FINAL PERFORMANCE REPORT

FEDERAL AID GRANT NO. T-37-P-1

MIGRANT SHOREBIRDS AND HABITAT QUALITY OF ISOLATED WETLANDS IN THE MIXED-GRASS PRAIRIE REGION

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

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FINAL REPORT

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GRANT NAME: Migrant Shorebirds and Habitat Quality of Isolated Wetlands in the Mixed-Grass Prairie Region

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ABSTRACT

This report summarizes four seasons of shorebird and shorebird habitat sampling data collected within the Mixed-grass Prairie Region of Oklahoma. We used a geographic information system to locate and survey potential shorebird habitat patches within ten broad scale experimental units from 2007 to 2009. Twenty-nine species of migrant shorebirds were encountered during surveys. American Avocet *(Recurvirostra americana),* Least Sandpiper *(Calidris minutilla),* White-rumped Sandpiper *(Calidris fucicollis)*, Baird's Sandpiper *(Calidris bairdii),* Long-billed Dowitcher *(Limnodromus scolopaceus)* and Wilson's Phalarope *(Phalaropus tricolor)* were the most abundant species during spring, while American Avocet, Lesser Yellowlegs *(Tringa flavipes),* Least Sandpiper, Pectoral Sandpiper *(Calidris melanotos),* and Baird's Sandpiper were the most abundant species during fall. We measured the composition and configuration of land cover types and shorebird habitat in each broad scale unit to describe the relationship between shorebird abundance and landscape pattern. Shorebird abundance was negatively related to increasing distance and dispersion among temporary habitat patches within broad scale units. We then described the relationship between shorebird abundance and fine scale habitat features. We found that high vegetation cover and tall vegetation characterized habitat unoccupied by shorebirds. Shorebird abundance increased when the ratio of shallow water was greater than saturated substrate within habitat patches. The distance between habitat patches was the best predictor of shorebird abundance among the variables in the fully saturated model. Shorebird abundance was inversely related to the distance between habitat patches and positively related to the interaction between habitat patch area and distance between habitat patches within broad scale units. Our results indicate that areas containing abundant and aggregated complexes of temporary wetlands are important to facilitating the migration of shorebirds through north-central Oklahoma.

OBJECTIVES

1. Determine relative abundances, species compositions, and migration chronologies of shorebirds using isolated wetlands in the Mixed-grass Prairie Region.

2. Determine habitat selection of migrant shorebirds using isolated wetlands in the Mixed-grass Prairie Region.

3. Determine habitat characteristics and invertebrate availabilities of isolated wetlands used by migrant shorebirds compared to wetlands not used by migrant shorebirds.

4. Characterize shorebird habitat-use patterns at two spatial scales (local [wetland-level] and landscape scales) and develop shorebird habitat models based on these scale-level analyses.

NEED

Environmental variation concurrently influences the response of biological communities at multiple spatial scales. These regional and fine scale dynamics determine the composition of species within a biological community (Ricklefs 1987, Cushman and McGarigal 2004). We often study ecological phenomena at a scale to which we are constrained because of logistical and technological constraints (Levin 1992). Organisms function, however, within a range of scales, especially within and among different life history stages such as breeding and dispersal. Considering the scale of patterns and how organisms are affected by patterns in the environment at different scales is primary to ecological studies (Wiens 1989, Levin 1992). It is therefore important that studies examining the stopover ecology of migrant bird species incorporate the hierarchical nature of a migrant's relationship to habitat during migration (Moore 2000). We should appropriately scale our observations of the effects of pattern on the focal organisms even when these studies are technically or logistically demanding (Addicott et al. 1987).

During avian migration, broad scale processes such as weather are extrinsic and affect habitat use patterns of species at the scale of hemispheres and geographic regions. Fine scale factors such as habitat composition and quality are intrinsic and affect habitat use patterns of species at the scale of local regions, staging areas, and stopover sites (Moore 2000). By measuring environmental patterns at different spatial scales we may more accurately describe the distribution and abundance of avian species during migration.

During their migration through the interior of North America, shorebirds rely on a variety of dispersed wetlands as stopover sites to replenish depleted energy and nutrient reserves (Farmer and Parent 1997, Davis and Smith 1998a). Specifically, shorebirds refuel briefly at smaller scale stopover wetlands dispersed broadly across a broad scale and travel shorter distances between migratory flights (Skagen 2006). These stopover sites are critical for continuance of migration and ultimately for the survival of many shorebird species (Myers 1983). For most of these shorebirds, isolated wetlands provide critical stopover habitat during spring and fall migration and are a crucial link between wintering and breeding areas. In particular, these isolated wetlands are critical to migrant shorebirds because they act as "stepping stones" for the birds to continue and complete their migration (Skagen and Knopf 1993)

Shorebirds migrating through Oklahoma likely adopt the "stepping stone" strategy, opportunistically using broadly dispersed stopover sites. Because Oklahoma is subject to cyclical dry and wet periods, the types of wetlands used for stopover may vary widely depending on seasonal and annual weather patterns. For example, during dry periods, permanent and semi-permanent wetlands may provide abundant habitat as mudflats becomes exposed in lakes, rivers, and ponds, whereas during wet periods, shallow temporary wetlands such as ephemeral pools and agricultural sheetwater may provide habitat when the exposed mud of more permanent wetlands is inundated by water.

Shorebirds along with other migratory birds that rely on wetlands as stopover sites have been severely impacted by the rapidly changing landscape in the interior of North America. For example, it is estimated that >90% of the wetlands in the Great Plains have been lost to agricultural development during the last 100 years (Dahl 1990). Moreover, these wetlands may be further altered and lost in the future due to climate change (Poiani and Johnson 1991). Farmer and Parent (1997) noted that these large-scale habitat changes raise serious concerns about maintaining an adequate network of stopover sites for migrant shorebirds as well as other migrant waterbirds.

Since 1970, several populations of North American shorebird species have cumulatively declined by more than 70%. These declines have resulted in a heightened awareness by state, federal, and international agencies to develop conservation strategies for shorebirds on a regional and hemispheric basis (Myers et al. 1987). The initial steps of developing conservation strategies have been to designate sites that serve as important stopover sites for migrant shorebirds. Within the Great Plains, the importance of stopover sites to migrant shorebirds has only recently been recognized (Skagen and Knopf 1993, Davis and Smith 1998a, De Leon and Smith 1999, Skagen 2006). Most of the attention however, has been on the Northern Great Plains with little attention on the Southern Great Plains.

Knowledge concerning species composition, habitat-use patterns, and migration chronology of shorebirds and an understanding of the types and quality of wetlands used by migrant shorebirds is essential for developing conservation and management strategies. Moreover, because the ecology of migrant shorebirds among different regions within interior North America can be quite different, state and federal agencies cannot rely solely on information from other regions to plan conservation and management strategies for migrant shorebirds. State and federal agencies must have site-specific information for their region.

In western Oklahoma, isolated wetlands throughout the Mixed-grass Prairie Region likely play a major role in providing stopover habitat for migrant shorebirds. When wetland conditions are optimal in this region, a myriad of migrant shorebirds likely use these wetlands as stopover sites. Many of these shorebird species are listed as species of greatest conservation need due to dramatic population declines during the last 20 years (e.g., snowy plover *(Charadrius alexandrinus)* [Tier I species], Wilson's phalarope *(Phalaropus tricolor)* [Tier II species], western sandpiper *(Calidris mauri)* [Tier II species], piping plover *(Charadrius melodus)* ([Tier II species], and Hudsonian godwit *(Limosa lapponica)* [Tier III species]) (ODWC 2006). Although recent research by Davis and Smith (1998a, 1998b, 2001, 2005) has shed some light on the importance of playa wetlands to migrant shorebirds in the Playa Lakes Region of the Southern Great Plains, little is known about the importance of isolated wetlands in other regions of the Southern Great Plains. Specifically, information on the distribution and habitat-use patterns of migrant shorebirds as well as an evaluation of the quality of habitat of wetlands used by shorebirds is lacking for most regions of the Southern Great Plains. Currently, development of conservation and management strategies for migrant shorebirds in the Mixed-grass Prairie Region of Oklahoma is severely hampered by this lack of information.

