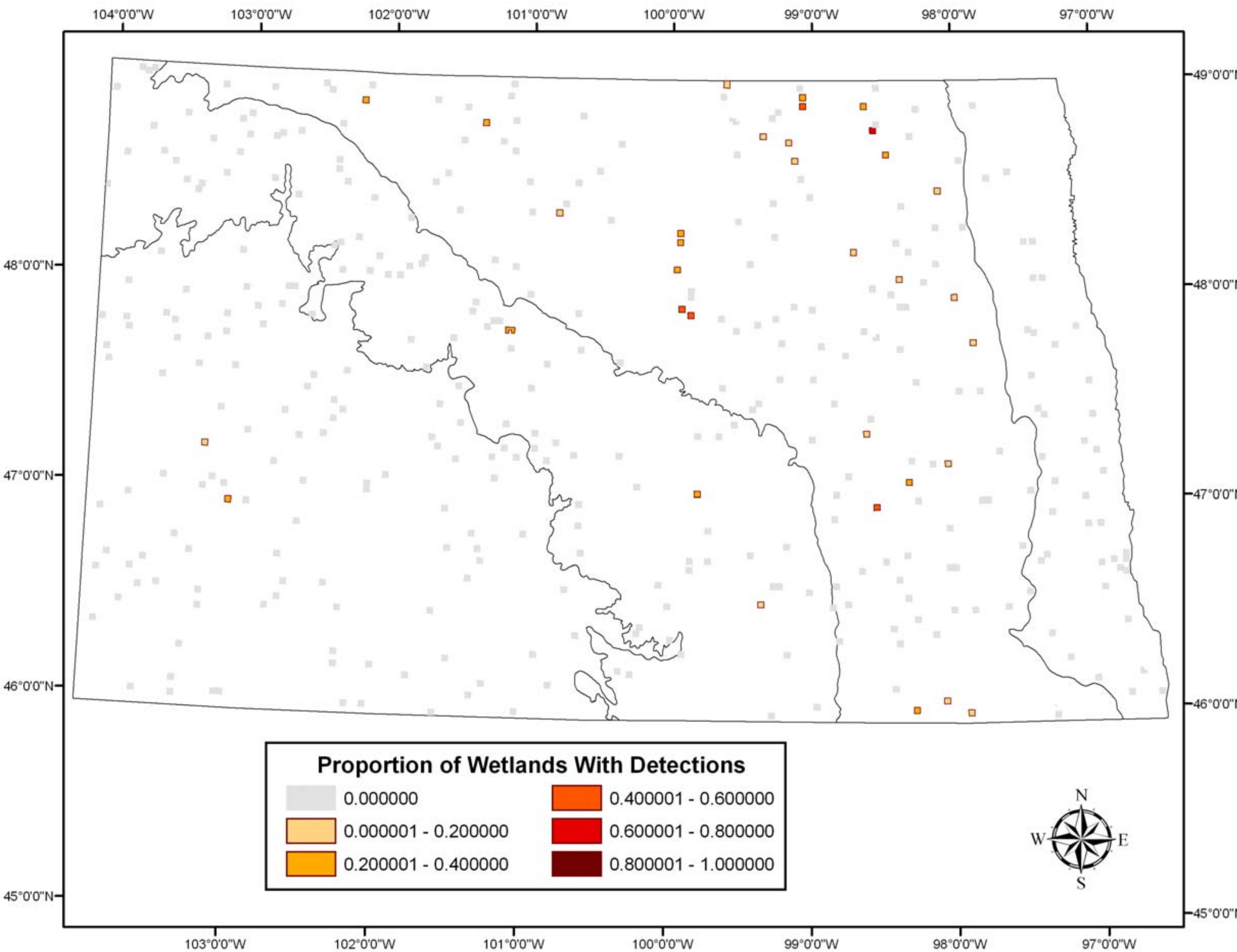
Distribution of Focal Species as Detected by Visual and Call-Playback Wetland Surveys in North Dakota

