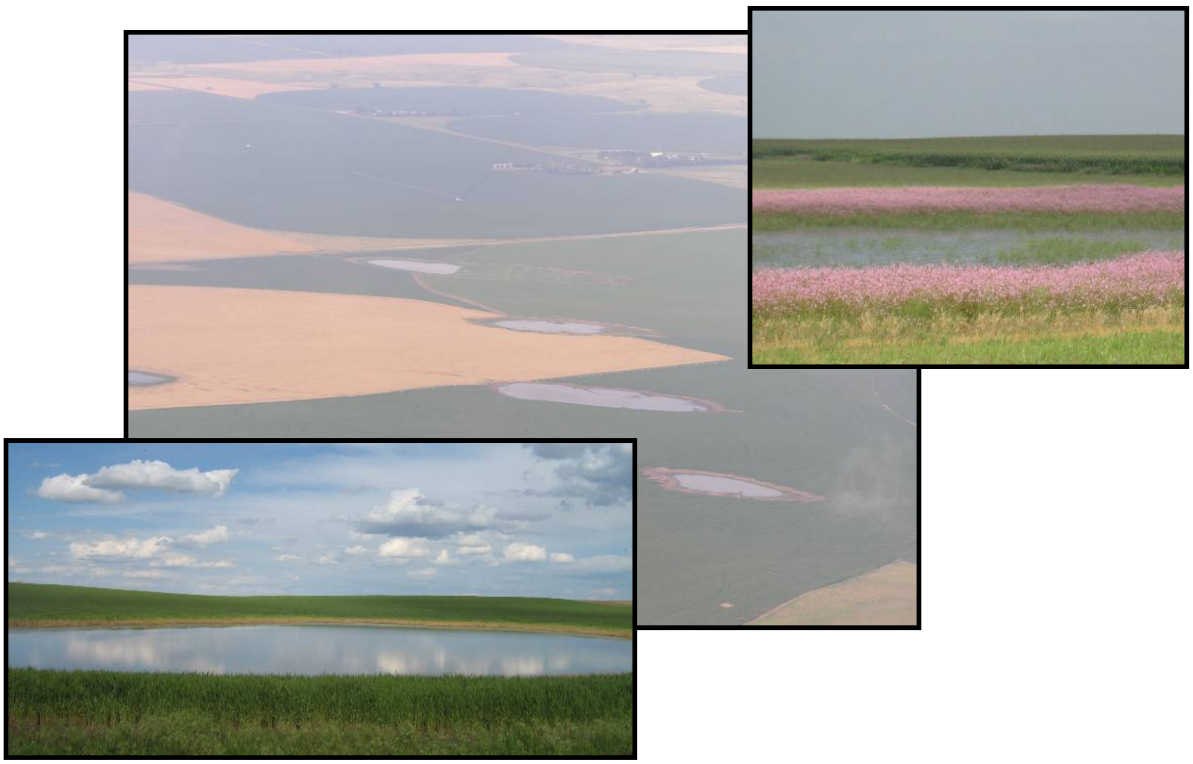
Biological Inventory and Evaluation of Conservation Strategies In Southwest Playa Wetlands

Final Report to the Nebraska Game and Parks Commission and the Playa Lakes Joint Venture



June 2009

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Executive Summary

Playas are wetlands fed by rainfall and associated runoff that provide excellent stopover habitat for migratory shorebirds, waterfowl, and other birds. Playas also provide many other important wetland functions, including flood mitigation, capturing and filtering surface runoff, recharging the Ogallala aquifer, and enhancing biodiversity on a landscape scale (Pezzolesi et al. 1998, Haukos and Smith 1994). Many playas have been affected by sedimentation in heavily modified agricultural landscapes. Buffers and conservation tillage practices may be effective in reducing sedimentation in playas but little is known about the effects of such practices on playa hydrology and wildlife use. In the Southwest Playa Complex of Nebraska, we investigated playa hydrological and habitat responses to heavy rainfall and use by frogs, toads, and migrating birds in relation to landscape composition, including buffer programs, such as the USDA's Conservation Reserve Program (CRP).

We conducted aerial surveys of two areas within the Southwest Playa Complex (LaGrange 2005) that received heavy rainfall. We analyzed aerial surveys of 1,738 playas for hydrologic responses to rainfall. Playas in grassland were more likely to become inundated than playas in cropland, and both became wetter than playas in watersheds planted to the taller, dense vegetation of CRP. Playa inundation was also positively related to the amount of rainfall received, the area of the playa, and weakly related to the proportion of low-permeability soils in the watershed.

Incorporating 9,362 field surveys of 558 playas, we modeled bird use using generalized linear mixed models which enabled us to model migration chronology, account for non-independence of repeat visits, and provide inference regarding variation among playas. Numbers of bird species, as well as counts of waterfowl, shorebirds, and landbirds all showed responses to landscape composition in addition to strong seasonal effects and non-linear responses to playa size, indicating rapid increases at smaller playas sizes, leveling off after approximately 4 ha (10 ac). The number of bird species using playas increased with the increasing proportion of playas in the surrounding landscape and decreasing proportion of the landscape in cropland. Use of playas by both waterfowl and landbirds increased with the area of CRP in the landscape. Shorebirds responded positively to the density of playas in the landscape and negatively to hydrological modifications (e.g., pits). We compared vantage surveys to full surveys incorporating flush counts for a subset of playas. Average numbers of waterfowl and shorebirds counted with vantage surveys were 71% and 31%, respectively, of numbers detected by full counts. Models including playa size and amount of vegetation in the playas indicated that flush counts improved the detection of species. However, we detected no effect of survey type on numbers of waterfowl or shorebirds, suggesting that survey methodology did not hinder our ability to model habitat and landscape relationships.

Of particular interest to the Nebraska Game and Parks Commission (NGPC), we documented 158,232 birds comprising 140 species on playa surveys in locations spanning ten counties. We found 29 avian species of concern according to the Nebraska Natural Legacy Project, including five Tier I species. Using Nebraska Natural Heritage Program (NNHP) protocols for nocturnal calling surveys, we documented use of 93% of playas by frogs and toads, comprising four species. We documented the occurrence of

70 plant species in playas, including four species of conservation concern according to NNHP. All of these data have been prepared into a database and given to NGPC and NNHP for their use and subsequent study.