APPROACH

Study Area.—We studied shorebird migration within north-central Oklahoma, United States. The study area encompasses Alfalfa, Blaine, Canadian, Garfield, Grant, Kingfisher, Logan, Major, Oklahoma, and Woods counties and had a total area of 24,372 km^2 (Fig. 1). Historically, the most common habitat type found within this region was mixed-grass prairie but the majority of this habitat has been converted to other land uses. Currently, less than 40% of the historic extent of native mixed-grass prairie remains in this region (ODWC 2006). Cultivated crops and grazing lands are the dominant land cover types (Vogelmann et al. 2001), and year-round grazing, invasive plant species and suppression of natural disturbance have altered this region (ODWC 2006). Although the native mixed-grass prairie plant community is diverse, little bluestem *(Schiszachyrium scoparium)* and sideoats grama (*Bouteloua curtipendula*) typically dominate (ODWC 2006).

Geographic Information System(GIS).— We used Environmental Systems Research Institute's (ESRI) ArcGIS 9.0 (1999-2004) geographic information system (GIS) software to assemble base data layers for each county that included countywide 1:25,000 USGS topographical image mosaics and countywide mosaics of 1.0 m resolution 1: 12,000 digital ortho-image quadrangles (DOQs). We used DOQs from 1999, 2003-2008 as base data (Fig. 2). DOQs, which are created from aerial photographs taken annually (since 2003) during the months of June and July to assess annual crop production within Oklahoma, were obtained from United States Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS) (USDA 2007). The images were taken and processed to assess (USDA 2007). The digital images from 1999 were collected in June.

Precipitation conditions when the aerial photographs for the DOQs taken varied dramatically. Generally lower than average precipitation levels and less abundant and smaller expanses of standing water characterized 2004 and 2006, while 2003 and 2008 were characterized by higher than average precipitation levels and more abundant and expansive standing water.

We defined a broad scale experimental unit as the total area a migrant shorebird may traverse to locate foraging habitat between arrival and departure flights. Our estimate of the area encompassed by a broad scale unit was based on radio telemetry research conducted on migrant shorebirds in the Midwestern USA (Farmer and Parent 1996). Farmer and Parent (1996) found that 90% of radio tagged shorebirds (n=110) never traveled >10 km from their release site during a stopover event. We therefore used a 10 km radius circle to approximate the foraging range of a shorebird during a stopover event. We randomly placed one 10 km radius circle within each county in the study area (Fig. 2). The area encompassed within each10-km radius circle was used as a broad scale experimental unit. The sample size of broad scale experimental units required to detect effects of interest were estimated prior to the commencement of the study using pilot study data and an *a priori* power analysis for sample size. Although lakes were relatively uncommon in the study area, they are dominant features within Alfalfa and Oklahoma counties and have been identified as common stopover sites for migrant shorebirds in the region.

We therefore placed broad scale units in these counties over these features to ensure we captured this type of shorebird foraging habitat.

We defined potential shorebird foraging habitat patches as saturated substrate and shallow water habitats within wetlands and around wetland edges. Non-habitat was any area surrounding potential habitat that did not meet these criteria (i.e., deepwater wetland areas or dry upland areas). We defined a fine scale experimental unit as a discrete area of contiguous potential shorebird foraging habitat encompassed by a matrix of non-habitat.

We used ESRI, ArcGIS 9.0 GIS software to visually examine the base layer DOQs for potential shorebird habitat. Within each broad scale unit, we located and then delineated each discrete patch of potential shorebird habitat as a fine scale experimental unit (Fig. 2). DOQs of each broad scale unit were viewed initially at a 1:200,000 scale. The broad scale unit was then systematically examined beginning at its furthest western edge at a 1:10,000 scale. The DOQs for each year in the series were examined at this scale. Any areas of interest within the 1:10,000 views were then enlarged and compared among years. When a discrete patch of shorebird habitat was identified it was categorized into one of three shorebird habitat classes (temporary, semi-permanent, and permanent habitats), delineated as a polygon and assigned a unique identification number. The temporary shorebird habitat class was defined as habitat present only during wet periods among the DOQs. The semi-permanent shorebird habitat class was defined as habitat not present in at least one dry year among the DOQs. The permanent shorebird habitat class was defined as habitat present in all years among the DOQs from 1999 to 2008. The determination of wet and dry periods within broad scale units were based on annual climatic data summaries from the Oklahoma Climatological Survey (2008), and visual assessments of all DOQs.

The fine scale experimental unit boundaries we delineated for temporary and semi-permanent habitat encompassed the greatest contiguous spatial extent of potential shorebird habitat among the annual series of DOQs (Fig. 2). The spatial extent between the lowest shoreline edge and the highest shoreline edge of a wetland area among the DOQs formed the boundaries of fine scale units in the permanent habitat class (Fig. 2). Because of logistical constraints, we did not delineate discrete potential habitat patches $<1000\ m^2$ or areas within channeled waterways <30 m wide.

When an area in a 1:10,000 scaled view was completely examined and all discrete habitat patches were delineated, the image was moved north/south and the next unexamined 1:10,000 area within a broad scale unit was inspected. When a border of a broad scale unit was reached, the image within the 1:10,000 view was moved east. We continued in this manner until a broad scale unit was fully examined and all fine scale experimental units were delineated (Fig. 3). Each broad scale unit was then assigned a unique identification number and was included in the GIS as a shorebird habitat class layer.

To further classify habitats in the study area, we added the 2001 National Land Cover Data (NLCD 2001) to the GIS. The NLCD 2001 base layer was in a raster grid format. Cells within the grid measured $30\ m^2$ and each cell was assigned to one of fifteen land-cover classes (Homer et al. 2004). We applied the NLCD 2001 raster grid layer to an ArcGIS 9.0 (ESRI 1999-2004) data layer reclassification program. Our objective was to merge the existing land cover classes into broader classes that we believed were biologically meaningful to migrant shorebird habitat-use patterns while maintaining the original distinctness of each land-cover class. We condensed the fifteen NLCD 2001 land cover classes into seven broader classes. We grouped land cover type subclasses that were in the same class and that were defined by the same dominant land cover (Vogelmann et al. 2001). Table 1 provides the names and description of the NLCD land-cover classes we merged into single classes. We used the combined classes in our analysis.

We applied the shorebird habitat class layer to ESRI, ArcGIS 9.0 GIS software data layer conversion program. The conversion program converted the shorebird habitat class layer from vector to raster data by converting each 30 m^2 of shorebird habitat within a fine scale unit polygon into a raster grid cell. Each 30 m^2 cell of shorebird habitat was also assigned the habitat class value of the fine scale unit. Areas not delineated as shorebird habitat were not assigned to any class.

The shorebird habitat grid output and the NLCD 2001 base layer were then applied to an ESRI, ArcGIS 9.0 GIS software data layer reclassification program. Within each broad scale unit, the program precisely overlaid the shorebird habitat raster grid onto the NLCD 2001 raster grid and combined the layers. Cells that shared a shorebird habitat class assignment and a land cover class assignment were reassigned only to the shorebird habitat class. In the final raster grid output, each 30m^2 cell within a broad scale unit belonged to either a land-cover class or to a shorebird habitat class (Fig. 4). The combined raster grid output of each broad scale unit was then displayed as a surface, assigned a unique identification code and included in the GIS.

We verified and refined mapping during field surveys. Before field surveys, observers were given a GPS receiver and 1:2,000 scale color ortho images of each delineated fine scale unit containing 100 m UTM grid coordinates. The UTM grids on the field maps were marked with incremental 25 m tick marks and 100 m grid lines along with the boundary of each fine scale unit. Changes to fine scale unit boundaries observed during field surveys were corrected on field maps. Larger scale maps of each broad scale unit were also available. Broad scale unit maps contained the boundaries of all fine scale units, 1000 m UTM grid coordinates, and road names. The location and extent of unidentified habitat discovered during surveys were recorded with a GPS receiver and delineated on fine scale and/or broad scale unit maps. Areas misidentified as shorebird habitat were also recorded. The observers assessed the habitat classification and recorded recommendations for each fine scale unit. The GIS database was regularly updated with field data and the type and number of corrections were recorded.

We used the software program FRAGSTATS (McGarigal et al. 2002) to summarize the landscape composition and configuration characteristics of each broad scale and fine scale unit using the combined shorebird habitat and land-cover data set. *A priori* to performing the analysis, we selected a suite of metrics that may be important to shorebird habitat use patterns (Table 2). We then calculated metrics at two different spatial levels. Class-level metrics were defined as metrics integrated over all patches of a given class (McGarigal et al. 2002). These were calculated for each land cover and shorebird habitat class within the ten broad scale units. Patch-level metrics were defined as metrics for individual patches and were calculated for each fine scale unit within the broad scale units (Table 3).