American avocet

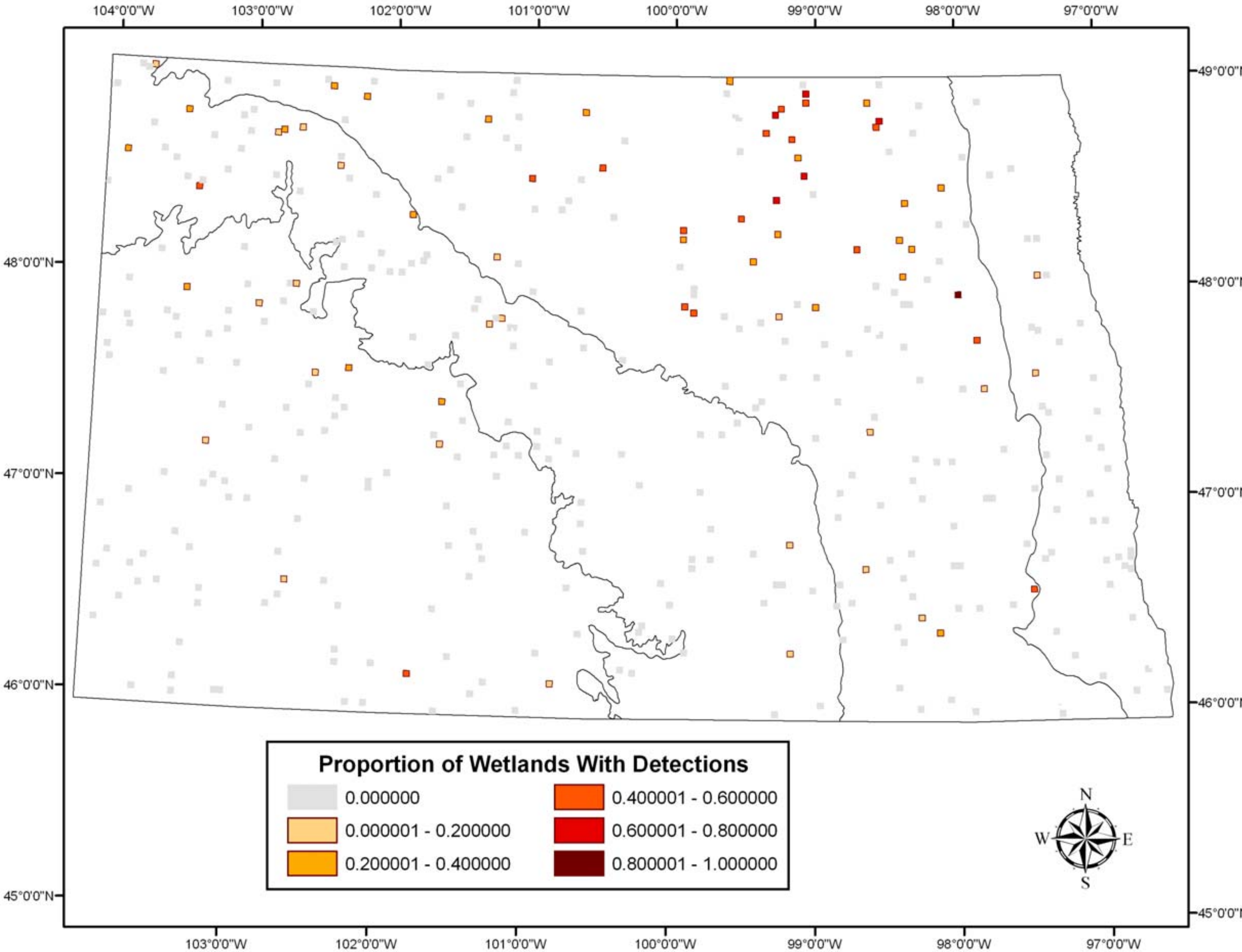


USGS

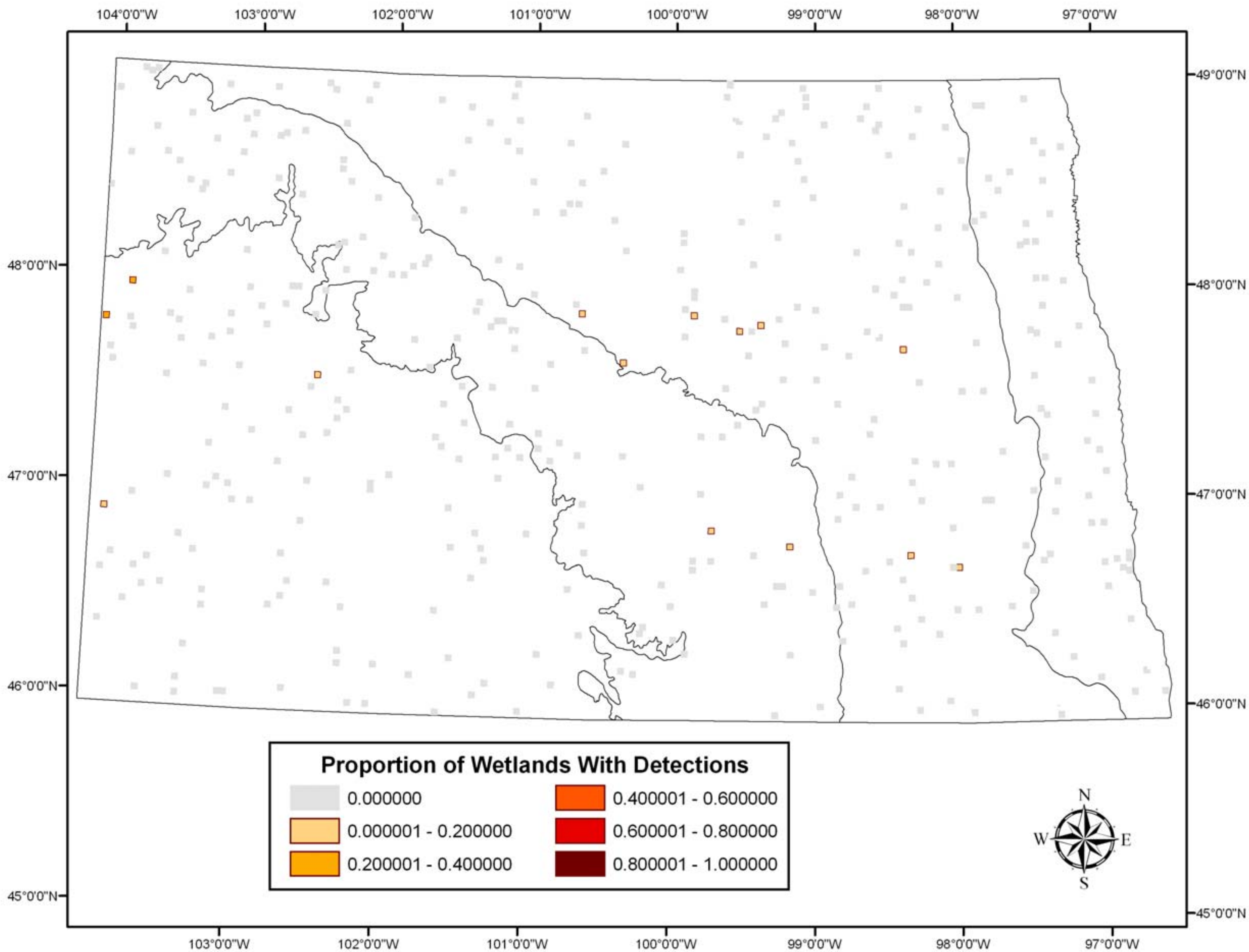
American bittern



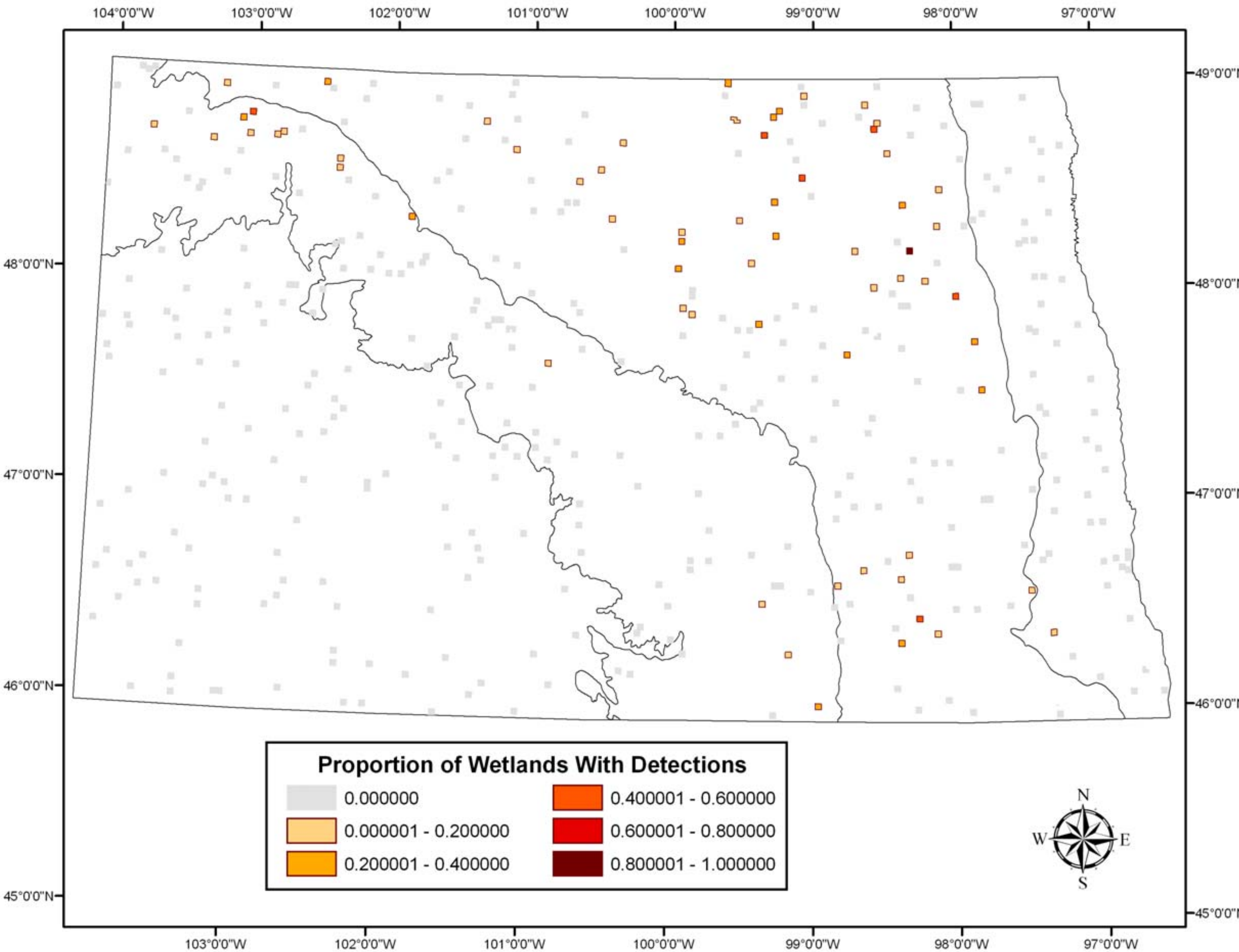
American coot



American white pelican



Black tern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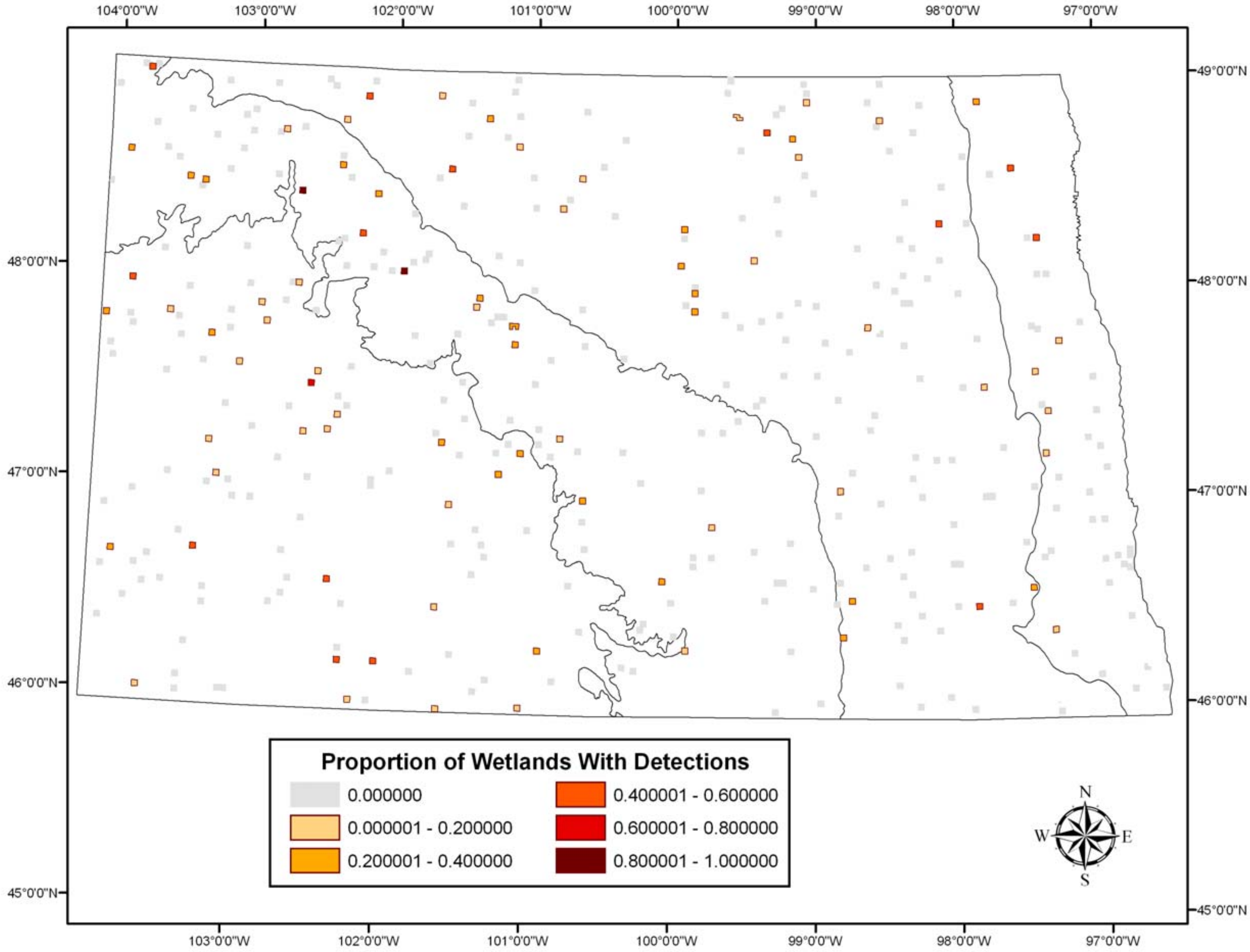
98°0'0"W
97°0'0"W
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
W
E
S

Bobolink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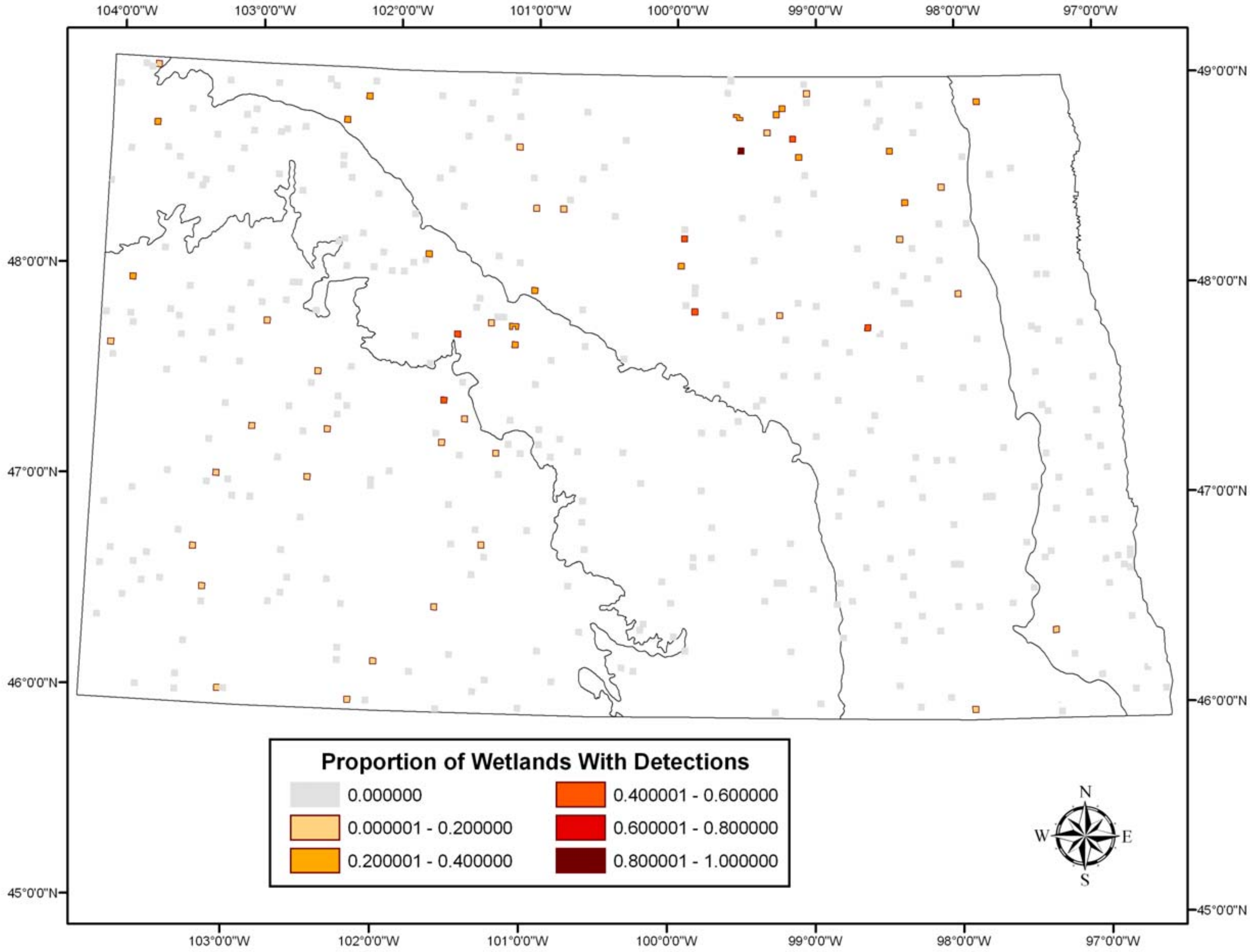
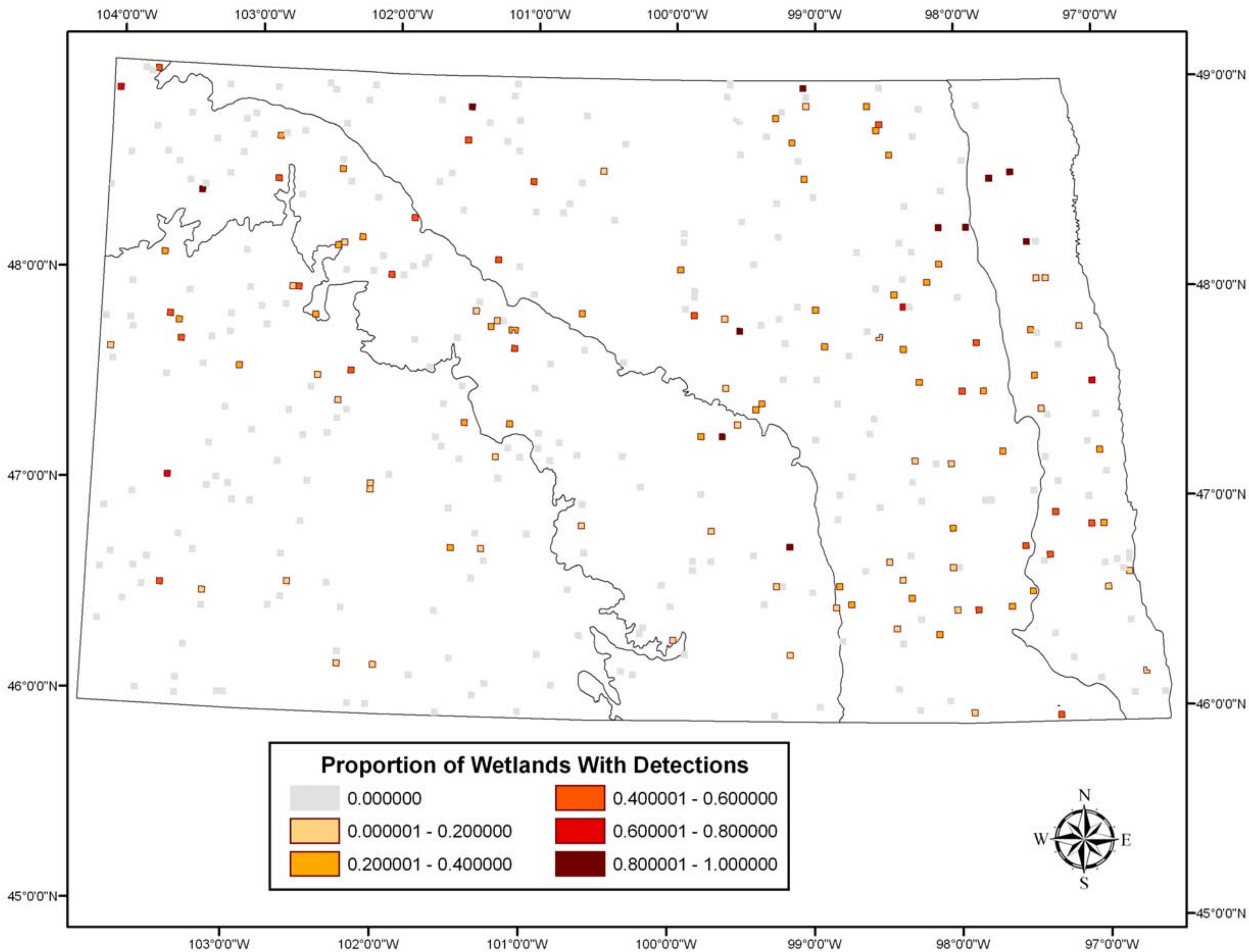
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
E
S
W