We also provide data pertinent to the biological planning efforts of Playa Lakes Joint Venture (PLJV), as follows:

- The GIS dataset resulting from this project contains 15,812 potential playas (8,893 ha [21,976 ac]), 12% more playas and 34% more area than predicted from National Wetlands Inventory data alone, the model previously in use by PLJV.
- We confirmed playas at an overall rate of 72% of predicted playa locations, with an additional 8% of locations classified as “possible playas” usually indicating depressions with heavy anthropogenic modifications. Future biological planning could apply these percentages for the proportion of mapped potential playa locations that are currently functioning as playas in the landscape.
- Based on our aerial survey data, pits accounted for 5% of the wet area or 2% of the mapped potential playa area. These figures are much lower than the estimates currently employed for this part of the Joint Venture, 40% of the wet area in pits or 6% of all the mapped playa area in pits.
- Combining percent cover by vegetation with water depth measurements, we estimated the proportion of wet playas that provided optimal foraging habitat for various classes of waterbirds. We found that on average, 20% of playa area was suitable for shorebirds (unvegetated, with water less than 12.7 cm [5 in] deep) and 39% was optimal for dabbling ducks (unvegetated, with water less than 40 cm). A more liberal estimate for waterfowl, allowing areas to be vegetated, would be 66%. These figures could be used to estimate the habitat area truly available to migrating birds. Our aerial survey data indicated that, following heavy rainfall, approximately 47% of basins became wet; combining these data with our average cover values for wet playas observed during the ensuing migratory season, on average 9% or 18% of playas provide conditions appropriate for foraging shorebirds and waterfowl, respectively. If one were able to predict the proportion of area in the PLJV that receives heavy rainfall each year or migratory season, then one could further model the total amount of habitat available to migratory birds.

These data represent the most comprehensive biological datasets for playas in the Nebraska Southwest Playa Complex. We hope that our research assists private landowners and resource partners in conservation planning and implementation for the perpetuation of playas in this landscape. Our results suggest that playas in native prairie may be especially valuable for having a higher probability of inundation by rain than playas in cropland or CRP programs while also being at lesser risk for sedimentation than playas in farmland. CRP was an important feature in the landscape associated with higher use by waterfowl and landbirds. A reduction in the probability of flooding for individual playas in CRP must be weighed against the beneficial influence of CRP in the landscape and the protection that buffers afford wetlands from sedimentation. Finally, larger playas in proximity to other playas may be particularly valuable for migratory waterbirds and should be considered in conservation planning.

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1 Introduction

Playas in the Southwest Complex of Nebraska.

Playas are shallow seasonal wetlands that are filled following heavy rainfall events in the short- and mid-grass regions of the Great Plains. Characteristic wet-dry cycles produce rich vegetation and insect resources that form critical migration habitat for waterfowl, shorebirds, and other wetland-dependent species (Skagen and Knopf 1993, Smith 2003). In the Southwest Playa Complex of Nebraska (Figure 1) there are estimated to be more than 16,000 playas totaling 8,774 ha (21,680 ac) (LaGrange 2005). However, due to localized and unpredictable rainfall events, not all playas are wet during an average year (Bolen et al. 1989). Information relating rainfall history to wet playa conditions is lacking, thereby hampering efforts to estimate habitat availability for migratory species (Hands 2005).

An estimated 70% of playas have been degraded due to sedimentation from agricultural landscapes (Smith 2003). Buffers and conservation tillage practices may help in reducing sedimentation in playas but the effects of such practices on playa hydrology are unknown. Conservation programs have been made available for buffer implementation, pit removal, and other practices, but there has not yet been an opportunity to monitor the hydrological and wildlife responses to these programs. Understanding the relationship between local and landscape features of playas and habitat use by amphibians and birds will enable landowners, managers, conservation partners, and others to engage in planning and implementation to conserve such habitats for wetland-dependent wildlife species of interest into the future.

Playa bisected by a road in southwest Nebraska.

Playas provide many other important wetland functions, including flood mitigation, capturing and filtering surface runoff, recharging the Ogallala aquifer, and enhancing biodiversity on a landscape scale (Pezzolesi et al. 1998, Haukos and Smith 1994). Understanding the relationship between rainfall events, the capture of surface runoff, and the storage of surface water may assist other conservation partners in water resource planning, including evaluating the possibility of using playa restoration and conservation as an offset to water depletions in western Nebraska.

The *Nebraska Natural Legacy Project* specifically articulates the need to conserve and restore Southwest Playas and further states that due to a lack of knowledge about these communities, "there is a need to conduct an analysis of these and other similar types of communities to identify priority sites for conservation action" (Schneider et al. 2005). This project addresses this information need by generating abundance and species lists for birds, amphibians, and other species using Playa Wetland and Wheatgrass Playa Grassland communities in the Shortgrass region of Nebraska.

This project similarly contributes to several high priority research needs of the Playa Lakes Joint Venture (PLJV), including increasing our understanding of the function of playa buffers, the highest priority research topic for the PLJV. The project also addresses two other high priority topics identified by the JV, including the monitoring of priority species during migration and the landscape-scale comparison of well-utilized and non well-utilized wetlands. The project also addresses two medium priority topics, the duration of inundation of individual playas, and comparing the rate of inundation and hydroperiod of playas in different land uses and landscape contexts.

Our primary study objectives were as follows:

1. Correlate various Geographic Information System (GIS) data layers, including satellite imagery from PLJV, National Wetland Inventory (NWI), Soil Survey Geographic (SSURGO), and aerial photography from USFWS to create a comprehensive map of playas in the region (PLJV Grant Objective 4, Nebraska Game and Parks Commission (NGPC) State Wildlife Grant (SWG) Objective 6).

2. Quantify playa hydroperiod responses to precipitation events, playa size, watershed size and condition, buffers, dominant land use, and mapped soil types (PLJV Grant Objective 1; SWG Objective 5).

3. Coordinate with the Nebraska Natural Heritage Program to document species of plants and animals using playas (SWG Objective 4).

4. Describe amphibian species composition and frequency of occurrence in playas (SWG Objective 2).

5. Quantify the diversity and abundance of bird species using wet playas during migration (PLJV Grant Objective 2, SWG Objective 1).