Field Methods.—During spring 2008 and 2009 and fall 2007 and 2008, we surveyed a sample of randomly selected fine scale units within each broad scale unit four times. We divide both spring (March 1-May 30) and fall (July 15-Oct. 15) migration periods into four 23-day intervals. Prior to the commencement of the study, we used pilot study data and an *a priori* power analysis for sample size to estimate the proportion of the total shorebird habitat class area per broad scale unit required to detect effects on the response variables of interest. Based on our results, we surveyed 13-15% of total area of fine scale units per broad scale unit once during each 23-day interval. The proportion of fine scale units surveyed in each shorebird habitat class within this sample was equal to the percentage of the total habitat area per broad scale unit each habitat class encompasses.

Selection of fine scale units for surveys was random. Each square meter of shorebird habitat in a broad scale unit will have the same probability of selection for a survey during each interval. When a square meter of habitat is selected within a discrete fine scale unit $\leq$5 hectares, the entire fine scale unit was surveyed. During shorebird survey trials conducted during the pilot study, we determined we could not effectively sample fine scale units >5 hectares during a single survey visit. Therefore, when a square meter of habitat was randomly selected within a fine scale unit >5 hectares we survey the nearest 5 hectares of habitat to the selected meter. To standardize sampling effort among fine scale units, we surveyed each fine scale unit $\leq$1 hectare for a minimum of 5 minutes during a visit. We added 2 minutes of survey time for each additional hectare of habitat we surveyed within a fine scale unit.

We performed surveys during daylight hours. Each day we conducted surveys within a single broad scale unit starting at a randomly selected fine scale unit and along a predetermined minimum distance travel route. Broad scale units with greater amounts of total habitat took more days to survey than broad scale units containing lower amounts (total habitat per broad scale unit range = 2,447 ha to 6,225 ha). To avoid biases associated with sampling the same broad scale unit on sequential days or surveying the same fine scale units during the same time of day, a different broad scale unit and starting location was randomly selected each day.

Surveys were conducted from a vehicle or on foot, depending on the visibility and location of the fine scale unit. After arriving at a fine scale unit, the observer waited several minutes before beginning a survey. Shorebirds were observed with a 10 x 60 spotting scope or 8 x 40 binoculars. Each shorebird observed during the survey of a fine scale unit was identified to species and counted.

We sampled habitat data during each visit to fine scale unit. Table 4 contains a list and description of the five variables we measured. Three cover variables were measured during field studies. Cover classes were used to estimate the proportion of a fine scale unit covered with shorebird habitat, the proportion of shorebird habitat covered in saturated substrate/shallow water (<16 cm), and vegetation. The cover classes were a variant of cover class schemes traditionally used (e.g. Domin 1928, Braun-Blanquet 1964, Daubenmire 1968). The cover categories and range of cover percentages are: 0 = 0%, 1 = 1-5%, 2 = 6-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-95%, and 6 = >95%. We used cover-class midpoints in the analysis.

Statistical Analysis.—We used zero inflated regression and alternative model selection to examine the relationship between shorebird abundance and two patch level landscape metrics (Table 2), and the habitat variables we measured within fine scale units (Table 4). Count data in ecology is often characterized by large quantities of zero values. Zero inflated regression models were developed for modeling count data with inflated zero observations that do not fit traditional distributions (Lambert 1992, Heilbron 1994). Standard models do not account for the processes behind zero values even though these processes are often of interest to researchers (Martin et al. 2005). Zero inflated modeling may be especially useful in ecological research when species are rare in the environment or difficult to detect (Cade and Dong 2008, MacKenzie et al. 2002).

Martin et al. (2005) described 2 potential causes of zero values in ecological research: true zero values are caused by the ecological process under investigation or false zero values occur in count data when the focal organisms may be present but are not or are missed by the observer. Zero inflated regression deals with identifying the processes behind true zeros and false zeros. First, a binomial regression model is used to predict the true zero observations. Second, a Poisson or negative binomial regression model is generated to analyze the false zero observations. Finally, the results of the two models are combined. Zero inflated regression modeling allows researchers to identify the processes behind the presence of a focal organism in a habitat and the processes behind the focal species abundance within a habitat. Because migrant shorebirds are relatively rare among wetlands within broad scale landscapes in Oklahoma, count data on shorebird abundance collected within the region may be best examined using this type of modeling.

To confirm the appropriateness of our analysis, we calculated the AIC values for these data for standard Poisson and negative binomial regression models and zero inflated Poisson and negative binomial regression models. We used the lowest AIC value and the delta AIC value (ΔAIC) greater than 2 among these models as the criteria for comparing and selecting the top model (Table 5). The zero inflated negative binomial model had the lowest AIC value (Table 5). A Vuong non-nested test statistic test confirmed these results ($Vuong = -5.73$). Therefore, we selected zero inflated negative binomial regression to perform the final analysis.

We constructed 74 model combinations for the final analysis. The fully saturated model contained 6 variables and 2 multiplicative terms. The interaction between the variables percent vegetation and dominate vegetation height and the variables Euclidian nearest neighbor distance (ENN) and habitat area were included in the saturated model. The binomial and negative binomial portions of the global model both contained the same variables and interactions. We removed the same single variable or interaction from each portion of the global model for the alternate candidate models. To create the first subset of candidate models we repeated this process until each variable had been removed once from the global model. The second subset contained only additive models. The same procedure of removing the same variable from both portions of each model was used to create the second subset of candidate models. This procedure was then repeated to create a subset of models only containing the variables involved in the selected multiplicative interactions. Lastly, subsets of simple models and of null models for each of these combinations were constructed.

The models with the lowest AIC values and ΔAIC values <2 were selected as the top models for describing these data. The AIC weights (AIC_w) for each model were also calculated. AIC_w were used to access the importance of each model. We calculated the composite model values for each explanatory variable using the AIC_w and the coefficients of each explanatory variable included in the top models. Zeros were used in these calculations when a variable was not present in a model.

RESULTS AND DISCUSSION

We surveyed 10 to 15% of each broad scale unit for migratory shorebirds 16 times during this study (n = 160 survey intervals). Twenty-nine species of migratory shorebirds were encounter during surveys of fine scale units containing habitat (Table 6). Table 7 contains a list of the counties in which each species was encountered. Among the species encounter during spring migration, American Avocet *(Recurvirostra americana),* Least Sandpiper *(Calidris minutilla),* White-rumped Sandpiper *(Calidris fucicollis)*, Baird's Sandpiper *(Calidris bairdii),* Long-billed Dowitcher *(Limnodromus scolopaceus)* and Wilson's Phalarope *(Phaloropus tricolor)* were the most abundant. Table 8 provides a chronology of all species encounter during spring surveys. In fall, American Avocet, Lesser Yellowlegs *(Tringa flavipes),* Least Sandpiper, Pectoral Sandpiper *(Calidris melanotos),* and Baird's Sandpiper were the most abundant species. Table 9 provides the chronology of the migratory shorebird species encounter during fall surveys. Least Sandpiper was the most frequently encountered migratory species during both spring and fall migration periods.

Among the landscape metrics we measured, shorebird abundance among broad scale units was most significantly correlated (r =>-0.9 and p = <0.03) with mean Euclidean nearest neighbor distance (MENN) of temporary shorebird habitat and interspersion and juxtaposition index (IJI) of temporary shorebird habitat (Table 10). The strong negative relationship between shorebird abundance and MENN among temporary habitat patches suggests as distance increases among temporary habitat patches shorebird abundance declines. The negative relationship between the IJI of temporary habitat patches and shorebird abundance supports these results. Lower values of the IJI indicate that shorebird habitat was aggregated within areas of broad scale units. Generally, all correlations among landscape metrics suggest that complexes of aggregated wetlands are correlated with greater shorebird abundance (Table 10).

Table 11 contains the results of the zero inflated negative binomial regression. Three models had a ΔAIC value <2. The saturated model was among the models with the lowest AIC values and a ΔAIC value <2. Among the top models, the absence of the variables dominant vegetation height or habitat area from the saturated model did not increase the ΔAIC value to >2 (Table 11). This indicates that these variables did not greatly improve the model. The removal of any other variable from the saturated model increased the ΔAIC to >2 indicting these variables and interactions improved the top models. The model with the lowest AIC value did not contain the variable vegetation height. This model and the fully saturated model had AIC_ws of 0.49 and 0.31, respectively.