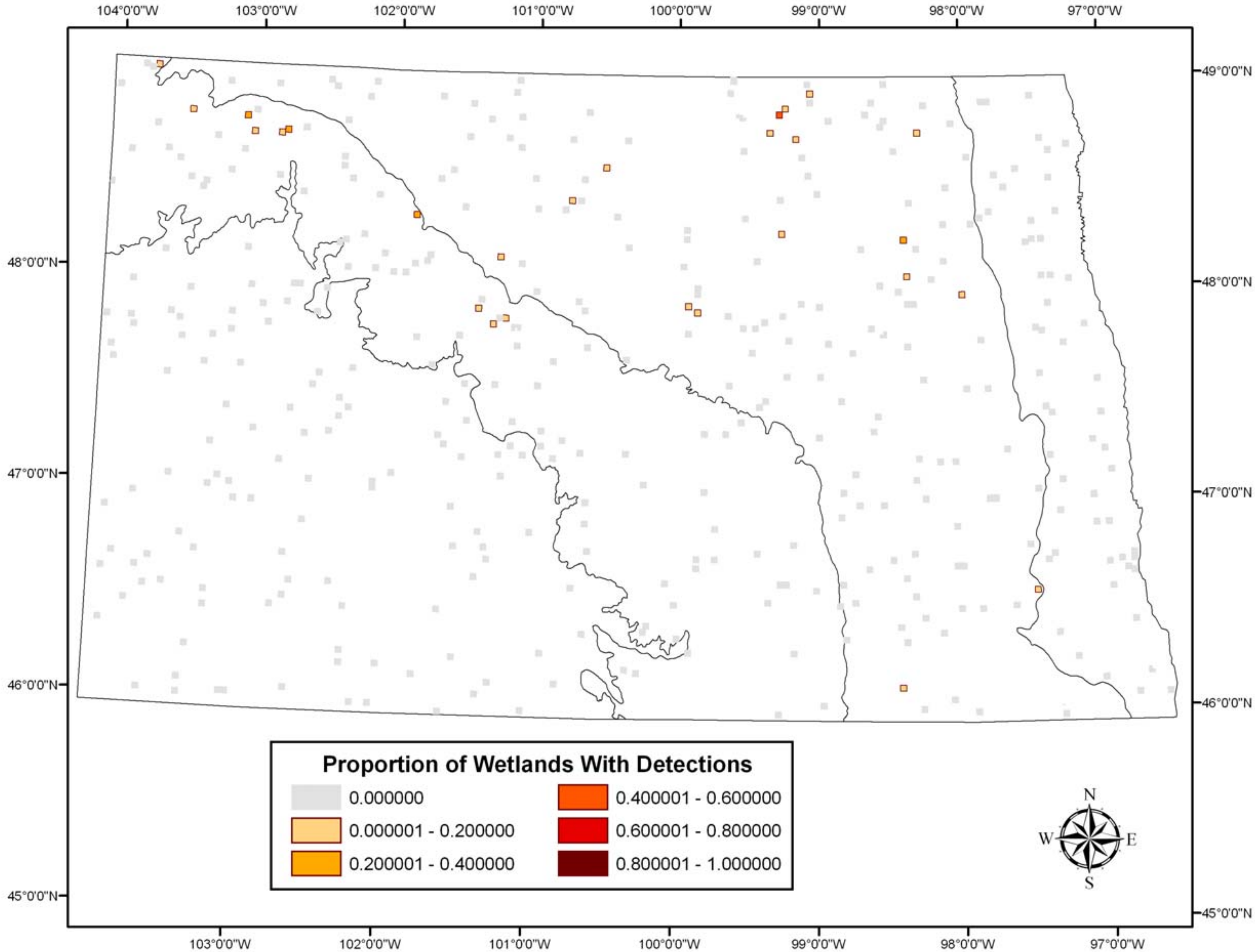
Common snipe



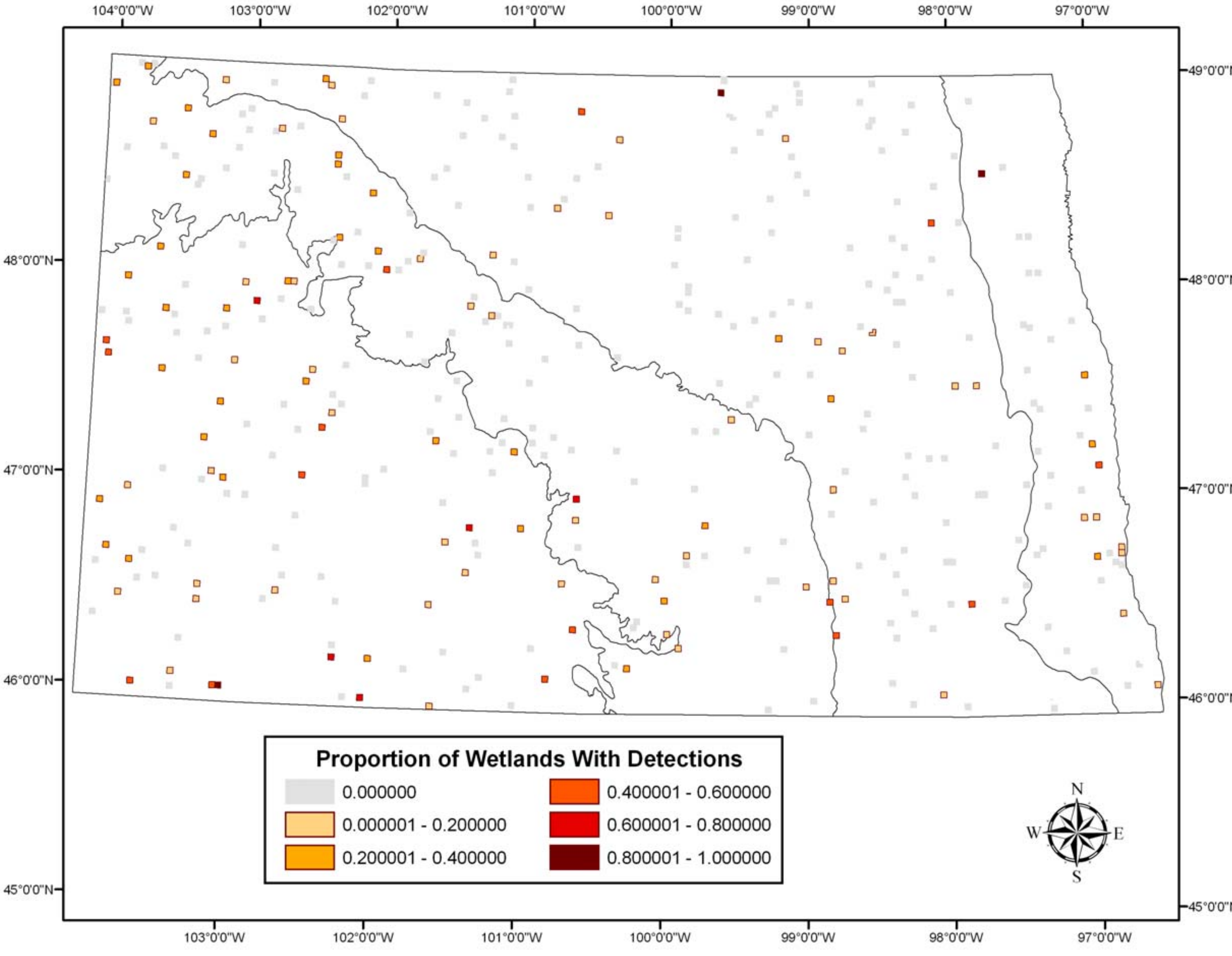
Common yellowthroat



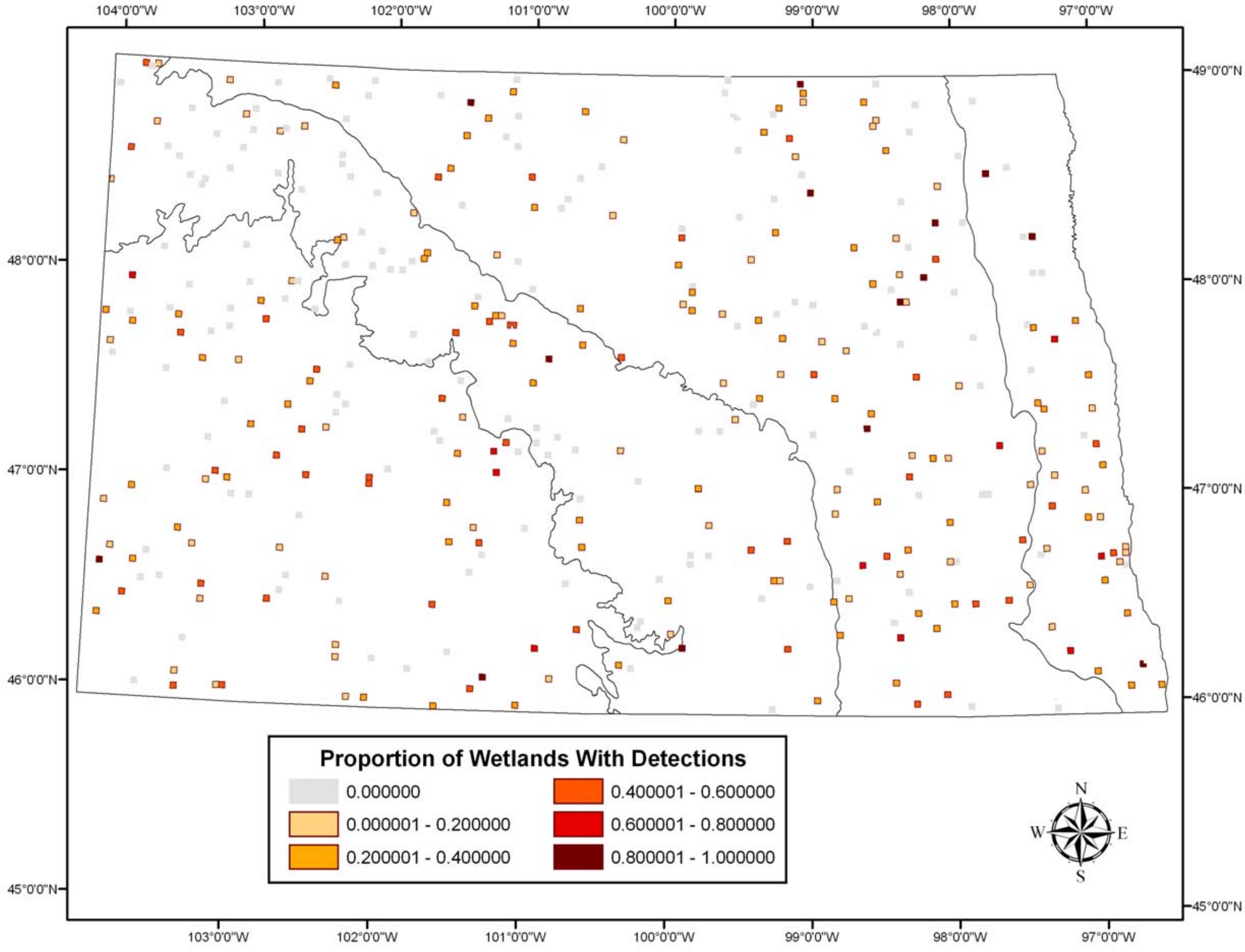
Grebes (Pied-billed and Horned)



Grasshopper sparrow



Killdeer



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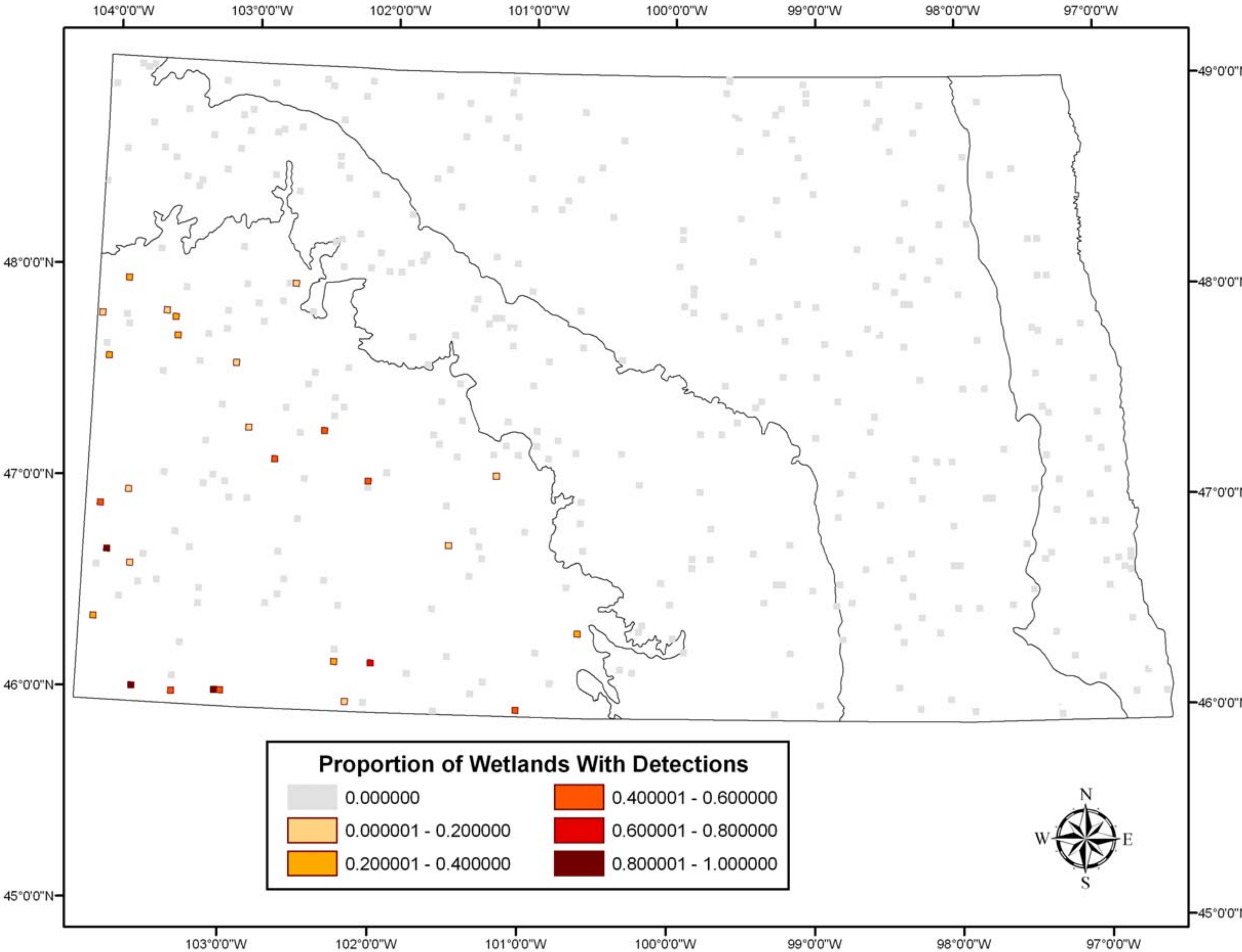
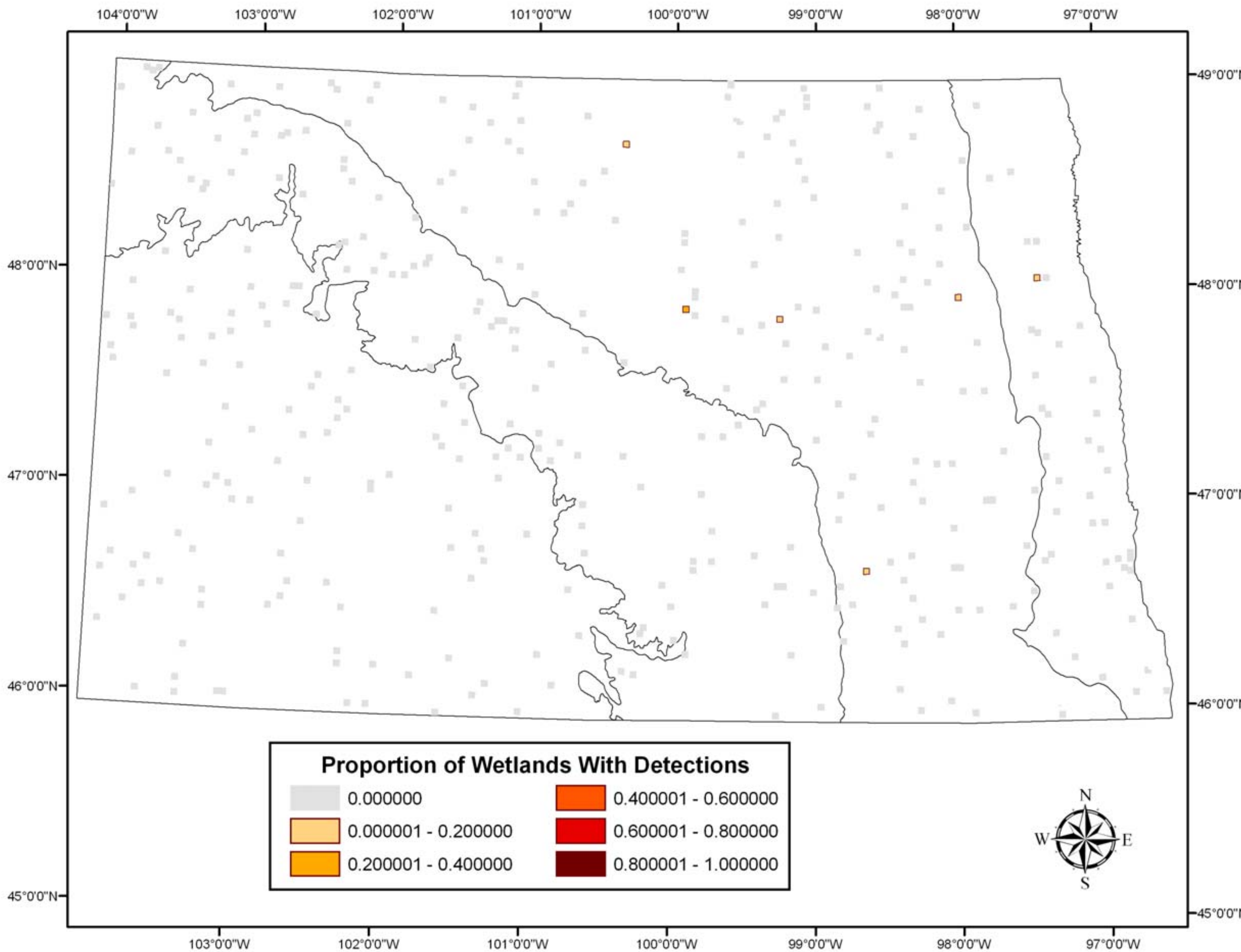
97°0'0"W
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
W
E
S