6. Analyze the relationship between bird and amphibian use and habitat variables within the wetland and landscape attributes of the surrounding watershed (PLJV Grant Objective 3; SWG Objective 3).

In addition, for a subset of playas to which we gained access, we documented the percent cover and species composition of vegetation and measured water depths. We also tested the degree to which vantage surveys represented bird use of playas by pairing vantage surveys with flush surveys.

This is the Final Report for NGPC State Wildlife Grant (SWG) *Biological Inventory and Evaluation of Conservation Strategies in Southwest Playa Wetlands* (T-41 Segments 1 and 2) and for PLJV Conoco-Phillips grants *Biological Inventory and Buffer Evaluation of Nebraska's Southwest Playas, Phases I – III,* which provided matching funds to the SWG.

2 METHODS

2.1 Study Area

The study area is the Southwest Playa Wetland Complex of western Nebraska (LaGrange 2005), encompassing 14,385 km^2 (5,554 mi^2) within the South-central Semi-arid Prairies Ecological Region (CEC 1997, Gauthier and Wiken 1998) and Shortgrass Prairie Bird Conservation Region 18 (US NABCI Committee 2000a, b). This region consists of flat to gently rolling topography, with occasional canyons and bluffs. The dominant native vegetation is shortgrass prairie composed of blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*) and western wheatgrass (*Pascopyrum smithii*). Irrigated and dry-land agriculture and livestock grazing are the primary land uses. Elevation ranges from 914 m (3,000 ft) to 1,646 m (5,400 ft), mean monthly temperature from -4^{o}C (24^{o}F) to 24^{o}C (76^{o}F) and annual precipitation ranges from 38 cm (15 in) to 51 cm (20 in) (Birdsall and Florin 1998). The area encompasses the Kimball Grasslands, Sandsage North, and Sandsage South Biologically Unique Landscapes as defined in the Nebraska Natural Legacy Project (Schneider et al. 2005) and the area of greatest playa density within the Playa Lakes Joint Venture in Nebraska (Figure 1).

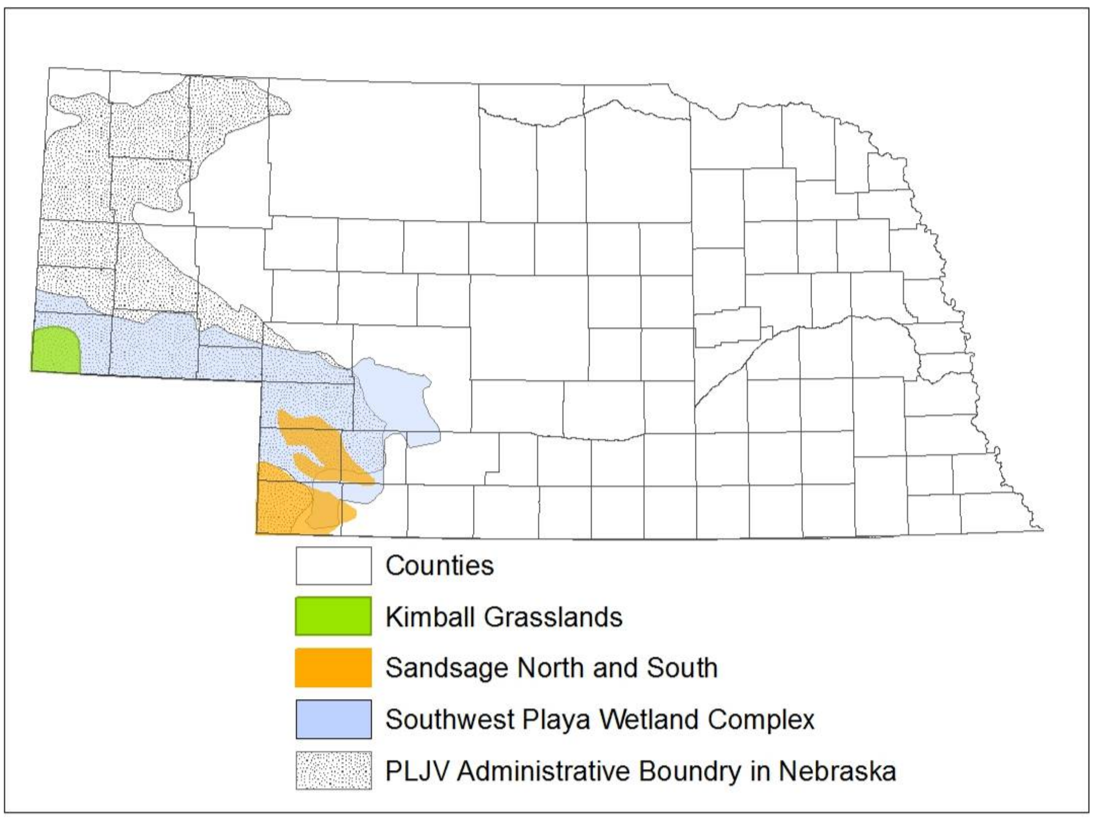


Figure 1. Boundaries of the Southwest Playa Wetland Complex, Playa Lakes Joint Venture, and Biologically Unique Landscapes in Nebraska.

2.2 GIS Database

At the inception of this project, we combined three data sources prepared by PLJV to make a GIS database of potential playa locations. The primary data source was the National Wetlands Inventory (imagery dates 1981-1982; Karen Callahan, PLJV, personal communication; USFWS 1982). PLJV included palustrine emergent wetlands with seasonal or temporary water status, excluding some water bodies, such as those associated with riverine systems and wetlands created by a dam. NWI provided 14,078 potential playa locations (6,653 ha [16,440 ac]) in our study area, the Southwest Playa Complex. In addition, PLJV identified polygons from the Soil Survey Geographic Database (SSURGO; USDA 1995) that were likely to be playas based upon soil types (n = 2,124; Karen Callahan, PLJV, pers. comm.). Many of these locations overlapped spatially with those in NWI; however, 529 additional locations (1,567 ha [3,872 ac]) were contributed by SSURGO. Finally, we added potential playa locations that were determined by PLJV by processing satellite imagery during wet periods between 1986 and 2000 (Landsat; n = 1,297), following the protocol used by Ducks Unlimited, Inc. (Karen Callahan, PLJV, pers. comm). Landsat contributed an additional 299 locations (263 ha [650 ac]). Adding SSURGO and Landsat playas increased the dataset by 6% in playa numbers and 28% of playa area due to the relatively larger sizes of SSURGO polygons.