Table 12 contains the composite model value of each explanatory variable for both portions of the zero inflated regression model. These values for the binomial portion of the model indicate that the variables percent vegetation cover and saturated substrate/ shallow water cover and the multiplicative interaction between percent vegetation cover and dominate vegetation height were important variables for explaining the absence of shorebirds from fine scale units. The base line odds of a shorebird being present in a fine scale unit were 0.17. These odds decreased by 333 times when percent vegetation cover was high. This decrease in odds was the greatest of any variable included in the top models. These results indicate that extensive vegetation cover may greatly decrease the value of a wetland habitat to a migrant shorebird.

The composite model values of the explanatory variables in the negative binomial portion of the model indicate that the variables ENN, saturated substrate/shallow water cover, and the multiplicative interaction between habitat area and ENN were important variables for explaining the abundance of shorebirds within fine scale units. Increased shorebird abundance was associated with decreases in the variables ENN and saturated substrate/shallow water cover. These results suggest that shorebirds were more abundant in wetlands that were closer to other wetlands as well as those that had a higher water to mudflat ratio. The importance of the variables habitat area and ENN and the interaction between them further supports the results of the class-level landscape metric analysis. Areas consisting with aggregated complexes of wetlands have a positive relationship with shorebird abundance.

Table 13 contains the mean values of the habitat measurements we collected within fine scale units. Generally, the habitat of Chalidridine sandpipers was characterized by a relatively moderate ratio of saturated substrate/shallow water cover and low vegetation cover. Higher vegetation cover associated with Pectoral Sandpipers was the exception (mean = 0.29). American Avocet, Greater Yellowlegs *(Tringa melanoleuca),* Lesser Yellowlegs, Solitary Sandpiper (*T. solitaria)* and Wilson's Phalarope habitats were characterized by higher shallow water cover and greater vegetation cover than Chalidridine sandpipers. The mean vegetation cover value for Wilson's Snipe *(Gallinago delicate)* was the highest among species (mean = 0.42). Mean habitat area was greatest for American Avocet and Black-necked Stilt *(Himantopus mexicanus)* (mean = 2.5 and 2.55 hectares, respectively).

The results of this research demonstrate that wetlands in north-central Oklahoma provide important habitat for a diverse array of migrant shorebirds. Many of the shorebirds species were found on wetlands that contained high amounts of mudflat and shallow water and low vegetation cover which indicates management efforts should be focus on maintaining these habitat characteristics when possible. On a landscape scale, areas of this region that contain abundant and aggregated complexes of temporary wetlands are extremely important for facilitating shorebird migration through this region. Conservation efforts should be focused on protecting and maintaining these complexes.

SIGNIFICANT DEVIATIONS

We were unable to obtain sufficient invertebrate samples to fully address Objective #3. Preliminary sampling of invertebrates was conducted during the first field season, but given the typically patchy distribution of benthic invertebrates, particularly in some of the more ephemeral wetlands surveyed for shorebirds, core samples frequently had no or very few benthic invertebrates. Furthermore, time constraints relative to the demands of surveying many wetlands across a wide area of western Oklahoma did not permit adequate sampling of invertebrates.

COSTS

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Table 1. List of each National Land Cover Database (2001) land-cover class, merged class name, and description of merged classes found within the study area.

NLCD 2001 Class Name	Merged Class Name	Merged Class Description
Developed Open Space Developed Low Intensity Developed Medium Intensity Developed High Intensity	Developed	Areas with impervious surface accounting for <20% - 100% total cover
Barren Land	Barren Land	Areas of barren accumulations of earthen material, with vegetation cover accounting for <15% of total cover.
Deciduous Forest Evergreen Forest Mixed Forest Shrub/Scrub	Forest	Areas with woody plant cover accounting for >20% of total cover.
Grassland/Herbaceous	Grassland/Herbaceous	Areas with graminoid or herbaceous vegetation accounting for >80% of total cover.
Pasture/Hay	Pasture	Areas of perennial grass and legumes planted for livestock. Pasture and hay vegetation account for >20% of total cover.
Cultivated Crops	Cropland	Areas of annual crops. Crop vegetation accounts for >20% of total cover
Woody Wetlands Open Water	Wetland Non-habitat	Areas of open deepwater (>16cm) or wetland areas dominated by woody vegetation canopy cover.

Table 2. A list of the class level and patch level metrics we measured within each broad scale unit using the program FRAGSTATS (McGarigal et al. 2002). The type, name and a description of the metrics we selected are provided. Descriptions of each metric were adapted from the metric descriptions provided with the program FRAGSTATS (McGarigal et al. 2002).

Level	**Metric Type**	**Metric**	**Description**
Patch	Area and Density	Patch Area	The area in hectares of each discrete focal patch of a given class.
Class		Total Class Area	The sum of all areas of a class type in hectares within a broad scale unit.
		Percentage of Broad scale unit	The sum of all areas of a class type divided by the broad scale unit area. The percentage of each broad scale unit comprised of a class.
		Mean Patch Area	The mean area value of discrete patches of a class type within a broad scale unit.
Patch	Isolation and Proximity	Euclidian Nearest Neighbor Distance	The straight-line distance measured from nearest focal patch edge to nearest patch edge of the same class type. It is measured from the center of each edge cell. As Euclidian Nearest Neighbor Distance approaches zero, the distance between patches of the same class decreases.
Class		Mean Euclidian Nearest Neighbor Distance	The sum of all of the shortest straight-line distances (m) from each focal patch to the nearest neighboring discrete patch of the same class type within each broad scale unit. The sum is divided by the total number of discrete patches within each broad scale-level unit.
Class	Shape	Mean Contiguity Index	The sum of the contiguity indexes for each patch of the same class type within each broad scale unit. The total number of discrete patches of the same class type divides this sum. The contiguity index is a measure of the spatial connectedness of grid cells within a focal patch. Larger contiguous patches result in a higher contiguity index value.

Table 2. cont.

Level	Metric Type	Metric	Description
Class	Contagion and Interspersion	Interspersion and Juxtaposition Index	The interspersion and juxtaposition index approaches zero when the distribution of adjacencies of patches of a class type becomes increasingly uneven. As the distribution of adjacencies becomes equal, the index approaches 100. This index measures the interspersion or intermixing of patches of a class type.

Table 3. The values of class level metrics for ten broad scale experimental units located in the Mixed-grass Prairie Region of Oklahoma. The results summarize the broad scale composition and configuration of land cover and shorebird habitat (SH) classes located within each listed broad scale unit (BU).

	Broad Scale Unit									
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Class Area (ha)										
Temporary SH	340.11	381.69	959.40	1719.27	1393.74	209.07	241.47	383.94	1235.52	98.46
Semi-Permanent SH	260.64	202.50	265.23	277.20	434.16	332.19	310.86	249.93	98.82	164.34
Permanent SH	494.73	558.36	2742.93	658.62	124.02	1134.18	435.87	417.24	71.10	94.59
Total SH	1095.48	1142.55	3967.56	2655.09	1951.92	955.80	988.20	1051.11	1405.44	357.39
% Of BU										
Developed	73.5	6.32	3.25	5.30	5.34	8.87	9.4	3.28	3.90	5.41
Barren Land	0.01	0.14	8.62	0.07	0.01	0.03	0.02	0.01	0.02	0.02
Forest	2.60	5.27	3.42	3.87	1.21	17.80	2.90	13.46	2.13	0.10
Grassland/Herbaceous	7.05	39.57	30.16	32.20	22.64	44.46	26.83	55.22	68.94	23.83
Cropland	7.28	44.53	17.73	48.86	64.32	22.18	56.62	24.49	20.25	66.17
Pasture	0.29	0.38	0.25	0.04	0.13	0.40	0.42	0.02	0.17	0.30
Wetland Non-Habitat	5.72	0.15	16.49	0.21	0.14	0.91	0.70	0.19	0.11	3.04
Temporary SH	1.08	1.21	3.05	5.47	4.44	0.66	0.77	1.22	3.93	0.31
Semi-Permanent SH	0.82	0.64	8.29	0.88	1.38	1.06	0.99	0.79	0.31	0.52
Permanent SH	1.57	1.78	8.73	2.10	0.39	3.61	1.39	1.32	0.23	0.30
Mean Patch Area										
Temporary SH	4.00	1.61	3.09	3.16	2.73	1.42	1.71	1.98	2.50	1.05
Semi-Permanent SH	3.67	2.22	18.35	1.95	2.15	1.17	1.57	1.30	1.35	1.03
Permanent SH	8.11	8.86	48.12	10.13	2.38	6.06	2.67	4.09	2.73	1.97

Table 3. cont.