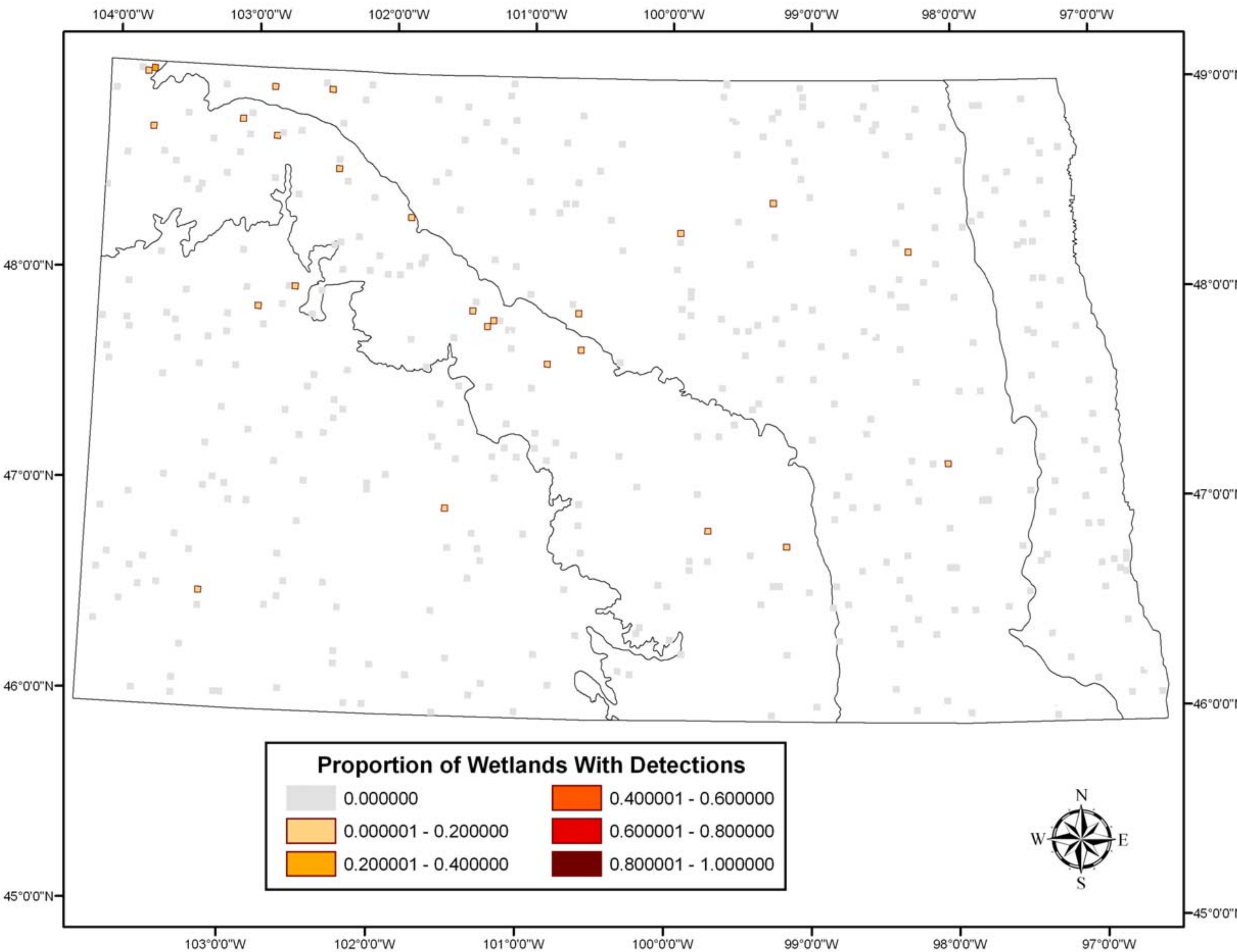
Lark Bunting



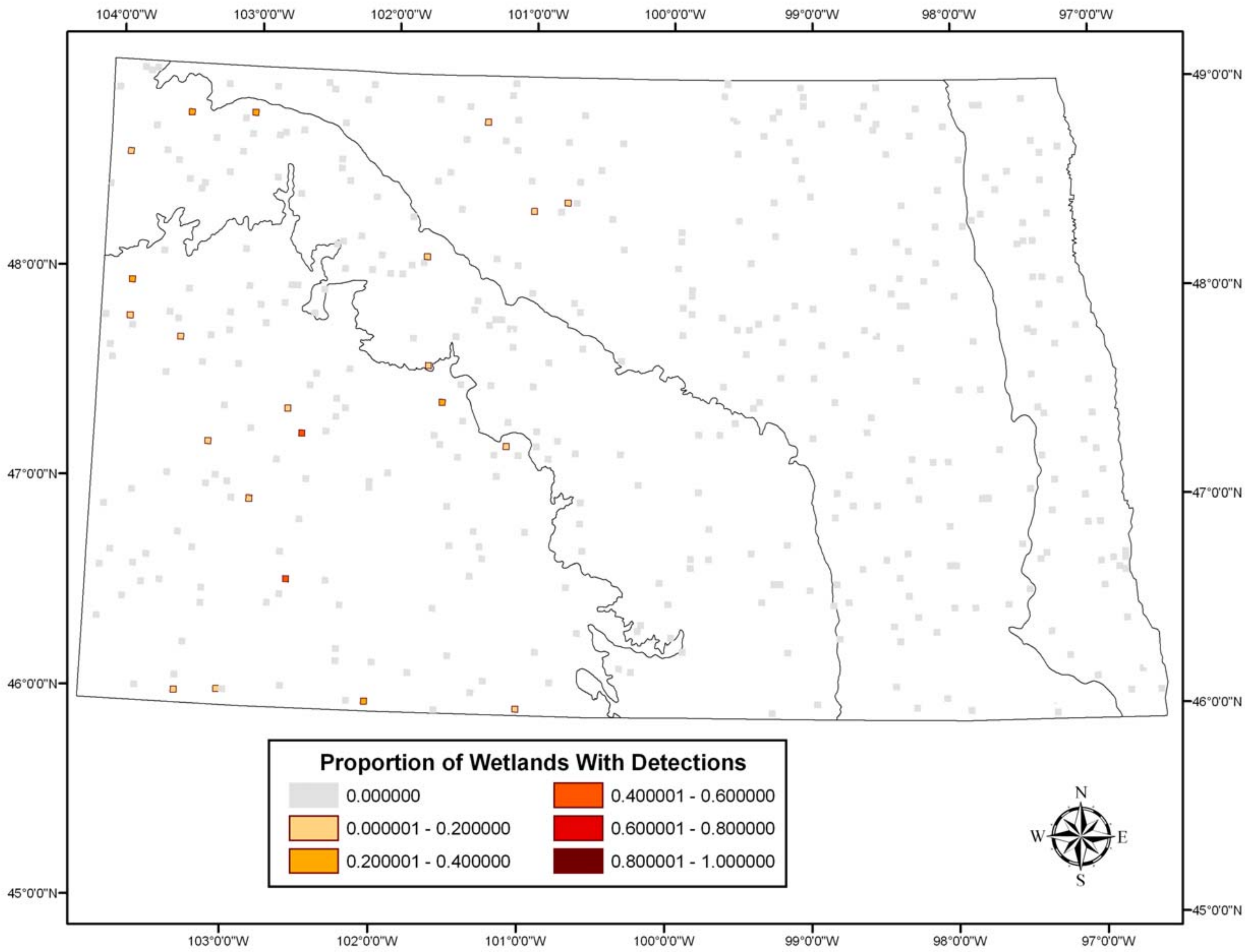
Least bittern



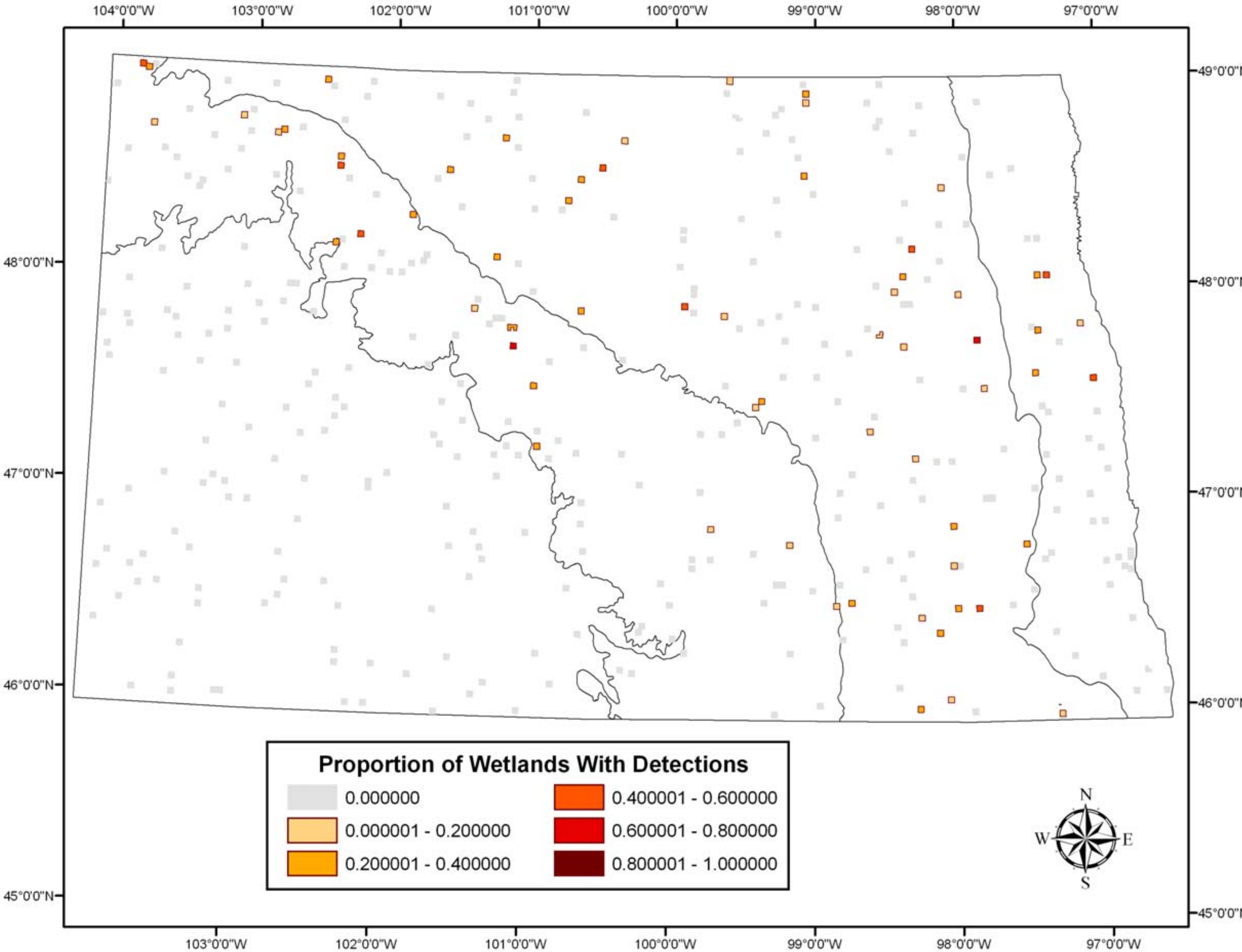
Lesser scaup



Marbled godwit



Marsh wren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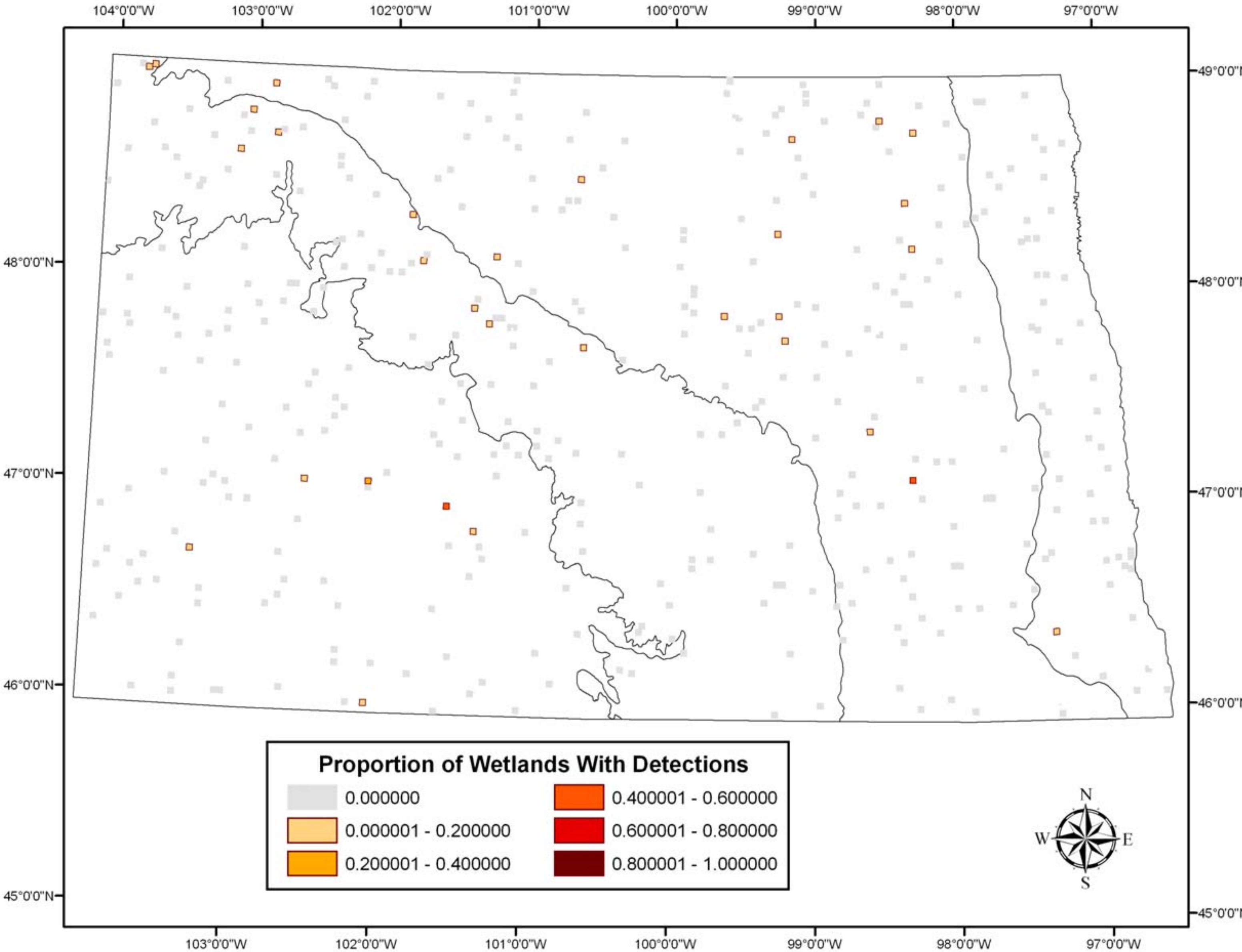