Throughout the project, we made revisions to the GIS dataset. When we discovered new locations through fieldwork, we used the Global Positioning System (GPS) locations and imagery provided by the National Agriculture Imagery Program (NAIP; 2 m resolution true color; USDA-FSA-APFO Aerial Photography Field Office 2006) to draw the playa basin with editing tools in ArcGIS 9.1 (ESRI 2005). Fieldworkers also identified misclassifications where waterbodies other than playas occurred, which we marked for removal. A review of the landcover by the USFWS in Nebraska led to the identification of additional potential playa locations (Andy Bishop, USFWS, personal communication). Finally, additional playa basins were identified by photo-interpretation of color infrared imagery (CIR; 1 m resolution) derived from aerial flights within the study area August 14, 2006 and May 31, 2008 (Andy Bishop, pers. comm.).

2.3 Field Surveys

2.3.1 Verification of Potential Playa Locations

For each location, we determined the status as follows: playa, possible playa, other waterbody, no access, or no confirmed playa. We defined a playa as a depressional wetland fed by rainfall and runoff that is hydrologically isolated from other natural water bodies in the landscape, particularly streams and creeks. “Possible playas” could not be confirmed at the time of visit, but had potential to be playa locations and were prioritized for repeat visits in subsequent field seasons. Other waterbodies included reservoirs, feedlot ponds, or stock dams within creek drainages. “No access” indicated that the road was not passable, was private, or for some other reasons the surveyor was not able to view the potential playa location (e.g., a windrow or tall standing crop obscured their view). “No confirmed playa” was reserved for cases when the surveyor was able to view the appropriate location and determined that a playa was not present. For each playa or possible playa, we collected the following information using a standardized field form:

- We marked the location with a handheld Garmin eTrex® Global Positioning System (GPS) unit and recorded the Universal Transverse Mercator (UTM) coordinates;
- We estimated the distance and bearing from the observer to the center of the playa, using a Bushnell Yardage Pro 500 laser rangefinder;
- We took at least one photograph and recorded the location, direction, and a written description for each photograph;
- We estimated playa size by using the rangefinder to measure distance from the observer to the near and far edges of the playa and converted diameter (<100 m, 100-250 m, and >250 m) to area (assuming playas were circular) to classify playas into one of three size classes (< 0.8 ha [2 ac], 0.8 – 5 ha [12 ac], or > 5 ha);
- We documented the relative wetness of playas by classifying the extent of standing water within the playa basin based on visual inspection in the field (> 100% full, e.g., water substantially in roadways; 50-100% areal extent covered by standing water, 1-50% areal extent covered by standing water), documenting indicators of past wetness (dry with hydrophytes present, dry with cracks visible), or noting if the playa was dry (no hydrophytes or cracks visible);
- We recorded the surrounding land use as dryland agriculture (cropland), irrigated cropland, USDA Conservation Reserve Program (CRP), grassland, or other;
- We noted the following agricultural uses in the playa: farmed, grazed, or hayed;
- We noted hydrologic modifications to the playa: pit/excavation, constructed inlet or outlet, impoundment/berm/terrace, and whether a well was present;
- We noted if the playa basin was bisected by a road;
- We estimated the average height of vegetation within the playa (<0.1 m, 0.1- <0.5 m, 0.5 – 1.0 m, and >1.0 m);
- For both the playa and the surrounding upland, we documented the percent cover to the nearest 5% in each of the following categories: bare ground, open water, grass, forb, shrub, cactus, and yucca;
- We documented wildlife use of the playa and the surrounding quarter section. We recorded the number of individuals of each bird species detected by sight and sound during the survey period. We also recorded the number and species of other wildlife, observed by sight or sign.

2.3.2 Assessments of Wet Playas

We visited wet playas weekly throughout the duration of the field season or until they dried (March – October). At each visit, we conducted a vantage count bird survey (see below). To describe habitat availability, we estimated the percent of the playa basin covered by the following categories: dry ground, dry ground vegetated, dry mud, dry mud vegetated, wet mud (saturated), wet mud vegetated, standing water (inundated), and standing water, vegetated. We also recorded the interspersion pattern of the vegetation as mostly unvegetated, hemi-marsh, mostly vegetated, ringed vegetation, or island vegetation.

2.3.3 Playa Inundation and Buffer Assessment

To evaluate the responses of playas to heavy rainfall events, we monitored daily rainfall in the study region in order to identify areas appropriate for aerial flight surveys. We used a National Weather Service website that integrates radar and rain gauge data (http://www.srh.noaa.gov/rfcshare/precip_download.php). We sought rain events that would pond water in at least some playas for several weeks, which we estimated was two or more inches of rain within 24 hours or 4 inches within a week. Furthermore, the selected areas needed to encompass at least 40 playas near roads including those embedded in cropland, grassland, and CRP.

The first such an event occurred on August 8, 2006, delivering 2 - 4 inches of rain in 48 hours, covering approximately 390 square miles in Chase and Perkins counties. A cursory ground survey accomplished by NGPC cooperators confirmed the abundance of ponded water in the area. Because of the prohibitive cost of flying the entire area, we selected four smaller units to reflect a gradient from 1.5 inches to 4 inches of rainfall. On August 14, 2006, with the cooperation of the U.S. Fish and Wildlife Service, an area of approximately 513 km^2 (198 mi^2) was flown to collect Color Infrared (CIR) imagery (1 m^2 resolution) of playa basins (see Figure 3).

2007 yielded no opportunities to collect aerial flight data. Only several rain events met our criteria, but particularly in the western part of the study area, the events did not fill enough playas as determined during our preliminary ground surveys to warrant a flight. On one occasion conditions were appropriate but the survey plane was unavailable.

The next flight opportunity came in late May 2008, when heavy rain fell in part of Perkins County (mean = 2.9 in, range = 1.5 – 4.3 in, recorded May 20 – 28). After a ground survey confirmed the presence of flooded playas, an aerial flight was conducted on May 31, 2008, encompassing playas receiving 1.1– 4.2 in rainfall in two areas totaling approximately 251 km^2 (97 mi^2; Figure 2).