Variable	Broad Scale Unit 1	2	3	4	5	6	7	8	9	10
Interspersion and Juxtaposition Index										
Temporary SH	64.13	48.94	62.96	43.46	41.99	53.09	45.51	47.39	42.66	54.96
Semi-Permanent SH	69.60	52.44	73.63	54.33	47.52	57.80	46.95	49.12	38.46	36.99
Permanent SH	71.71	56.80	66.54	57.54	50.20	61.57	55.72	55.56	41.11	37.26
Total BU	70.43	65.20	67.06	59.72	50.50	68.11	59.30	65.69	50.74	45.56
Mean Contiguity Index										
Temporary SH	0.64	0.59	0.61	0.62	0.62	0.57	0.59	0.59	0.60	0.54
Semi-Permanent SH	0.63	0.59	0.66	0.61	0.59	0.55	0.57	0.55	0.57	0.56
Permanent SH	0.61	0.64	0.63	0.64	0.66	0.63	0.64	0.62	0.66	0.63
Total BU	0.64	0.60	0.52	0.62	0.61	0.59	0.60	0.58	0.59	0.53
Mean Euclidian Nearest Neighbor Distance										
Temporary SH	619.64	303.70	203.35	211.30	249.16	483.84	513.63	408.06	223.42	782.25
Semi-Permanent SH	664.59	662.94	297.38	557.63	500.68	434.03	466.96	508.86	779.90	564.33
Permanent SH	308.35	665.27	377.25	722.26	909.72	446.17	509.96	624.04	1084.05	966.49
Total BU	265.59	256.57	141.85	181.52	194.32	248.36	255.30	305.37	208.88	193.35

Table 4. Description of the habitat variables that were measured at each fine scale unit of shorebird habitat during shorebird surveys.

Variable Name	**Variable Code**	**Description**
Saturated substrate/ shallow water cover	s	% total cover of saturated substrate within the portion of a fine scale unit covered by shorebird habitat. The remaining portion of the % cover estimate is shallow water (<16 cm).
% Vegetation cover	v	% total cover of emergent vegetation within the portion of a fine scale unit covered by shorebird habitat.
Dominant vegetation height	h	The dominant height category of the emergent vegetation cover within the portion of a fine scale unit covered by shorebird habitat. The height categories are: (1) 0m (2) < 0.5m (3) >0.5m - <1.5m (4) >1.5m.
Dominant slope	d	The dominant slope angle category between the edge of shorebird habitat and non-habitat within the portion of a fine scale unit covered by shorebird habitat. The slope categories are: (1) minimal, <20 degrees; (2) moderate, >20 < 45 degrees; and (3) steep, >45 degrees. Estimated in degrees with an optical clinometer.
% Habitat area	a	% total cover of saturated substrate and shallow water within an entire fine scale unit.

Table 5. AIC table with AIC values (AIC), degrees of freedom (DF), delta AIC (Δ AIC) and AIC weights (AIC_w) calculated using saturated regression models of the shorebird count data. The AIC values were compared among standard and zero inflated Poisson and negative binomial models to access the fit of the shorebird count data to the underlying model.

Model Type	**AIC**	**DF**	**Δ AIC**	**AIC_w**
Zero inflated negative binomial	1138.1	19	0	1
Standard negative binomial	1200.5	10	62.5	
Zero inflated Poisson	3637.5	18	2499.5	
Standard Poisson	6336.2	9	5198.1	

Table 6. List of migratory shorebird species that were encountered during study.

Species
Black-bellied Plover *(Pluvialis squatarola)*
American Golden-Plover *(Pluvialis dominica)*
Semipalmated Plover *(Charadrius semipalmatus)*
American Avocet *(Recurvirostra americana)*
Black-necked Stilt *(Himantopus mexicanus)*
Willet *(Tringa semipalmata)*
Lesser Yellowlegs *(Tringa flavipes)*
Greater Yellowlegs *(Tringa melanoleuca)*
Solitary Sandpiper *(Tringa solitaria)*
Whimbrel *(Numenius phaeopus)*
Long-billed Curlew *(Numenius americanus)*
Hudsonian Godwit *(Limosa haemastica)*
Marbled Godwit *(Limosa fedoa)*
Ruddy Turnstone *(Arenaria interpres)*
Red Knot *(Calidris canutus)*
Sanderling *(Calidris alba)*
Dunlin *(Calidris alpina)*
Semipalmated Sandpiper *(Calidrispusilla)*
Western Sandpiper *(Calidris mauri)*
Least Sandpiper *(Calidris minutilla)*
White-rumped Sandpiper *(Calidris fucicollis)*
Pectoral Sandpiper *(Calidris melanotos)*
Baird's Sandpiper *(Calidris bairdii)*
Buff-breasted Sandpiper *(Tryngites subruficollis)*
Long-billed Dowitcher *(Limnodromus scolopaceus)*
Wilson Snipe *(Gallinago delicate)*
Stilt Sandpiper *(Calidris himantopus)*
Wilson's Phalarope *(Phalaropus tricolor)*
Red-necked Phalarope *(Phalaropus lobatus)*

Table 7. A list of the migratory shorebird species encountered during the surveys of broad scale experimental units. An X within a column indicates the species was encountered within a broad scale unit located within the corresponding county.

Species	**Alfalfa Cty.**	**Blaine Cty.**	**Canadian Cty.**	**Garfield Cty.**	**Grant Cty.**	**Kingfisher Cty.**	**Logan Cty.**	**Major Cty.**	**Oklahoma Cty.**	**Woods Cty.**
Black-bellied Plover *(P. squatarola)*	X			X		X				
American Golden-Plover *(P. dominica)*	X			X						
Semipalmated Plover *(C. semipalmatus)*	X					X	X	X		
American Avocet *(R. americana)*	X			X		X			X	X
Black-necked Stilt *(H. mexicanus)*	X			X		X				
Willet *(T. semipalmata)*	X		X	X		X		X		
Lesser Yellowlegs *(T. flavipes)*	X		X	X	X	X	X	X	X	X
Greater Yellowlegs *(T. melanoleuca)*	X	X	X	X	X	X	X	X	X	X
Solitary Sandpiper *(T. solitaria)*	X		X	X		X		X	X	X
Whimbrel *(N. phaeopus)*	X									
Long-billed Curlew *(N. americanus)*	X									
Hudsonian Godwit *(L. haemastica)*	X			X					X	
Marbled Godwit *(L. fedoa)*	X			X		X				
Ruddy Turnstone *(A. interpres)*	X									
Red Knot *(C. canutus)*	X									

Table 7. cont.

Species	Alfalfa Cty.	Blaine Cty.	Canadian Cty.	Garfield Cty.	Grant Cty.	Kingfisher Cty.	Logan Cty.	Major Cty.	Oklahoma Cty.	Woods Cty.
Sanderling *(C. alba)*	X									
Dunlin *(C. alpina)*	X									
Semipalmated Sandpiper *(C. spusilla)*	X		X	X		X		X	X	X
Western Sandpiper *(C. mauri)*	X		X	X		X				
Least Sandpiper *(C. minutilla)*	X	X	X	X	X	X	X	X	X	X
White-rumped Sandpiper *(C. fucicollis)*	X		X	X		X	X	X	X	X
Pectoral Sandpiper *(C. melanotos)*	X	X	X	X		X		X		X
Baird's Sandpiper *(C. bairdii)*	X	X	X	X		X	X	X	X	X
Buff-breasted Sandpiper *(T. subruficollis)*	X			X		X				
Long-billed Dowitcher *(L. scolopaceus)*	X		X	X		X		X	X	X
Wilson Snipe *(G. delicate)*	X	X	X	X	X	X	X	X	X	X
Stilt Sandpiper *(C. himantopus)*	X		X	X		X		X		X
Wilson's Phalarope *(P. tricolor)*	X		X	X	X	X		X	X	X
Red-necked Phalarope *(P. lobatus)*	X									

Table 8. The migration chronology of shorebird species surveyed during the spring migration periods of the study. The number of asterisks indicates the percentage of the total population surveyed that was present during the given time range (*<5% ** <25%*** <50%**** >50%).

Species	**Early March-Late March**	**Late March-Mid April**	**Mid April-Early May**	**Early May-Late May**
Black-bellied Plover *(P. squatarola)*				****
American Golden-Plover *(P. dominica)*	****	**		
Semipalmated Plover *(C. semipalmatus)*			****	***
American Avocet *(R. americana)*	**	**	***	***
Black-necked Stilt *(H. mexicanus)*			***	****
Willet *(T. semipalmata)*			****	**
Lesser Yellowlegs *(T. flavipes)*		**	****	**
Greater Yellowlegs *(T. melanoleuca)*	**	***	***	**
Solitary Sandpiper *(T. solitaria)*		**	****	**
Whimbrel *(N. phaeopus)*			**	****
Long-billed Curlew *(N. americanus)*			**	****
Hudsonian Godwit *(L. haemastica)*			**	****
Marbled Godwit *(L. fedoa)*				
Ruddy Turnstone *(A. interpres)*			*	****
Red Knot *(C. canutus)*				

Table 8. cont.