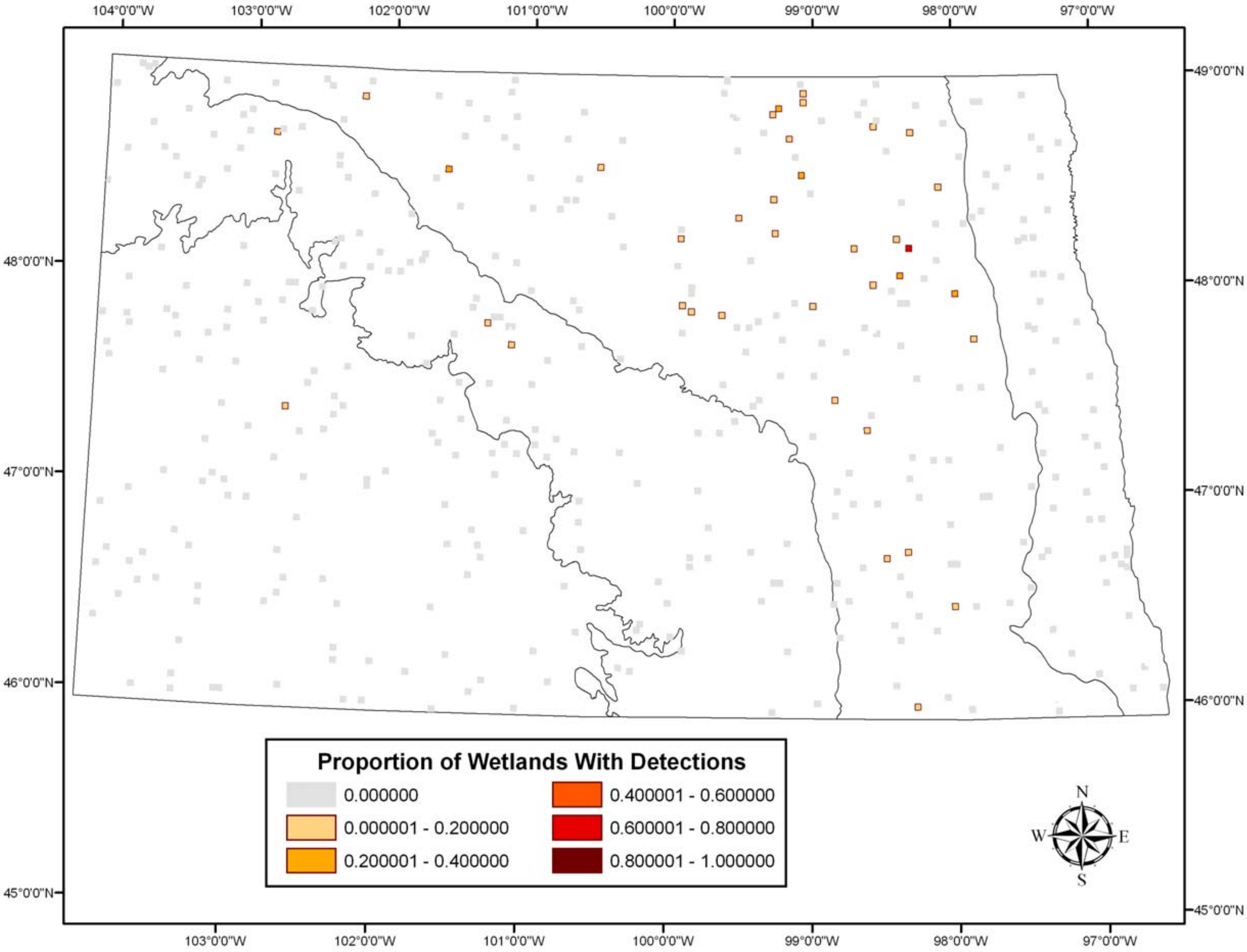
97°0'0"W
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
S
E
W

Northern pintail



Redhead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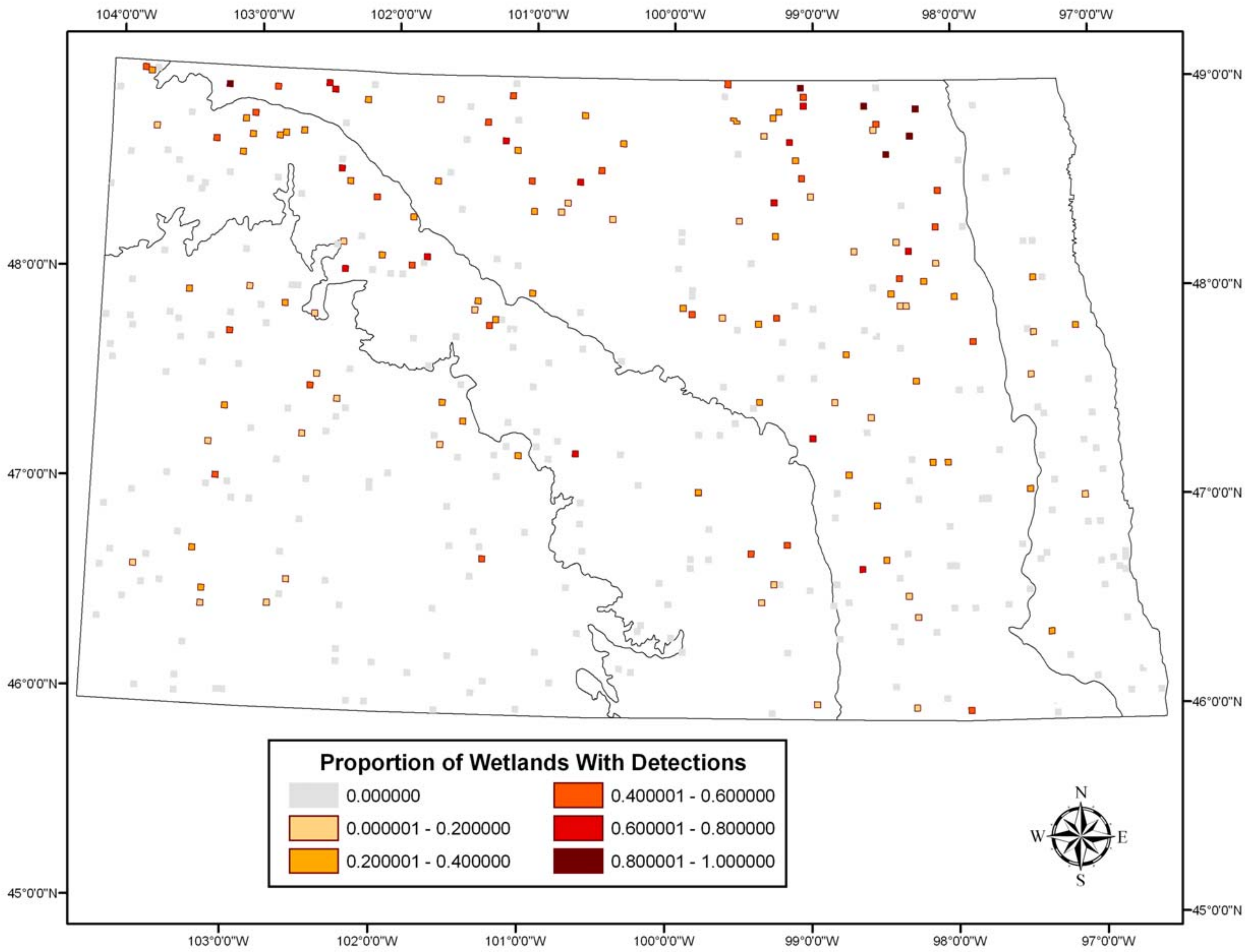
97°0'0"W
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
W
E
S