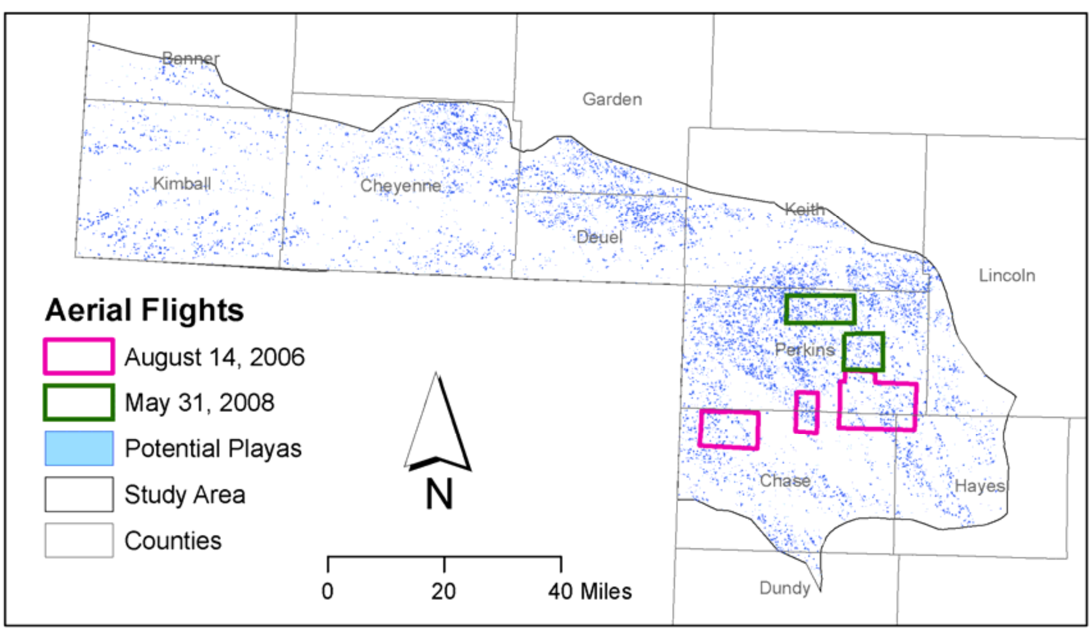


Figure 2. The flight areas for color infrared photography, August 2006 and May 2008.

2.3.4 Hydroperiod Lengths

To assess hydroperiod length, the duration of time that playas retained standing water, we visited all confirmed playa locations that contained water on the initial visit in subsequent weeks until no water remained standing in the playa or until the end of the migration season (November 1), whichever came first. On each visit we visually estimated the percent of the playa basin containing standing water. We monitored several sets of playas in this way.

In 2006, we monitored 44 playas in the flight area (43 in cropland; 1 in grassland) with 2-18 semi-weekly field visits. We selected for visitation all of the locations within 100 m of the road in the anticipated flight area of those greater than 0.4 ha (1 ac), and a random subset of those less than 0.4 ha. This yielded n = 32 for this analysis. In addition, we selected 12 playas to represent conditions greater than 200 m from the road.

In the 2008 flight area, we monitored 26 playas (3 in grassland, 2 in CRP, and 21 in cropland), each visited 2-6 times. All were within 100 m of the road; we attempted to monitor hydrology for all of those in grassland or CRP within the flight area and a randomly selected subset of 15 playas in cropland cover. We accomplished visits opportunistically, with intervals between visits ranging from weekly to monthly.

Following heavy rainfall in Kimball County in late July 2008, we monitored 20 playas including five in grassland and five in CRP. We made up to seventeen visits semi-weekly through the end of October.

2.3.5 Hydrologic and Habitat Profiles

For playas to which we gained access, we conducted surface hydrologic surveys to measure water depths. We measured water depths while walking four transects across each basin. The transects were placed by pacing a baseline across one edge of the playa, dividing the distance by five, and then walking across the playa in four equally-spaced transects perpendicular to the baseline.

Hydrological monitoring along a transect.

Measurements of water presence and depth and vegetation presence and height were taken at the playa edge and every 10 m (by pacing) thereafter along each transect. Each point was classified as dry, saturated (damp to the touch but no standing water), or wet. For wet points, the depth of standing water was measured to the nearest cm by reading a meter stick at arm's length. Water depths exceeding 100 cm were recorded as > 100 cm. Each point was also classified as vegetated if a 0.5 m radius around the observer was at least 25% covered by vegetation when viewed from above (an amount of vegetation we estimated to correspond to providing cover and visual obstruction for birds). We also recorded vegetation heights in categories as follows: A (0-20 cm), B (21-50 cm), C (51-100 cm), and D (>100 cm).

2.3.6 *Vegetation Sampling*

We surveyed the vegetation of 24 playas in 3 counties (6 in Chase, 7 in Kimball, and 11 in Perkins), including 2 playas in grassland, 5 in CRP fields, and 18 within cropland. Surveys were conducted from September 24 – October 23 in 2006, 2007, and 2008; each playa was surveyed once. We used ten to fifteen 1-m^2 quadrats to characterize plant species composition and estimate percent cover. Ten plots were placed around the playa, in the perimeter band of vegetation. The location of each plot was determined by measuring the length of the playa, dividing by five, and locating each plot at the appropriate interval along the long axis of the playa. Quadrats were placed toward the inner and outer edges of the vegetation band in alternating fashion. If vegetation was present in the center of the playa and appeared to differ in composition from the perimeter, five additional plots were sampled from the playa center. Additional plots were sampled at ten playas.

We estimated cover of plant species, bare ground, open water, litter, and unknown residual vegetation using six cover classes: 1 = 0-5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75, 5 = 75-95% and 6 = 95-100%. Total percent cover could exceed 100% in some cases due to layering.

1 m^2 plot for estimating canopy cover.

We identified plants to species when possible. Any unknown plants were collected, labeled, pressed, and identified by local botanical expert Don Hazlett (of New World Plants and People). Plants in the genus *Carex*, *Juncus,* and *Eleocharis*, were generally not identified to species. Before leaving the area, observers scanned the entire wetland to see if there were additional plant species not found on the sampled plots. These species were recorded on the form and if unknown, they were collected for later identification.