Species	Early March-Late March	Late March-Mid April	Mid April-Early May	Early May-Late May
Sanderling *(C. alba)*			**	****
Dunlin *(C. alpina)*		*	*	****
Semipalmated Sandpiper *(C. spusilla)*		*	**	****
Western Sandpiper *(C. mauri)*			**	****
Least Sandpiper *(C. minutilla)*	*	**	****	**
White-rumped Sandpiper *(C. fucicollis)*			**	****
Pectoral Sandpiper *(C. melanotos)*		*	***	****
Baird's Sandpiper *(C. bairdii)*	**	****	**	*
Buff-breasted Sandpiper *(T. subruficollis)*				****
Long-billed Dowitcher *(L. scolopaceus)*	*	**	****	
Wilson Snipe *(G. delicate)*	***	***	**	*
Stilt Sandpiper *(C. himantopus)*	*	*	**	****
Wilson's Phalarope *(P. tricolor)*		*	****	***
Red-necked Phalarope *(P. lobatus)*				

Table 9. The migration chronology of shorebird species surveyed during the fall migration periods of the study. The number of asterisks indicates the percentage of the total population surveyed that was present during the given time range (*<5% ** <25%*** <50%**** >50%).

Species	Mid July-Early August	Early August-Late August	Late August-Mid September	Mid September-Mid October
Black-bellied Plover *(P. squatarola)*			**	****
American Golden-Plover *(P. dominica)*			*	****
Semipalmated Plover *(C. semipalmatus)*		***	****	
American Avocet *(R. americana)*	***	***	***	**
Black-necked Stilt *(H. mexicanus)*	****	***	**	
Willet *(T. semipalmata)*	***	***	***	
Lesser Yellowlegs *(T. flavipes)*	**	***	***	***
Greater Yellowlegs *(T. melanoleuca)*	**	***	***	***
Solitary Sandpiper *(T. solitaria)*	**	****	*	
Whimbrel *(N. phaeopus)*				
Long-billed Curlew *(N. americanus)*				
Hudsonian Godwit *(L. haemastica)*				
Marbled Godwit *(L. fedoa)*	***	***		
Ruddy Turnstone *(A. interpres)*				****
Red Knot *(C. canutus)*				****

Table 9. cont.

Species	Mid July-Early August	Early August-Late August	Late August-Mid September	Mid September-Mid October
Sanderling *(C. alba)*			*	****
Dunlin *(C. alpina)*				****
Semipalmated Sandpiper *(C. spusilla)*	****	***	**	*
Western Sandpiper *(C. mauri)*		****	***	
Least Sandpiper *(C. minutilla)*	**	**	***	***
White-rumped Sandpiper *(C. fucicollis)*				
Pectoral Sandpiper *(C. melanotos)*	**	****	***	**
Baird's Sandpiper *(C. bairdii)*	***	***	***	*
Buff-breasted Sandpiper *(T. subruficollis)*			****	
Long-billed Dowitcher *(L. scolopaceus)*	*	****	***	**
Wilson Snipe *(G. delicate)*		**	***	****
Stilt Sandpiper *(C. himantopus)*	***	***	***	
Wilson's Phalarope *(P. tricolor)*	***	***	***	*
Red-necked Phalarope *(P. lobatus)*			*	****

Table 10. Spearman's Rank Correlation Coefficients (r) of class level variables that were significantly correlated with shorebird abundance among broad scale units. We considered correlations ≥ 0.7 or ≤ -0.7 significant ($p = \leq 0.20$).

Class-level Landscape Metric	r	p
Total Class Area of Total Shorebird Habitat	0.7	0.19
Percentage of Temporary Shorebird Habitat	0.7	0.19
Mean Contiguity Index of Temporary Shorebird Habitat	0.7	0.19
Mean Euclidean Nearest Neighbor Distance of Temporary Shorebird Habitat	-0.9	<0.003
Mean Euclidean Nearest Neighbor Distance of Total Shorebird Habitat	-0.8	0.1
Interspersion and Juxtaposition Index of Temporary Shorebird Habitat	-0.9	<0.003

Table 11. AIC table with AIC values (AIC), degrees of freedom (DF), delta AIC (Δ AIC) and AIC weights (AIC_w). Seventy four model combinations were used in the analysis. Three models had an Δ AIC <2. The variable code (e) was used to represent Euclidian nearest neighbor distance all other variable codes are listed in Table 4.

Model Name	**AIC**	**DF**	**Δ AIC**	**AIC_w**
model.svdeaxeaxvh[a]	1137.2	17	0.0	0.49
model.svhdeaxeaxvh	1138.1	19	0.9	0.31
model.svhdexeaxvh	1139.4	17	2.2	0.16
model.vhdeaxeaxvh	1143.3 17	17	6.1	0.02

[a] An x present in a model name indicates a multiplicative term was included in model. The codes following the x indicate those variables included in the term. Codes not preceded by an x in the model name were additive.

Table 12. Variable importance values calculated using the composite model method. Calculations were made using the coefficients for each variable and AIC_w summed across the top 3 models selected. The variable code (e) was used to represent Euclidian nearest neighbor distance all other variable codes are listed in Table 4.

Variable Code	Composite Variable Value	Composite Variable Value
	Binomial Portion	***Negative Binomial Portion***
s	2.16	0.80
v	8.00	0.03
h	0.24	0.61
d	1.69	0.56
e	0.53	0.96
a	3.70e-4	0.47
xea	1.23e-6	0.79
xvh	4.04	0.42

Table 13. The mean and standard deviation values of habitat measurements collected within fine scale units in which the listed shorebird species was present. Only species encountered >10 times among discrete fine scale units were included.

Species	Saturated substrate/ shallow water cover	% Vegetation cover	Dominate Vegetation Height	Dominate Slope	Habitat Area
American Avocet *(R. americana)*	0.80 (0.18)	0.09 (0.15)	1.7 (0.82)	1.02 (0.15)	2.50 (1.60)
Black-necked Stilt *(H. mexicanus)*	0.80 (0.27)	0.19 (0.21)	2.18 (0.88)	1 (0)	2.55 (1.73)
Lesser Yellowlegs *(T. flavipes)*	0.83 (0.15)	0.29 (0.24)	2.07 (0.57)	1.03 (0.18)	1.67 (1.37)
Greater Yellowlegs *(T. melanoleuca)*	0.75 (0.22)	0.19 (0.22)	1.73 (0.63)	1.09(0.29)	1.57 (1.43)
Solitary Sandpiper *(T. solitaria)*	0.74 (0.24)	0.25 (0.23)	2.30 (0.67)	1.11 (0.32)	1.66 (1.60)
Semipalmated Sandpiper *(C. spusilla)*	0.74 (0.19)	0.04 (0.09)	1.41 (0.71)	1.06 (0.24)	2.11 (1.46)
Western Sandpiper *(C. mauri)*	0.77 (0.14)	0.05 (0.12)	1.22 (0.46)	1.22 (0.42)	2.21 (1.81)
Least Sandpiper *(C. minutilla)*	0.69 (0.20)	0.10 (0.15)	1.68 (0.65)	1.05 (0.25)	1.67 (1.41)
White-rumped Sandpiper *(C. fucicollis)*	0.76 (0.20)	0.06 (0.12)	1.66 (0.91)	1.09 (0.28)	2.00 (1.57)
Pectoral Sandpiper *(C. melanotos)*	0.78 (0.16)	0.29 (0.24)	2.08 (0.61)	1.05 (0.22)	1.85 (1.40)
Baird's Sandpiper *(C. bairdii)*	0.68 (0.20)	0.09 (0.14)	1.66 (0.63)	1.09 (0.29)	1.51 (1.34)
Long-billed Dowitcher *(L. scolopaceus)*	0.80 (0.15)	0.17 (0.17)	1.86 (0.45)	1.04 (0.19)	1.73 (1.54)
Wilson Snipe *(G. delicate)*	0.71 (0.25)	0.42 (0.23)	2.32 (0.62)	1.03 (0.18)	1.66 (1.37)
Stilt Sandpiper *(C. himantopus)*	0.79 (0.13)	0.13 (0.17)	1.7 (0.55)	1.06 (0.25)	2.34 (1.75)
Wilson's Phalarope *(P. tricolor)*	0.84 (0.16)	0.21 (0.19)	2 (0.64)	1.03 (0.17)	2.21 (1.68)

Figure Legends

Figure 1. Map of study area indicated by blue counties and location of the Mixed-grass Prairie Region as indicated by green in the inset image. The study area encompasses Alfalfa, Blaine, Canadian, Garfield, Grant, Kingfisher, Logan, Major, Oklahoma, and Woods counties.