Sora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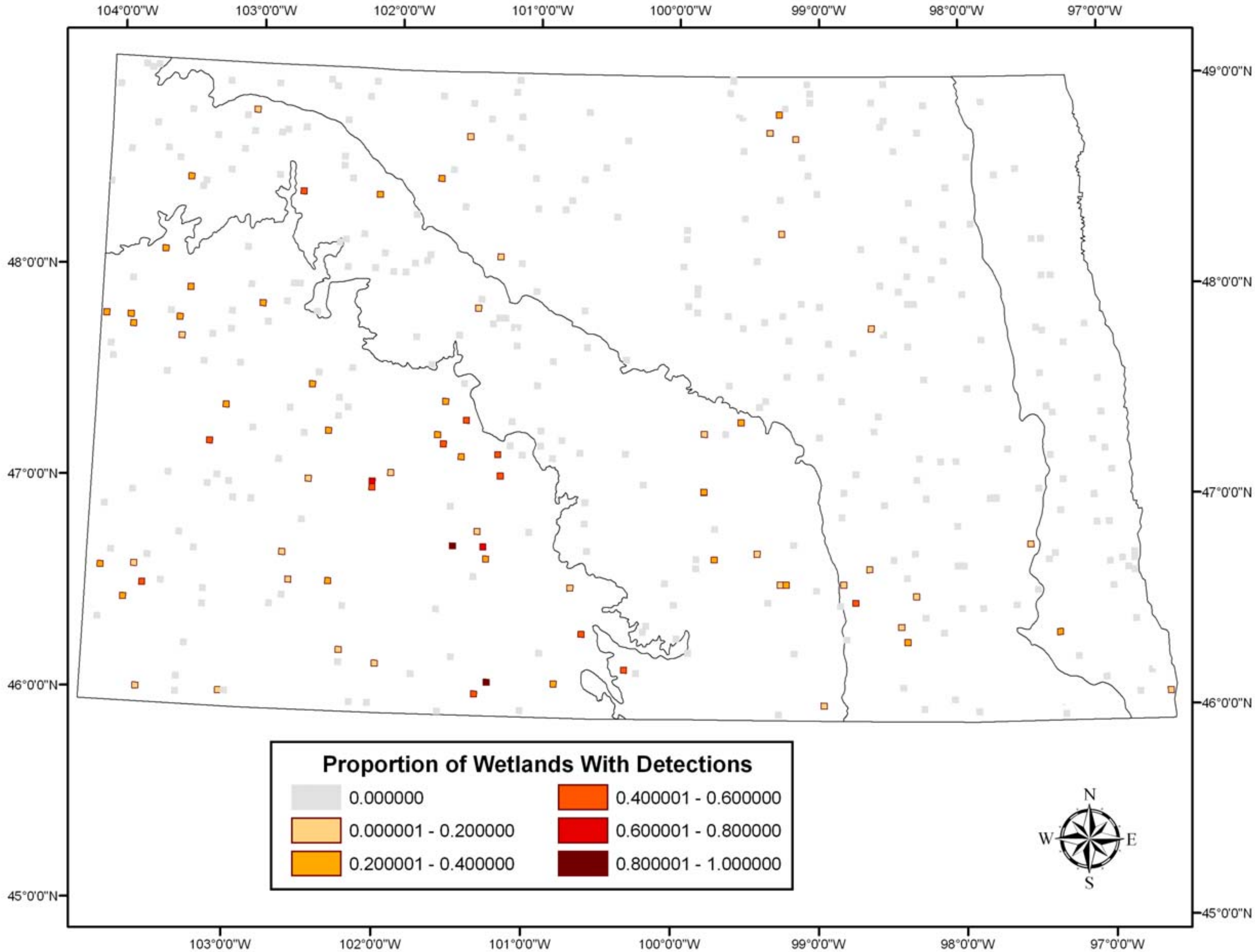
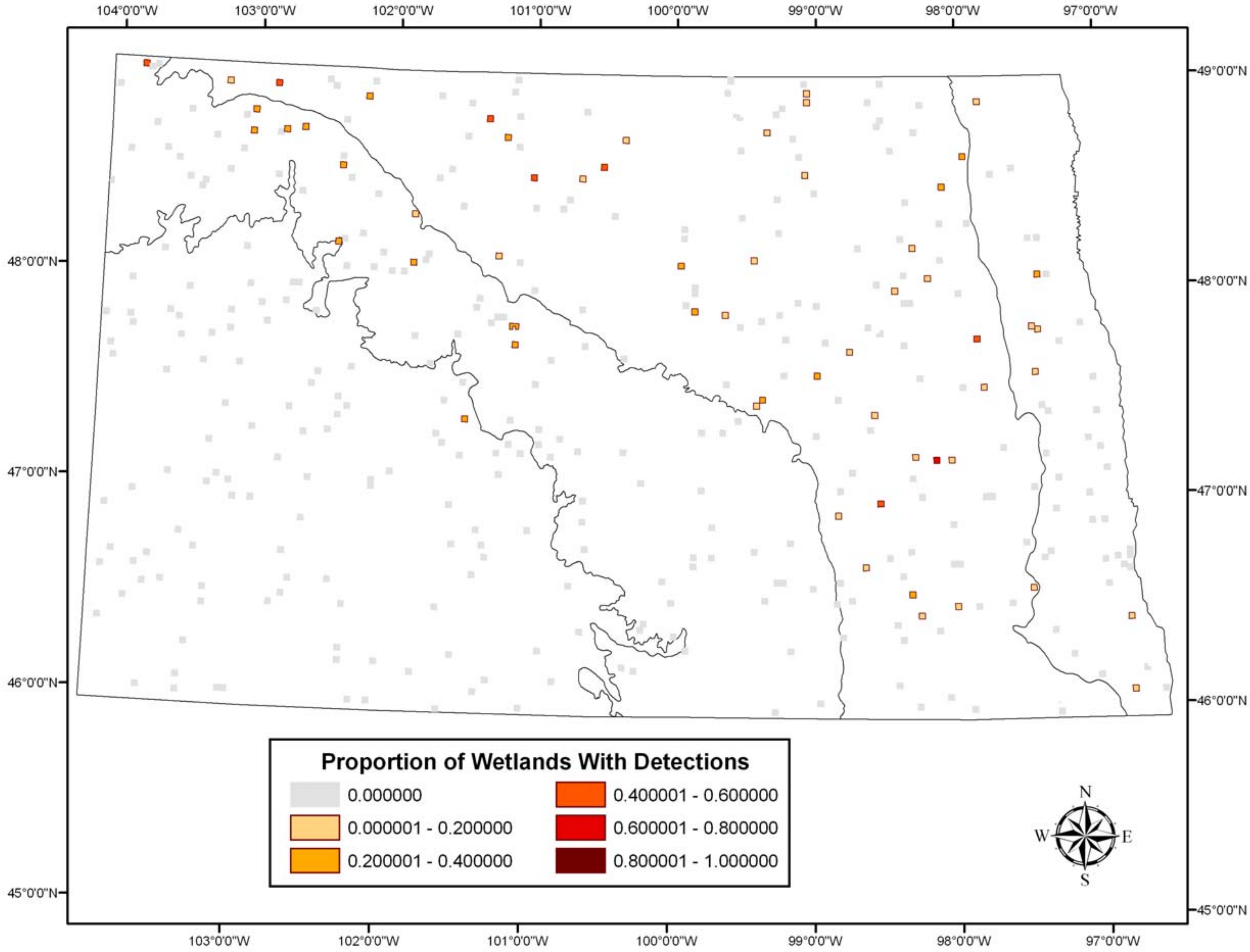
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
W
E
S

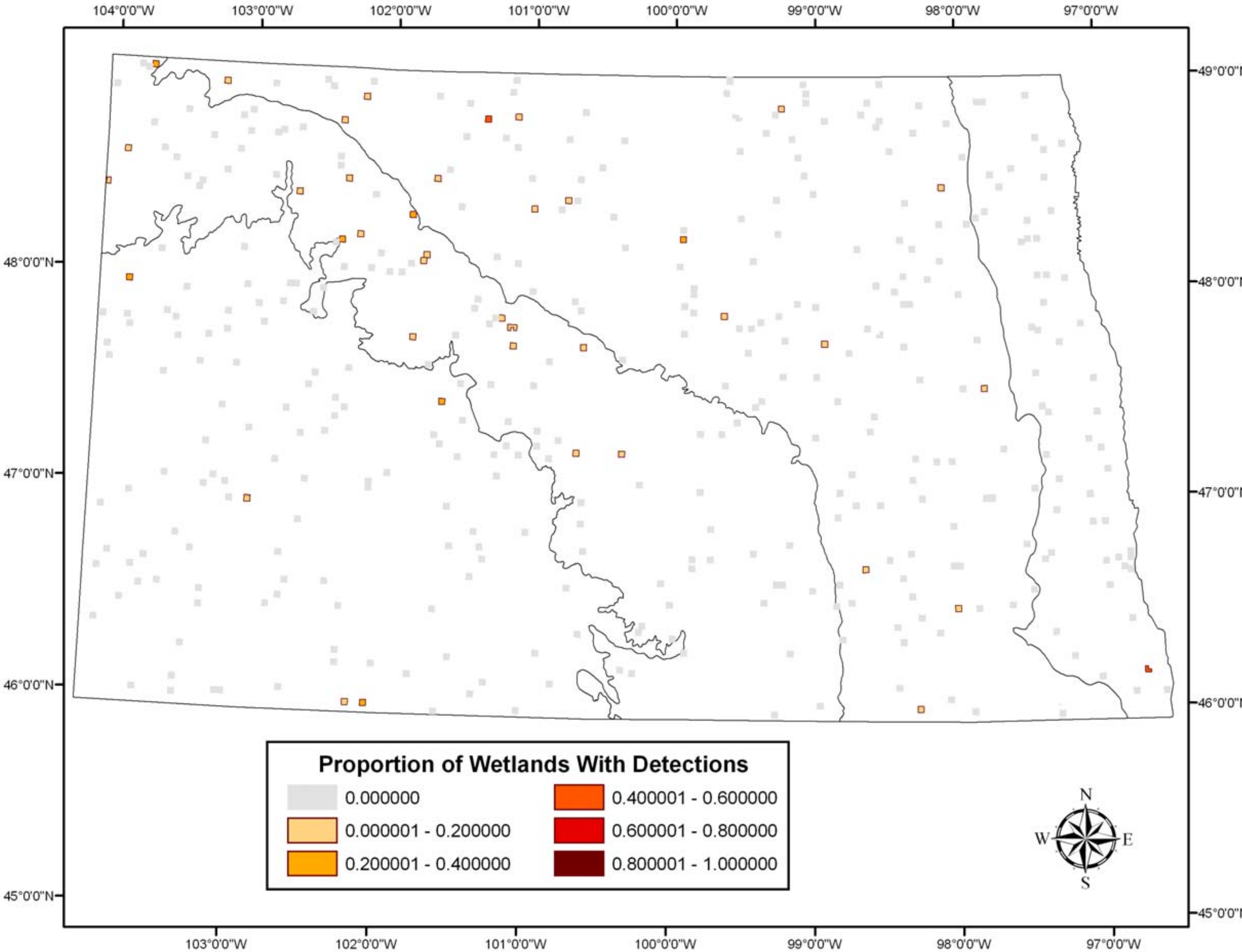
Upland sandpiper



Virginia rail



Willet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49°0'0"N
48°0'0"N
47°0'0"N
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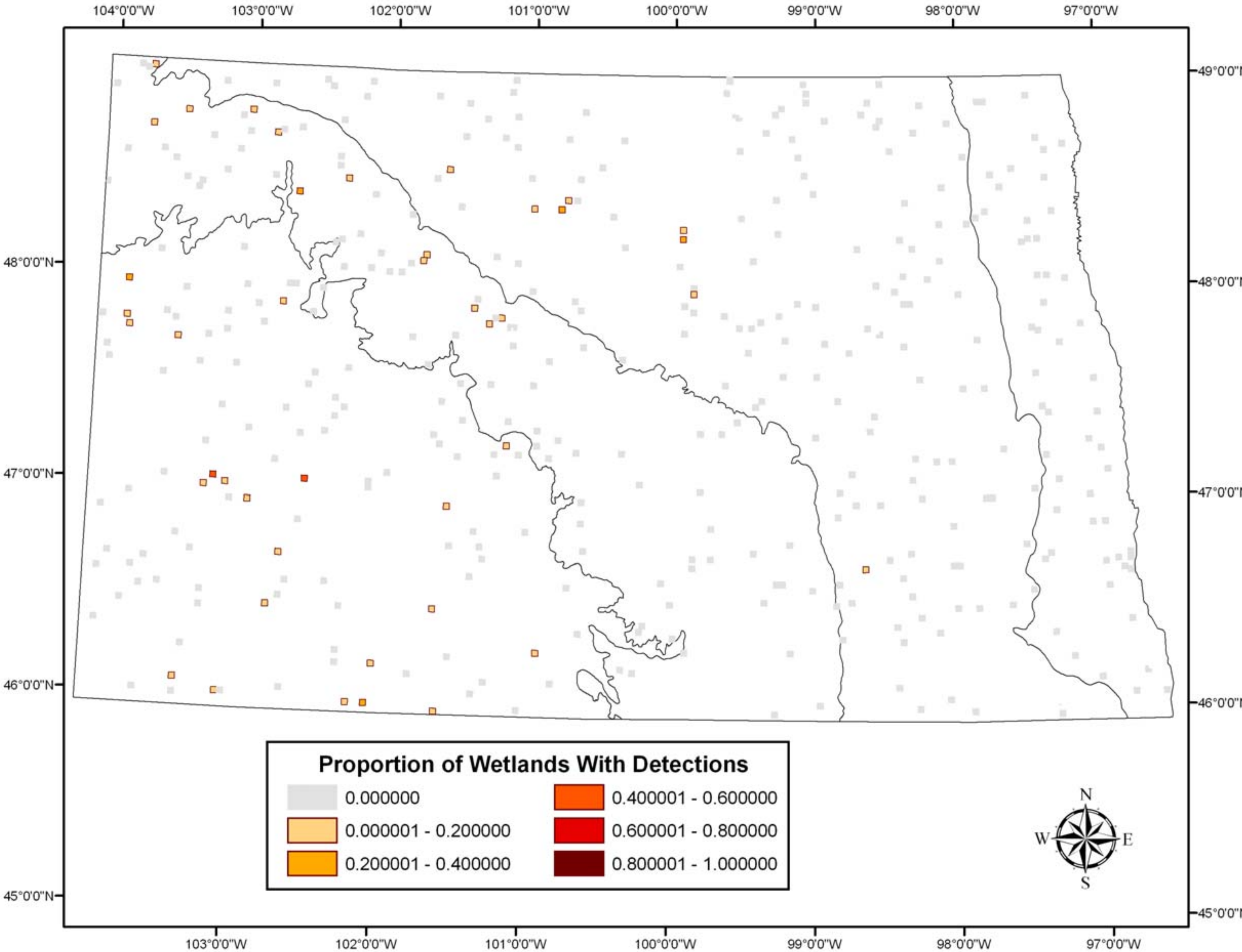
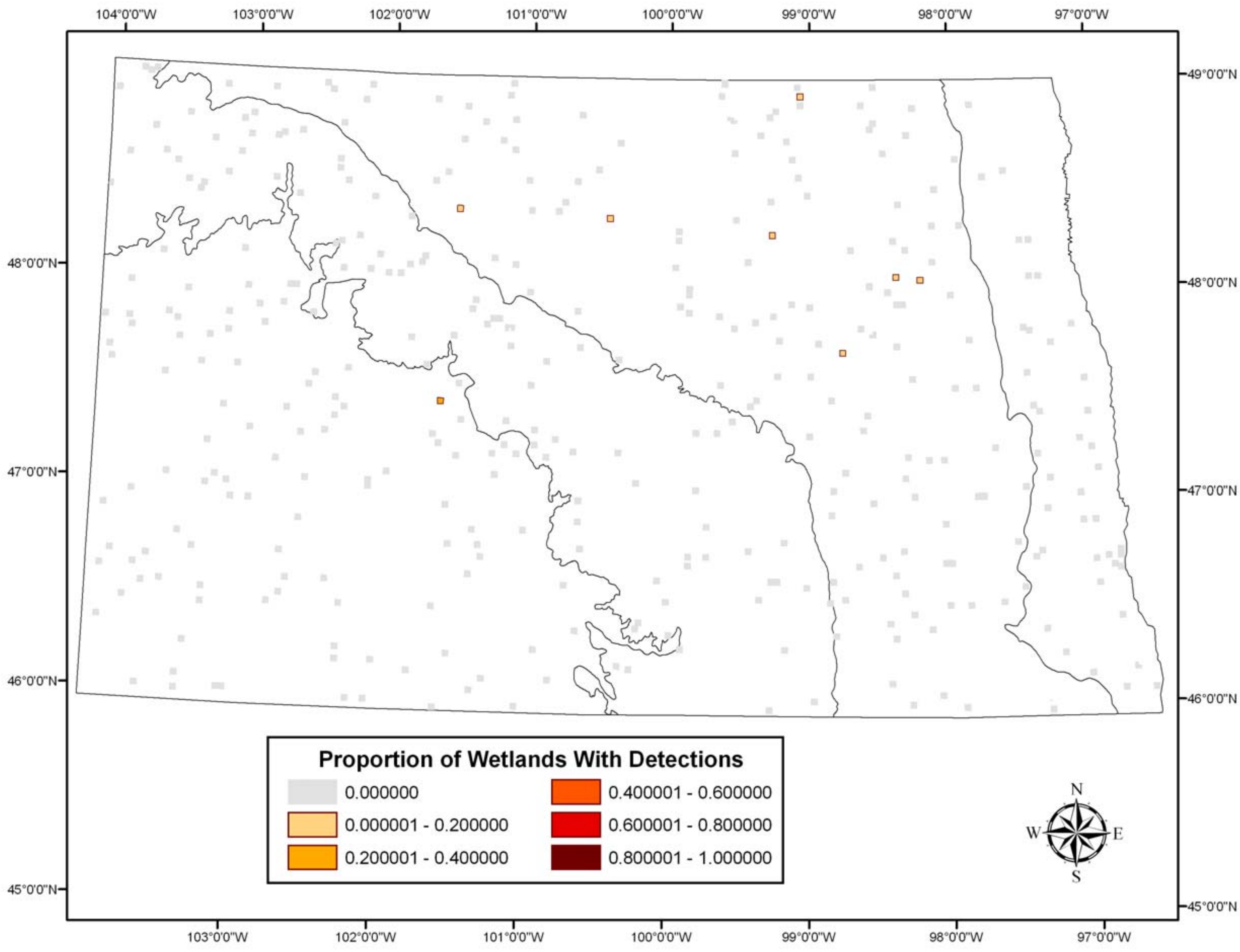
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
E
S
W