2.3.7 *At-risk Species and Other Species Surveys*

We were given the names of the following at-risk species of plants to look for by Gerry Steinauer of NGPC: Eared redstem *(Ammannia auriculata),* Texas bergia *(Bergia texana),* Shortseed waterwort *(Elatine brachysperma),* Purple spikerush *(Eleocharis atropurpurea),* Blackfoot quillwort *(Isoetes melanopoda),* Lowland rotala *(Rotala ramosior), Schoenoplectus saximontana,* and Poison suckleya *(Suckleya suckleyana).* No faunal species were recommended to us for special survey effort, but we report on any at-risk species (NGPC 2005) detected using playas. Tier I species are considered at-risk on the national or global as well as state level, are state or federally listed as endangered or are known to be declining (NGPC 2005). Tier II species are those which are state listed at a level of concern S1-S3, but did not otherwise meet the national or global standards to be considered a Tier I species (NGPC 2005).

2.3.8 Bird Surveys

For each bird survey, we recorded the beginning and end times and weather conditions including temperature, wind speed using the Beaufort scale, and cloud cover. We recorded all birds detected during the duration of the survey, and we noted if bird numbers were estimated. When possible, we recorded the habitat association of each bird, using the categories described above (e.g. dry vegetated, wet mud not vegetated, open water, upland). We also recorded the activity of the birds, including bathing, drinking, flushing, foraging, resting, preening, flying low near the playa), flying high (probably unassociated with playa), and other. If individuals of some species could not be identified, they were classed into groups (e.g., “light goose” for Snow Goose, *Chen caerulescens*, and Ross’ Goose, *C. rossii*; “unknown scaup” for Greater and Lesser Scaup, *Aythya marila* and *A. affinis*, “unknown yellowlegs” for Greater and Lesser Yellowlegs, *Tringa melanoleuca* and *T. flavipes*; “unknown peep” for small sandpipers in the genus *Calidris*).

Most surveys were vantage surveys, in which observers used a spotting scope or binoculars to survey birds from a remote vantage point (often using the vehicle as a blind), attempting not to flush any birds. The observer panned from one side of the wetland basin to the other, counting individuals of a given species. The observer repeated this action for each species, until the impoundment was fully surveyed. If few birds were present (e.g., < 50) in the wetland, the panning method was still used, but tallying was done all at once rather than with repeated pans for each species.

Roadside vantage count using binoculars and spotting scope.

To estimate detection probability for our vantage surveys, we employed double sampling (Bart and Earnst 2002, Farmer and Durbian 2006) at a subset of playas for which we obtained permission to access (n = 27 playas). First we accomplished a vantage count following the same protocol as for all vantage surveys. Immediately thereafter, we commenced a flush survey of the wetland, recording all birds detected while walking throughout or around the perimeter of the wetland. The flush count was designed to be a full re-count of the birds present during the vantage count. We noted if birds arrived, were present throughout, or exited during each survey period, to facilitate comparison of the two survey methods (n = 241 surveys).

2.3.9 Anuran Surveys

In the spring of 2007, both nocturnal and diurnal surveys were used for frogs and toads. The protocol used for nocturnal calling surveys had been used for previous anuran surveys in Nebraska (personal communication, Mike Fritz, NGPC). Nocturnal surveys were conducted during three windows of time: April 1 - May 4, May 7 - June 4, and June 13 - July 10. During each of three survey periods, directly following a rain event, we surveyed all wet playas in our roadside study group. Overall we surveyed 95 playas in Chase (n = 15), Keith (n = 45), Lincoln (n = 4), and Perkins (n = 31) counties. Because the number of wet playas varied through time, sample sizes during each period varied and not all playas were visited three times (n = 48 surveyed 3x; n = 35 surveyed 2x; n = 12 surveyed 1x). We surveyed 87 playas April 26-30, 65 playas May 20-24, and 75 playas June 18-23. Surveys began thirty minutes after sunset, with temperatures above 40 degrees Fahrenheit and wind speeds <15mph. The average temperatures during the three survey periods were 16 ºC, 21 ºC, and 24 ºC, respectively.

Woodhouse's Toad found on a playa.

For each survey, we noted the weather conditions in the prior 48 hours, playa location, playa identification number, distance and direction to the playa from the survey point, distance from the last playa surveyed, current air temperature, wind speed, sky conditions and start time. We also recorded a noise index as a measure of background noise, using a scale of 0-4, ranging from no appreciable effect to profoundly affecting sampling ability. Observers waited two minutes after arriving to record detections. Species were recorded with their call frequency ranging from 1 (individuals can be counted, no overlap) to 3 (full chorus). After three minutes a line was drawn across the data sheet and all species heard for the next two minutes were recorded to provide datasets comparable to other studies. All data were recorded on the data sheet and with a digital recorder. To ensure data quality, a set of digital recordings was sent to Mike Fritz for species verification.

We also conducted daytime anuran surveys at all playas visited for bird surveys (March – June, n = 121). We recorded all species heard calling during the survey period.

2.4 Data Analysis

We entered all of the field data digitally into a *Microsoft Access* database designed specifically for this project. Data management included standardizing nomenclature for birds and plants, searching for missing data records, and proofing the data in multiple queries. Ten percent of all of the datasheets were re-examined for accuracy in data entry. At least 90% of that sample was required to be correct. Failure to meet this criterion triggered a 100% proofing of all datasheets containing similar data. We managed data using *MS Access*, *MS Excel*, *Program R*, and *JumpIn® 4.0.4* (SAS Institute Inc. 2001).

To understand playa confirmation, inundation, and bird use in relation to local and landscape factors, we built a series of generalized linear mixed models (McCulloch 2003). In this section we describe our general approach; specifics for each analysis follow. These models assumed a normal distribution for the random effects of Playa ID, Year, Flight Area, and Cluster or County and included a block covariance structure for the categorical effects (PROC GLIMMIX, SAS Institute 2008). We investigated the suitability of the binomial, Poisson and negative binomial family distributions for each response variable by fitting the full model and examining the quasi-likelihood over-dispersion parameter (McCullagh and Nelder 1989; Pearson X^2 statistic / degrees of freedom). We used the over-dispersion parameter as an indication of variation in excess of the mean, and we selected the negative binomial distribution when the over-dispersion parameter was > 1.2 (Anderson et al. 1994). All models used the logit or log link function, and the parameters were estimated using maximum likelihood with Adaptive Quadrature (SAS Institute 2008).