Figure 2. A model depicting the acquisition and assemblage of the base data layers, the placement of broad scale units within the study area, and the examination of each broad scale unit for shorebird habitat. All identified shorebird habitat was delineated and then classified into 1 of the 3 habitat classes shown.

Figure 3. A layout displaying the entire extent of shorebird habitat delineated in 3 broad scale units within the study area.

Figure 4. A map displaying a raster grid of shorebird habitat and land cover classes within a broad scale unit. A raster gird layer of 3 classes of shorebird habitat was merged with a raster grid layer of 7 NLCD (2001) based land cover classes to create this output. The legend depicts the resulting 10 land-cover classes. The last 3 land-cover classes in the legend are the shorebird habitat classes that were delineated and classified.

Figure 1.

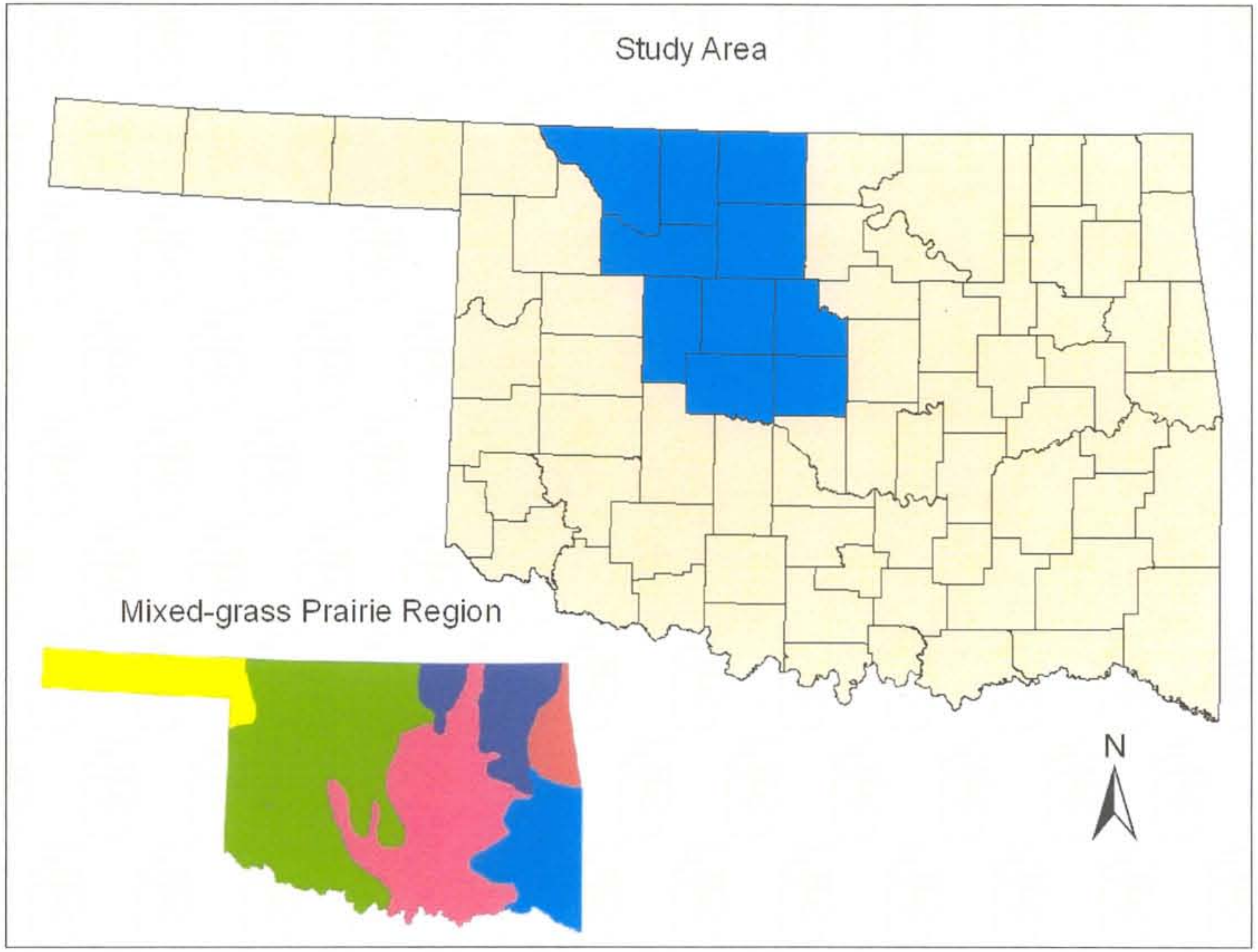


Figure 2.

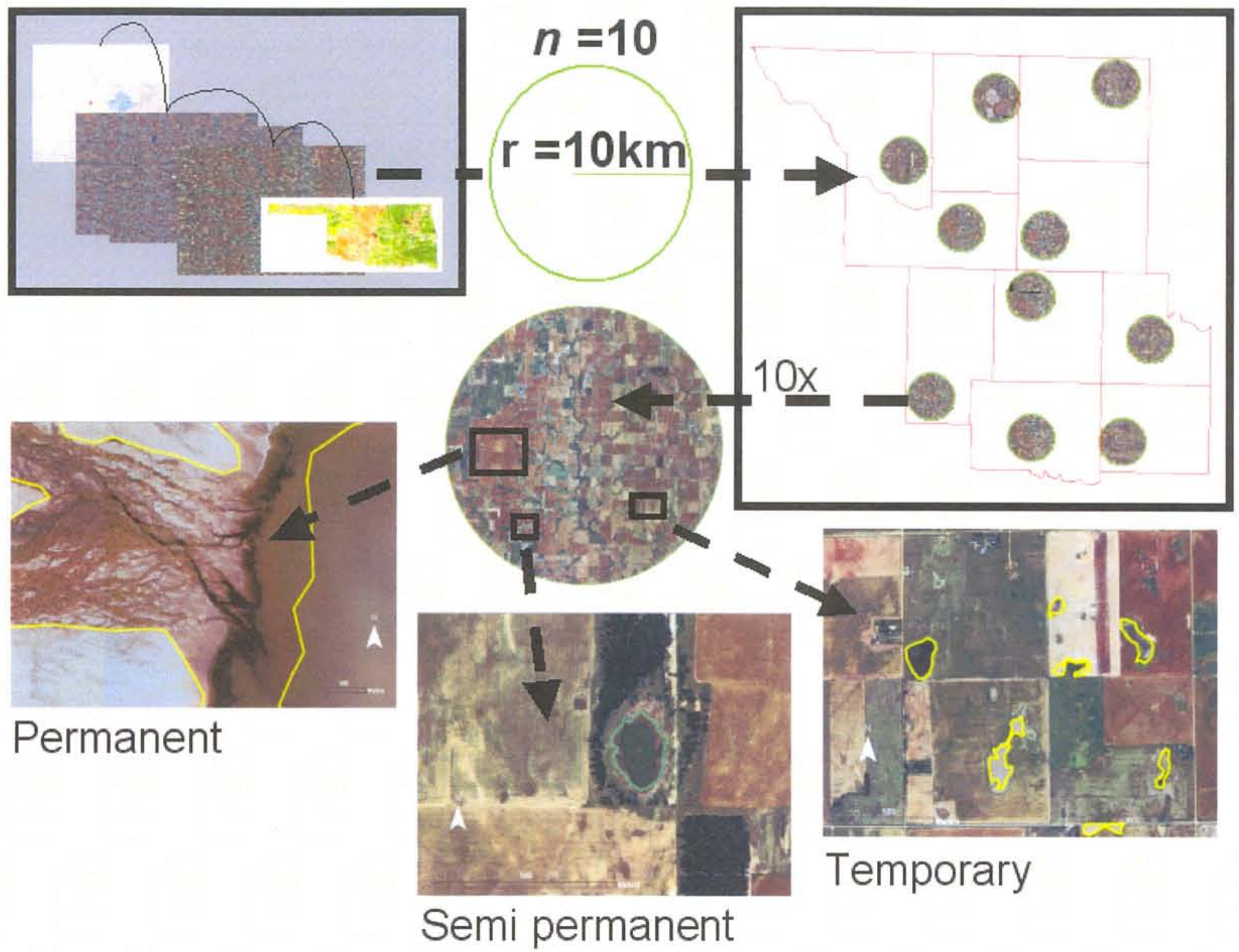


Figure 3.