Wilson's phalarope



Yellow rail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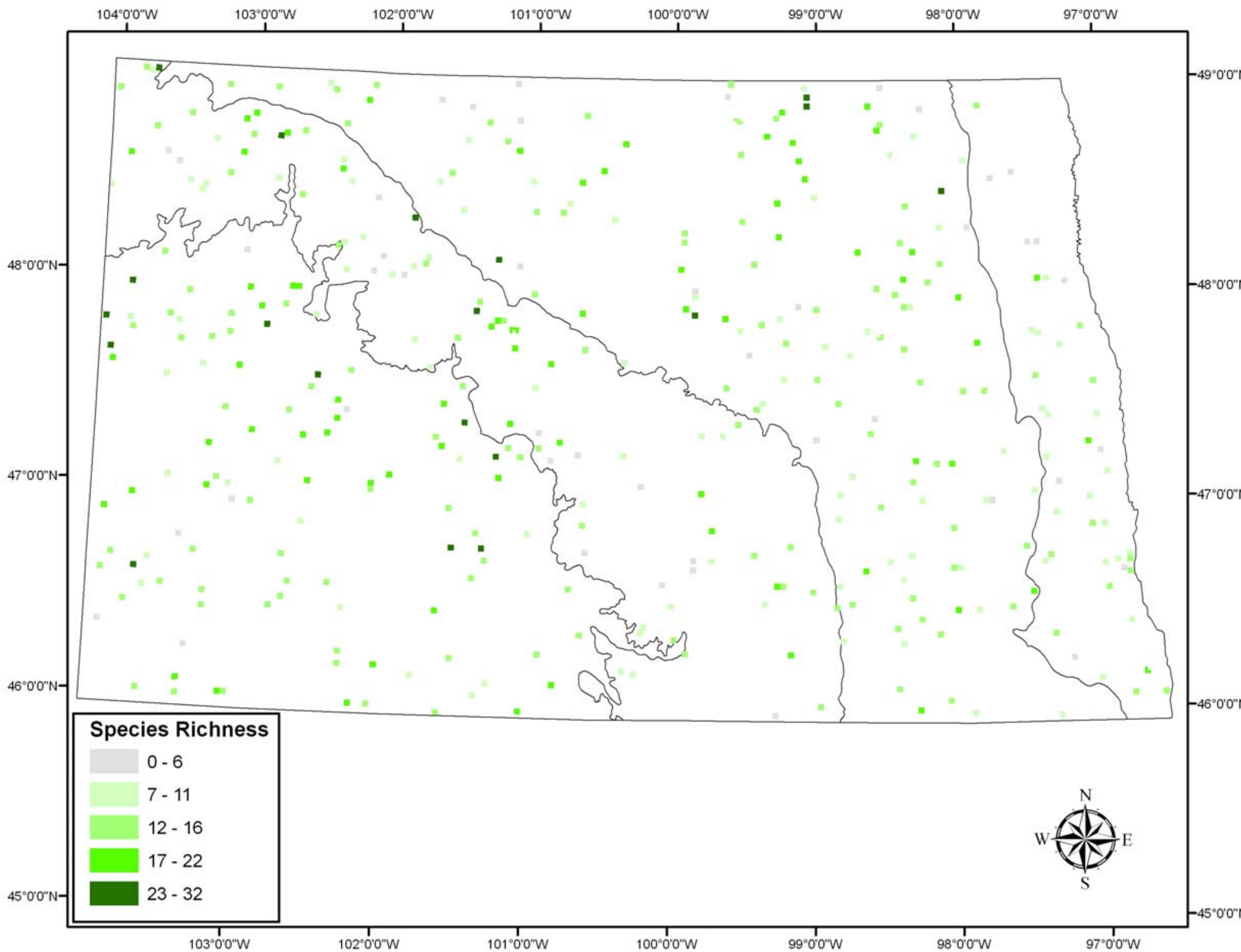
99°0'0"W
98°0'0"W
97°0'0"W
49°0'0"N
48°0'0"N
47°0'0"N
46°0'0"N
45°0'0"N
Proportion of Wetlands With Detections
0.000000
0.000001 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
N
S
E
W

Species richness



USGS

Table 8. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of wetlands or immediate adjacent lands that are important for predicting occurrence of American bittern (AMBI), sora (SORA), Virginia rail (VIRA), and American coot (AMCO) on wetlands throughout North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	AMBI		SORA		VIRA		AMCO	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		.	0.00	.	0.00	.	0.00	.	0.00
2 (Full)	R[a], WF[b], WF^2, WC[c], WT[d], WM[e], SAG[f], SAW[g], SWE[h]	5.41	0.04	4.61	0.09	2.12	0.15	4.07	0.11
3	R, WF, WF^2, WC, WT, WM	8.08	0.01	6.44	0.04	2.82	0.11	5.28	0.06
4	R, WF, WF^2, WC, WM, SWE	0.00	0.57	0.00	0.88	3.00	0.10	0.00	0.83
5	R, WF, WF^2, SAG	5.74	0.03	.	0.00	4.02	0.06	.	0.00
6	R, WF, WC, WM, SAG, SWE	7.67	0.01	.	0.00	.	0.00	.	0.00
7	WF, WF^2, WC, WT, WM, SAW	.	0.00	.	0.00	0.00	0.44	.	0.00
8	R, WC, WM, SAG, SAW, SWE	.	0.00	.	0.00	.	0.00	.	0.00
9	WC, SAG, SWE	.	0.00	.	0.00	.	0.00	.	0.00
10	R, WF, WF^2, WM, SAG, SWE	1.52	0.26	.	0.00	5.29	0.03	.	0.00
11	R, WF, WM, SWE	4.53	0.06	.	0.00	.	0.00	.	0.00
12	WF, WC, WM, SAG, SAW	.	0.00	.	0.00	.	0.00	.	0.00
13	R, WF, WM, SAG	.	0.00	.	0.00	.	0.00	.	0.00
14	R, WC	.	0.00	.	0.00	.	0.00	.	0.00
15	WF	.	0.00	.	0.00	.	0.00	.	0.00
16	WC, SAG	.	0.00	.	0.00	.	0.00	.	0.00
17	R, SAG, SAW, SWE	.	0.00	.	0.00	.	0.00	.	0.00
18	WC, WT, WM	.	0.00	.	0.00	.	0.00	.	0.00
19	R, SWE	7.18	0.02	.	0.00	.	0.00	.	0.00
20	WF, WF^2, WM	.	0.00	.	0.00	2.92	0.10	.	0.00

[a] Region
[b] Percent of wetland basin full of water
[c] Wetland vegetation cover class
[d] Presence of trees within the wetland basin
[e] Wetland manipulation
[f] Percent of the areas surrounding the wetland covered with grass
[g] Percent of the areas surrounding the wetland covered with woodland
[h] Percent of the areas surrounding the wetland covered with other wetlands

Table 9. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of wetlands or immediate adjacent lands that are important for predicting occurrence of grasshopper sparrow (GRSPI), lark bunting (LARB), bobolink (BOBO), marsh wren (MAWR), and common yellowthroat (COYE) on wetlands throughout North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	GRSP		LARB[a]		BOBO		MAWR		COYE	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
2 (Full)	R[b], WF[c], WF^2, WC[d], WT[e], WM[f], SAG[g], SAW[h], SWE[i]	0.00	0.73	0.84	0.26	1.84	0.08	6.91	0.03	4.61	0.06
3	R, WF, WF^2, WC, WT, WM	9.42	0.01	2.47	0.11	2.65	0.05	.	0.00	.	0.00
4	R, WF, WF^2, WC, WM, SWE	.	0.00	.	0.00	.	0.00	.	0.00	1.09	0.33
5	R, WF, WF^2, SAG	4.02	0.10	.	0.00	0.52	0.15	.	0.00	.	0.00
6	R, WF, WC, WM, SAG, SWE	7.28	0.02	.	0.00	4.98	0.02	.	0.00	.	0.00
7	WF, WF^2, WC, WT, WM, SAW	.	0.00	1.20	0.22	.	0.00	.	0.00	.	0.00
8	R, WC, WM, SAG, SAW, SWE	5.72	0.04	.	0.00	5.15	0.02	.	0.00	.	0.00
9	WC, SAG, SWE	.	0.00	.	0.00	1.89	0.08	.	0.00	.	0.00
10	R, WF, WF^2, WM, SAG, SWE	5.23	0.05	.	0.00	1.82	0.08	0.00	0.90	0.00	0.57
11	R, WF, WM, SWE	.	0.00	.	0.00	.	0.00	.	0.00	4.91	0.05
12	WF, WC, WM, SAG, SAW	.	0.00	0.00	0.39	1.65	0.09	.	0.00	.	0.00
13	R, WF, WM, SAG	5.53	0.05	.	0.00	0.20	0.18	.	0.00	.	0.00
14	R, WC	.	0.00	.	0.00	6.37	0.01	.	0.00	.	0.00
15	WF	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
16	WC, SAG	.	0.00	.	0.00	0.00	0.20	.	0.00	.	0.00
17	R, SAG, SAW, SWE	.	0.00	.	0.00	3.63	0.03	.	0.00	.	0.00
18	WC, WT, WM	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
19	R, SWE	.	0.00	.	0.00	6.06	0.01	.	0.00	.	0.00
20	WF, WF^2, WM	.	0.00	.	0.00	.	0.00	5.24	0.07	.	0.00

[a] Candidate models for lark sparrow do not contain region.
[b] Region
[c] Percent of wetland basin full of water
[d] Wetland vegetation cover class
[e] Presence of trees within the wetland basin
[f] Wetland manipulation
[g] Percent of the areas surrounding the wetland covered with grass
[h] Percent of the areas surrounding the wetland covered with woodland
[i] Percent of the areas surrounding the wetland covered with other wetlands

Table 10. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of wetlands or immediate adjacent lands that are important for predicting species richness (RICH) and occurrence of black tern (BLTE), grebes (pied-billed grebe and eared grebe combined; GREB), northern pintail (NOPI), and redhead (REDH) on wetlands throughout North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	RICH		BLTE		GREB		NOPI		REDH	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
2 (Full)	R[a], WF[b], WF^2, WC[c], WT[d], WM[e], SAG[f], SAW[g], SWE[h]	0.00	0.78	4.85	0.07	4.68	0.04	7.84	0.01	2.54	0.13
3	R, WF, WF^2, WC, WT, WM	.	0.00	.	0.00	1.28	0.22	6.63	0.02	0.39	0.38
4	R, WF, WF^2, WC, WM, SWE	2.50	0.22	0.00	0.74	0.00	0.42	6.23	0.02	0.00	0.46
5	R, WF, WF^2, SAG	.	0.00	.	0.00	.	0.00	0.87	0.27	.	0.00
6	R, WF, WC, WM, SAG, SWE	.	0.00	2.69	0.19	.	0.00	.	0.00	6.71	0.02
7	WF, WF^2, WC, WT, WM, SAW	.	0.00	.	0.00	0.65	0.30	1.04	0.25	6.25	0.02
8	R, WC, WM, SAG, SAW, SWE	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
9	WC, SAG, SWE	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
10	R, WF, WF^2, WM, SAG, SWE	.	0.00	.	0.00	.	0.00	5.85	0.02	.	0.00
11	R, WF, WM, SWE	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
12	WF, WC, WM, SAG, SAW	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
13	R, WF, WM, SAG	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
14	R, WC	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
15	WF	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
16	WC, SAG	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
17	R, SAG, SAW, SWE	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
18	WC, WT, WM	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
19	R, SWE	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
20	WF, WF^2, WM	.	0.00	.	0.00	8.23	0.01	0.00	0.42	.	0.00