We used information-theoretic model selection to evaluate the likelihood of the models given the parameters and to estimate the amount of Kullback-Liebler Information lost when models are used to approximate reality (Burnham and Anderson 2002). Akaike's Information Criteria corrected for sample size (AICc) was used to rank the set of candidate models (Burnham and Anderson 2002). The AICc weights (w_i) and evidence ratios were used as strength of evidence for the competing models (Burnham and Anderson 2002). In some cases, we used cumulative AICc weights [$w_{i+}(j)$] to evaluate the importance of each predictor variable (Burnham and Anderson 2002). The effect sizes were evaluated using the asymptotic approximation for 95% confidence intervals (Sokal and Rohlf 1981) and in some cases we presented differences in the least squares means and odds ratios (SAS Institute 2008). We presented parameter estimates for the best approximating model, and competing models when the associated parameter estimates exhibited coefficient of variation (CV) < 0.6. Parameters with CV < 0.6 and 95% confidence intervals with narrow coverage of zero were considered to have marginal effect sizes.

We measured covariates in ArcGIS (ESRI 2005) to depict effects occurring at the landscape and basin scale (Table 1). To represent the proportion of the surrounding landscape that was in different landcover types, we buffered the playas in a doughnut configuration with 2 km-radii from the edge of the playa polygons, intersected this with the Playa Lakes Joint Venture landcover data (USFWS 2007), and extracted the landcovers using the Thematic Raster Summary Hawth's Tools extension (Beyer 2004). We also used this approach for 100 m buffers and buffers representing the watershed size (Table 1). Within the 2 km-radius buffers, we measured the area covered by playas in the surrounding landscape by summing the playa area and dividing by the area of the buffer. The density of playas was calculated by dividing the count of playas in the buffer by the area of the buffer. We calculated the distance from the center of playas to other wetlands that were not playas using wetlands represented in the National Hydrography Dataset (USGS 2000). To represent the quantity of roads in the landscape surrounding each playa, we calculated road density (km^{-1}) within the 2 km-buffers for each playa by dividing the total road length (km) by the area (km^2) of the buffer. We calculated the distance from playa center to nearest road using the TIGER roads GIS layer (US Census Bureau 2007).

Table 1. Variables used in models to determine the effects on playa confirmation, hydrology, and avian use.

Group	Variable	Description	Range or Levels
Precipitation	Precip_Initial	Precipitation (cm) received at playa during initial event (August 5-14, 2006 and May 20-31, 2008)	2.8 – 10.7 cm
	Precip_Ensuing	Precipitation (cm) received at playa after initial event through first date dry	1.4 – 36.7 cm
	Precip_Total	Precipitation (cm) received at playa from initial event through first date dry	6.1 – 44.0 cm
	Log_e*InitialPrecip	Natural log of precipitation (cm) at playa during initial rainfall event	
Habitat	Full	Percent of playa categorized as having standing water (vegetated or not)	0-100%
	Vegetated	Percent of playa categorized as vegetated	0-100%
	Open Water	Percent of playa categorized as open standing water	0-100%
	Wet Unvegetated	Percent of playa categorized as open water or mud, unvegetated	0-100%
Basin	Data Source	Source for predicted potential playa location	NWI; SSURGO; or both
	Playa Size	Playa area from polygon in the GIS database	0.1 – 33.9 ha (0.25 – 83.8 ac)
	log_e*Playa Size	Natural log of playa size	
	Landcover (100)	Dominant landcover type surrounding playa to 100 m, from PLJV landcover	Grass, Crop, CRP
	Adjacent Landuse (dom)	Dominant landuse adjacent to playa from field surveys	Grass, Crop, CRP
	Adjacent Landuse (continuous)	Percent landuse adjacent to playa from field surveys (playas) or 100 m radius from landcover (non-playa locations or non-field sampled, e.g., many in inundation analysis)	Grass, Crop, CRP
	Hydro	Hydrologic modification of playa, including impoundments, berms, and pits	Altered, Intact
	Road Impact	If playa was split or bordered by a road	Impacted, Intact
	Road Distance	Distance (km) from playa center to nearest road	0.0 – 1.3 km
Landscape	Playa Landscape	Area (%) within 2 km from playa edge comprised by other playas	0.0 – 6.8%
	Playa Density	Density of playas within 2 km of playa	0.0 – 6.1 km^{-2}
	Wetland Distance	Distance (km) from playa center to nearest non-playa wetland indicated in National Hydrography Dataset (USGS 2000)	1.1 – 23.0 km
	Landcover (dom)	Dominant landcover type in 2 km surrounding playa, from PLJV landcover	Grass, Crop, CRP
	Landcover (continuous)	In 2 km radius surrounding playa, % in each major landcover type, from PLJV landcover	Grass, Crop, CRP
	Landcover (watershed)	Percent of landcover type in the estimated watershed buffer	Grass, Crop, CRP
	Road Density	Length of roads in 2 km surrounding playa	0.3 – 3.2 km
	Soil Group	Dominant soil group (by particle size) in modeled watersheds surrounding playa	Loam, Sand

2.4.1 Playa Confirmation

We conducted an analysis to determine patterns in playa confirmation, which could reflect differences in the reliability of data sources in the GIS model, and/or variation in loss rates of playas among data sources, and/or variation in our ability to confirm those playas when present. Because the LANDSAT data source exhibited nearly 100% confirmation and sample sizes were limited, we analyzed confirmation rates for the NWI, SSURGO and NWI/SSURGO data sources. To estimate the probability of confirmation, we coded playas confirmed in the field as 1 and those unable to be confirmed as 0. We used 655 playa surveys in this analysis.

We modeled the confirmation status of playas as a function of covariates using a generalized linear mixed model with the binary distribution and logit link function (McCulloch 2003; PROC GLIMMIX, SAS Institute 2008). The parameters were estimated using maximum likelihood with Adaptive Quadrature (SAS Institute 2008). We followed a sequential model building strategy that first determined the structure for the random effects and then determined the inclusion of the basin covariates (Table 1). We determined the structure of the random effects by comparing a model with the effect of County to a model assuming independent observations. After determining the structure of the random effects, we evaluated all subsets of the basin variables: Source, $\log_e$*Playa Size, Road Distance, and Adjacent Landuse (dom) (Table 1).