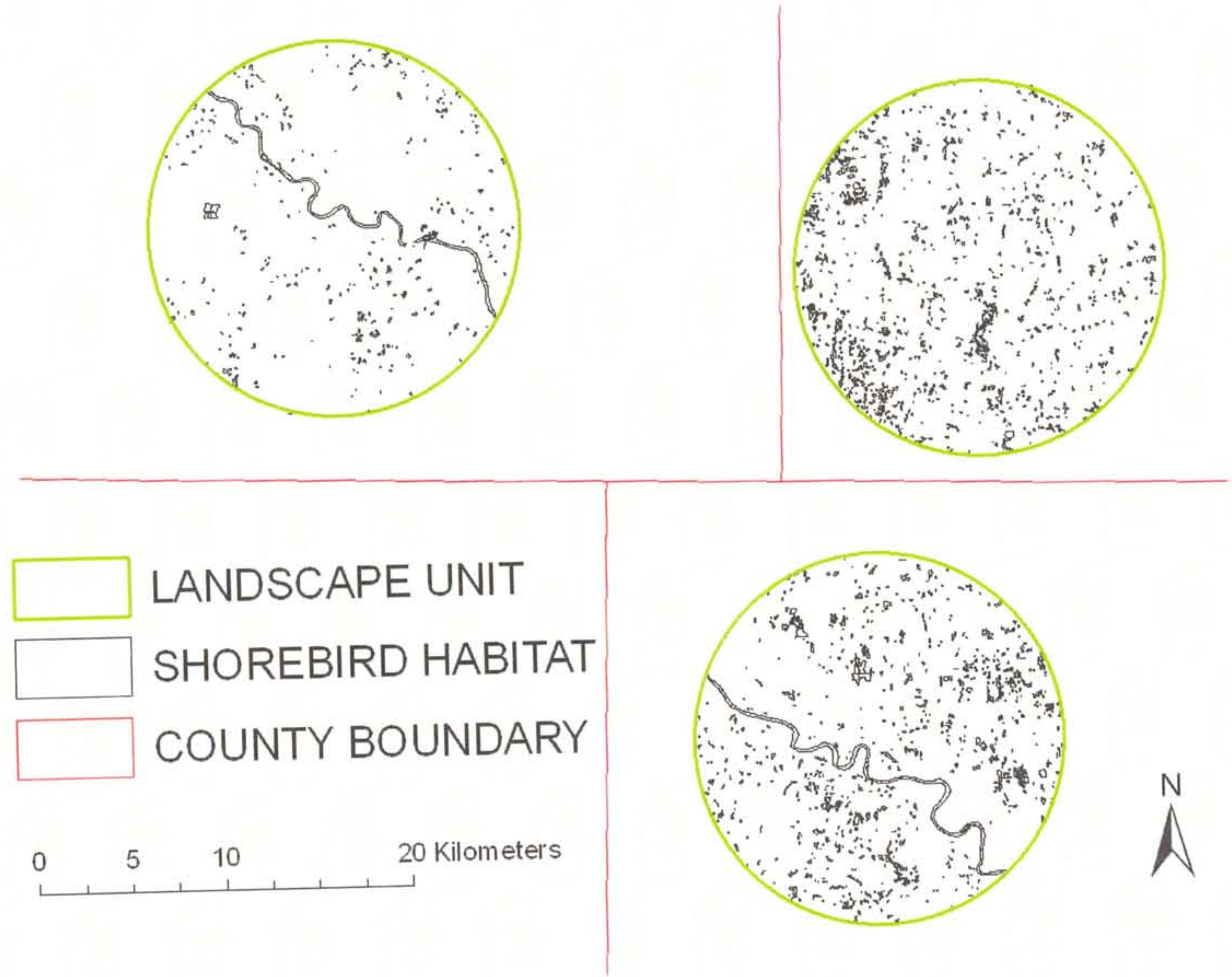
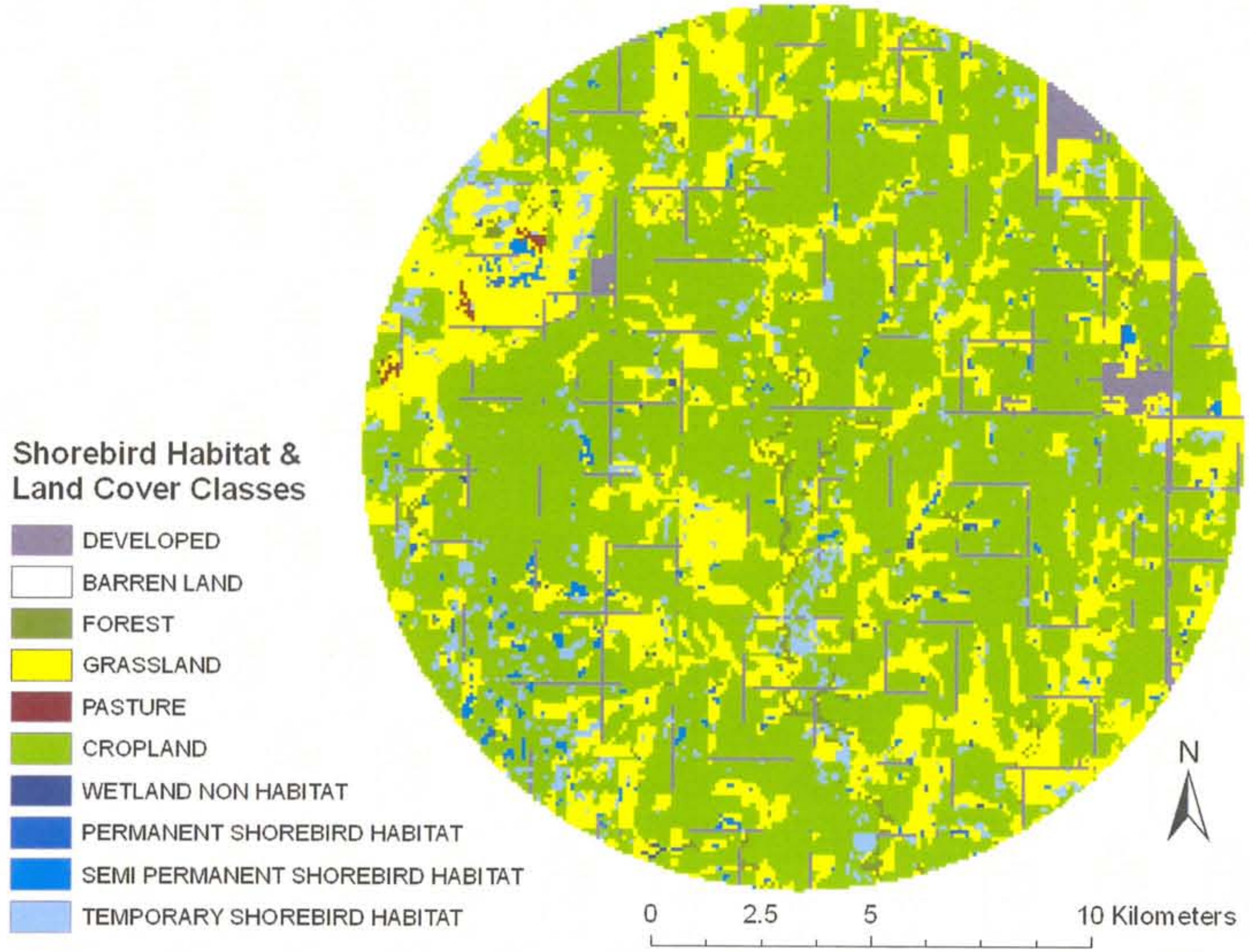

LANDSCAPE UNIT
SHOREBIRD HABITAT
COUNTY BOUNDARY
0
5
10
20 Kilometers
N

Figure 4.


Shorebird Habitat &
Land Cover Classes
DEVELOPED
BARREN LAND
FOREST
GRASSLAND
PASTURE
CROPLAND
WETLAND NON HABITAT
PERMANENT SHOREBIRD HABITAT
SEMI PERMANENT SHOREBIRD HABITAT
TEMPORARY SHOREBIRD HABITAT
N
0
2.5
5
10 Kilometers