[a] Region
[b] Percent of wetland basin full of water
[c] Wetland vegetation cover class
[d] Presence of trees within the wetland basin
[e] Wetland manipulation
[f] Percent of the areas surrounding the wetland covered with grass
[g] Percent of the areas surrounding the wetland covered with woodland
[h] Percent of the areas surrounding the wetland covered with other wetlands

Table 11. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of wetlands or immediate adjacent lands that are important for predicting occurrence of upland sandpiper (UPSA), killdeer (KILL), common snipe (COSN), marbled godwit (MAGO), willet (WILL), and Wilson's phalarope (WIPH) on wetlands throughout North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	UPSA		KILL		COSN		MAGO		WILL		WIPH	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
2 (Full)	R[a], WF[b], WF^2, WC[c], WT[d], WM[e], SAG[f], SAW[g], SWE[h]	3.95	0.04	1.80	0.29	7.67	0.01	4.86	0.07	3.71	0.11	3.68	0.14
3	R, WF, WF^2, WC, WT, WM	1.38	0.14	.	0.00	.	0.00	0.00	0.84	7.01	0.02	0.00	0.86
4	R, WF, WF^2, WC, WM, SWE	2.76	0.07	.	0.00	6.04	0.02	9.38	0.01	.	0.00	.	0.00
5	R, WF, WF^2, SAG	4.96	0.02	.	0.00	.	0.00	10.20	0.01	0.00	0.72	.	0.00
6	R, WF, WC, WM, SAG, SWE	2.79	0.07	.	0.00	8.85	0.00	.	0.00	.	0.00	.	0.00
7	WF, WF^2, WC, WT, WM, SAW	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
8	R, WC, WM, SAG, SAW, SWE	3.53	0.05	0.00	0.71	5.74	0.02	7.07	0.02	.	0.00	.	0.00
9	WC, SAG, SWE	.	0.00	.	0.00	1.87	0.15	.	0.00	.	0.00	.	0.00
10	R, WF, WF^2, WM, SAG, SWE	6.69	0.01	.	0.00	6.40	0.02	6.41	0.03	3.25	0.14	.	0.00
11	R, WF, WM, SWE	2.77	0.07	.	0.00	4.53	0.04	.	0.00	.	0.00	.	0.00
12	WF, WC, WM, SAG, SAW	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
13	R, WF, WM, SAG	3.74	0.04	.	0.00	.	0.00	10.29	0.00	.	0.00	.	0.00
14	R, WC	0.00	0.29	.	0.00	.	0.00	9.65	0.01	.	0.00	.	0.00
15	WF	.	0.00	.	0.00	8.56	0.01	.	0.00	.	0.00	.	0.00
16	WC, SAG	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
17	R, SAG, SAW, SWE	3.84	0.04	.	0.00	0.00	0.37	.	0.00	.	0.00	.	0.00
18	WC, WT, WM	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
19	R, SWE	1.32	0.15	.	0.00	0.11	0.35	.	0.00	.	0.00	.	0.00
20	WF, WF^2, WM	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00

[a] Region
[b] Percent of wetland basin full of water
[c] Wetland vegetation cover class
[d] Presence of trees within the wetland basin
[e] Wetland manipulation
[f] Percent of the areas surrounding the wetland covered with grass
[g] Percent of the areas surrounding the wetland covered with woodland
[h] Percent of the areas surrounding the wetland covered with other wetlands

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Table 12. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of landscapes that are important for predicting species richness (RICH) and occurrence of black terns (BLTE), redhead (REDU), American bittern (AMBI), sora (SORA), Virginia Rail (VIRA), and American coot (AMCO) at 4-square-mile sites east of the Missouri River in North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	RICH		BLTE		REDH		AMBI		SORA		VIRA		AMCO	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)				.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
2 (FULL1)	R[a], LWET[b], LST[c], LG[d], LWO[e]	0.70	0.29	1.89	0.19	4.35	0.02	1.99	0.13	3.13	0.05	2.80	0.09	3.82	0.06
3 (FULL2)	R, LWW[f], LST, LG, LWO	3.07	0.09	1.21	0.26	4.78	0.02	0.00	0.35	3.17	0.05	0.90	0.24	8.80	0.01
4	R, LST, LG, LWO	4.75	0.04	0.00	0.48	3.26	0.04	0.46	0.28	3.43	0.04	0.81	0.25	7.42	0.01
5	LWET, LST, LG, LWO	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
6	LWW, LST, LG, LWO	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
7	LWET, LST, LG	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
8	LWW, LST, LG	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
9	LWET, LG, LWO	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
10	LWW, LG, LWO	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
11	R, LWET, LG	7.61	0.01	.	0.00	0.85	0.13	.	0.00	1.55	0.11	.	0.00	0.89	0.27
12	R, LWW, LG	.	0.00	.	0.00	1.37	0.10	5.29	0.02	1.71	0.10	.	0.00	4.92	0.04
13	R, LWET, LST	0.00	0.42	7.83	0.01	0.98	0.12	.	0.00	1.19	0.13	.	0.00	0.00	0.42
14	R, LWW, LST	2.46	0.12	6.75	0.02	1.45	0.09	7.71	0.01	1.42	0.12	6.35	0.02	5.37	0.03
15	R, LST	5.43	0.03	6.66	0.02	0.00	0.19	.	0.00	2.69	0.06	7.23	0.01	4.34	0.05
16	R, LWO	.	0.00	7.25	0.01	0.55	0.15	1.04	0.21	0.00	0.24	0.00	0.37	4.09	0.05
17	R, LG	.	0.00	.	0.00	0.59	0.14	8.20	0.01	1.79	0.10	8.02	0.01	3.58	0.07
18	LWET	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
19	LWW	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00
20	LG	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00	.	0.00

[a] Region
[b] Percent of the area of wetlands that are covered with water
[c] Percent of the wetlands that are either seasonal or temporary
[d] Percent of the landscape covered with grass
[e] Percent of the landscape covered with woodland
[f] Percent of the landscape covered with open water

Table 13. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of landscapes that are important for predicting occurrence of grasshopper sparrow (GRSP), bobolink (BOBO), marsh wren (MAWR), and common yellowthroat (COYE) at 4-square-mile sites east of the Missouri River in North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	GRSP		BOBO		MAWR		COYE	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		.	0.00	0.00	0.21	6.79	0.01	.	0.00
2 (FULL1)	R[a], LWET[b], LST[c], LG[d], LWO[e]	0.00	0.41	6.84	0.01	2.21	0.07	5.33	0.02
3 (FULL2)	R, LWW[f], LST, LG, LWO	1.53	0.19	6.14	0.01	0.55	0.16	5.35	0.02
4	R, LST, LG, LWO	7.02	0.01	5.16	0.02	1.08	0.12	3.40	0.05
5	LWET, LST, LG, LWO	1.66	0.18	5.29	0.01	.	0.00	1.90	0.11
6	LWW, LST, LG, LWO	3.03	0.09	4.84	0.02	6.55	0.01	1.92	0.11
7	LWET, LST, LG	.	0.00	4.56	0.02	6.38	0.01	0.00	0.28
8	LWW, LST, LG	.	0.00	4.04	0.03	4.71	0.02	0.08	0.27
9	LWET, LG, LWO	.	0.00	3.57	0.04	.	0.00	.	0.00
10	LWW, LG, LWO	.	0.00	3.00	0.05	.	0.00	.	0.00
11	R, LWET, LG	7.97	0.01	5.24	0.02	2.00	0.08	.	0.00
12	R, LWW, LG	8.94	0.00	4.41	0.02	1.57	0.10	.	0.00
13	R, LWET, LST	4.28	0.05	5.36	0.01	3.19	0.04	4.21	0.03
14	R, LWW, LST	5.56	0.03	4.57	0.02	2.01	0.08	4.48	0.03
15	R, LST	8.97	0.00	3.96	0.03	2.75	0.05	2.48	0.08
16	R, LWO	6.82	0.01	2.91	0.05	7.39	0.01	.	0.00
17	R, LG	8.84	0.00	4.55	0.02	0.00	0.21	.	0.00
18	LWET	.	0.00	0.71	0.15	.	0.00	.	0.00
19	LWW	.	0.00	0.15	0.19	.	0.00	.	0.00
20	LG	.	0.00	1.99	0.08	5.73	0.01	.	0.00

[a] Region
[b] Percent of the area of wetlands that are covered with water
[c] Percent of the wetlands that are either seasonal or temporary
[d] Percent of the landscape covered with grass
[e] Percent of the landscape covered with woodland
[f] Percent of the landscape covered with open water

Table 14. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of landscapes that are important for predicting occurrence of willet (WILL), upland sandpiper (UPSA), killdeer (KILL), and common snipe (COSN) at 4-square-mile sites east of the Missouri River in North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	WILL		UPSA		KILL		COSN	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		0.46	0.10	7.61	0.01	.	0.00	4.36	0.04
2 (FULL1)	R[a], LWET[b], LST[c], LG[d], LWO[e]	3.91	0.02	8.07	0.01	3.72	0.05	4.88	0.03
3 (FULL2)	R, LWW[f], LST, LG, LWO	3.45	0.02	3.67	0.05	0.11	0.31	4.49	0.04
4	R, LST, LG, LWO	2.44	0.04	8.30	0.01	2.87	0.08	2.89	0.08
5	LWET, LST, LG, LWO	4.58	0.01	4.74	0.03	4.61	0.03	.	0.00
6	LWW, LST, LG, LWO	3.28	0.02	0.00	0.33	1.98	0.12	.	0.00
7	LWET, LST, LG	4.86	0.01	6.70	0.01	.	0.00	.	0.00
8	LWW, LST, LG	4.11	0.02	0.76	0.23	.	0.00	.	0.00
9	LWET, LG, LWO	3.03	0.03	4.61	0.03	2.69	0.08	8.37	0.01
10	LWW, LG, LWO	1.34	0.06	1.61	0.15	0.00	0.32	8.34	0.01
11	R, LWET, LG	1.79	0.05	.	0.00	.	0.00	3.79	0.05
12	R, LWW, LG	0.93	0.08	6.90	0.01	.	0.00	4.38	0.04
13	R, LWET, LST	2.12	0.04	8.46	0.00	.	0.00	3.82	0.05
14	R, LWW, LST	2.45	0.04	4.02	0.04	.	0.00	3.94	0.05
15	R, LST	1.04	0.07	.	0.00	.	0.00	2.06	0.12
16	R, LWO	0.56	0.09	5.84	0.02	.	0.00	0.00	0.34
17	R, LG	0.00	0.12	.	0.00	.	0.00	2.39	0.10
18	LWET	2.43	0.04	.	0.00	.	0.00	6.11	0.02
19	LWW	0.65	0.09	4.59	0.03	.	0.00	6.27	0.01
20	LG	1.67	0.05	6.46	0.01	.	0.00	6.18	0.02

[a] Region
[b] Percent of the area of wetlands that are covered with water
[c] Percent of the wetlands that are either seasonal or temporary
[d] Percent of the landscape covered with grass
[e] Percent of the landscape covered with woodland
[f] Percent of the landscape covered with open water

Table 15. Parameters, candidate models, delta AIC, and model weights (W) used for multimodel inference to examine the characteristics of landscapes that are important for predicting species richness (RICH) and occurrence of upland sandpipers (UPSA), killdeer (kill), lark bunting (LARB), grasshopper sparrow (GRSP), bobolink (BOBO), and common yellowthroat (COYE) at 4-square-mile sites in the northwestern Great Plains of North Dakota. Delta AIC not reported for models with zero weight.

Model Number	Parameters	RICH		UPSA		KILL		LARB		GRSP		BOBO		COYE	
		ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W	ΔAIC	W
1 (Null)		.	0.00	0.00	0.23	1.89	0.07	.	0.00	0.00	0.16	7.17	0.01	.	0.00
2 (Full)	LWW[a], UCW[b], LG[c], LWO[d]	3.61	0.07	6.61	0.01	4.21	0.02	2.00	0.14	4.93	0.01	1.99	0.13	1.83	0.07
3	UCW, LG, LWO	.	0.00	5.48	0.02	4.44	0.02	0.00	0.37	3.78	0.02	8.04	0.01	0.23	0.16
4	LWW, LG, LWO	7.22	0.01	5.11	0.02	2.70	0.05	.	0.00	3.00	0.04	2.09	0.12	4.88	0.02
5	LWW, UCW, LWO	1.99	0.16	4.75	0.02	2.62	0.05	2.11	0.13	4.21	0.02	0.00	0.35	2.07	0.06
6	LWW, UCW, LG	1.61	0.19	4.63	0.02	3.38	0.03	.	0.00	3.10	0.03	7.22	0.01	1.96	0.07
7	LG, LWO	.	0.00	3.88	0.03	2.70	0.05	.	0.00	1.81	0.06	6.88	0.01	3.05	0.04
8	LWW, UCW	0.00	0.42	2.77	0.06	1.76	0.08	.	0.00	2.44	0.05	5.22	0.03	1.81	0.07
9	LWW, LWO	5.38	0.03	3.12	0.05	0.85	0.12	.	0.00	2.82	0.04	0.74	0.24	.	0.00
10	UCW, LG	.	0.00	3.64	0.04	5.67	0.01	.	0.00	2.15	0.05	.	0.00	0.10	0.17
11	UCW, LWO	.	0.00	3.61	0.04	2.75	0.05	0.11	0.35	3.07	0.03	6.21	0.02	0.54	0.13
12	LWW, LG	5.29	0.03	3.12	0.05	1.87	0.07	.	0.00	1.15	0.09	7.34	0.01	5.40	0.01
13	LWW	3.44	0.08	1.13	0.13	0.00	0.19	.	0.00	1.02	0.10	5.86	0.02	.	0.00
14	UCW	8.44	0.01	1.75	0.10	3.86	0.03	.	0.00	1.56	0.07	7.39	0.01	0.00	0.17
15	LG	.	0.00	1.99	0.09	3.78	0.03	.	0.00	0.17	0.15	8.50	0.01	3.43	0.03
16	LWO	.	0.00	1.89	0.09	0.85	0.12	.	0.00	1.58	0.07	5.62	0.02	.	0.00

a Percent of the landscape covered with open water
b Percent of the landscape covered with unclassified wet areas
c Percent of the landscape covered by grass
d Percent of the landscape covered by woodland