2.4.2 Playa Inundation and Buffer Assessment

To estimate the proportion of playas that filled by rain, our USFWS partners delineated the amount of ponded water visible in the CIR photography and associated it with potential playas in the GIS dataset. To minimize errors derived from a spatial offset among the various source data layers, water polygons that intersected a potential playa polygon were associated with that playa, regardless of whether all of the water was contained within the potential playa polygon. Pits or excavations in playas were delineated separately, so that the acreage of pits could be compared to the acres in unexcavated playas. Some water was delineated as sheetwater when the GIS analyst was unsure if the water represented a playa basin. Pitted, sheetwater, and unexcavated playa acres were summed together to represent the flooded area for each playa. Percent full was calculated by dividing the flooded acreage by the acreage of the potential playa polygon. Ponded water polygons that appeared to be playas but did not intersect a potential playa polygon were considered to be new and were added to the dataset.

We calculated the amount of initial precipitation using Gridded Rainfall Data from the National Weather Service (4 km grid). The Gridded Rainfall Data layers were compiled and summed over seven days preceding the flight date. We used the Geostatistical Analyst extension in ArcGIS (ESRI 2005) to interpolate the summed Gridded Rainfall Data. Global trends along the x,y axes were de-trended prior to fitting semivariogram models, after which the trend was added back to the final mapped surface. We fit four empirical semivariograms to the data: exponential, Gaussian, Matérn and spherical models. We used the cross validation function in the Geostatistical Analyst extension to evaluate the fit of the models (ESRI 2005). The semivariogram model exhibiting the value of the root-mean-squared standardized error closest to one was selected for generating the prediction maps. We used the Ordinary Kriging model (Cressie 1988) to interpolate the data and to generate the final prediction maps for the amount of preceding rainfall. We used the Zonal Statistics Hawth's Tools extension (Beyer 2004) to estimate the mean preceding precipitation for each playa polygon.

Watershed sizes could not be determined for all of the playas in the study because in this relatively flat environment United States Geological Survey quadrangle maps and 10-meter digital elevation models provided insufficient topographic detail. Therefore, we estimated the watershed size for each playa using a predictive model based on the watershed and basin size of 48 playa wetlands. The watersheds of 48 playas were delineated by Natural Resources Conservation Service (NRCS) personnel using GIS, topographic features and local knowledge. Areas within watersheds that were hydrologically isolated from the playa by roads, impoundments, or other impediments were delineated. Those intercepted areas were subtracted from the final watershed sizes so the watersheds reflect current drainage areas. We modeled the size of the watersheds as a function of $\log_e$(Playa Size) using a generalized linear model with the normal distribution and log link function (PROC GENMOD, SAS Institute 2008). The resulting equation for estimating the size of playa watersheds (ac) was exp(y) = 3.3151 + 0.5481[$\log_e$(Playa Acres)].

To understand the effects of buffer type and watershed composition on playa hydrology, we extracted landcover information from GIS layers. The dominant landcover type (grassland, cropland, or CRP) was determined for 100 m buffers, as well as watershed-sized buffers, for all playas in the Southwest Playa Complex. We used Thematic Raster Summary Hawth's Tools extension (Beyer 2004) in ArcGIS (ESRI 2005) to extract these data from the enhanced PLJV landcover (USFWS 2007).

We estimated the relative permeability of soils in the watersheds by using the surface soil records in SSURGO (USDA 1995). We extracted the soil data using buffers based on the predicted watershed size. Soil types were classified into four texture classes: sandy/coarse, loamy sand, sandy loam, and loamy. We calculated the percentage of texture class using the area of each watershed. We further collapsed the soil types into loamy (low permeability) or sandy (high permeability) categories for analysis.

Our research objective was to determine how soil texture at the watershed scale and landuse at the basin, buffer and watershed scales influenced the probability of playa inundation. To estimate the probability of inundation, we coded all playas that were inundated as 1 and those that did not fill as 0. Although we collected data for percent full as a continuous variable, we found that 74% of the playas were either 0% or 100% full. Therefore categorizing the playas as wet or dry did not result in much information loss. We analyzed the inundation status of 1,744 playas sampled in 2006 and 2008.

We modeled the inundation status of playas as a function of covariates using a generalized linear mixed model with the binomial distribution and logit link function (McCulloch 2003; PROC GLIMMIX, SAS Institute 2008). The parameters were estimated using maximum likelihood with Adaptive Quadrature (SAS Institute 2008). We followed a sequential model building strategy that first determined the structure for the random effects and then determined the inclusion of Precipitation and the basin, buffer and watershed covariates (Table 1). The structure of the random effects was determined by including Fight Polygon, Year, and Fight Polygon nested within Year into the full model one at a time. After determining the structure of the random effects, we evaluated all subsets of the basin [$\log_e$*Ensuing Precipitation, Playa Size, Landcover (100)] and , watershed [Soil Type, Landcover (watershed)] variables (Table 1).

2.4.3 Hydroperiod Lengths

We summarized observed hydroperiod lengths as the days from initial rainfall date (August 8, 2006; May 20, 2008; and July 27, 2008) to the first date dry. We summarized rainfall by summing the rainfall for the nearest rain grid for the period from the main rain event through the flight (initial rainfall), as well as the rain from that point forward through the end of each playa hydroperiod (subsequent rainfall). For the playas followed after the 2006 and 2008 flights, we modeled hydroperiod length in a model containing playa size, rain event date, hydrological modifications, road bisection, and surrounding landuse.

2.4.4 Hydrologic and Habitat Profiles

For every week during which hydrology transect data were collected, we provide the mean percent of each playa in each cover type class. Secondly, we report the mean water depths for areas that were flooded. Third, we summed all of the plots per wetland and generated a proportion in each of the following water depth classes (dry, saturated/mud, water 0 - 4 cm, 4.1 - 10 cm, 10.1 - 20 cm, 20.1 - 40 cm, and greater than 40 cm deep). Water depth classes were based on literature regarding the foraging preferences of various species of shorebirds and waterfowl (e.g., Helmers 1993; Batt et al. 1992). We also calculated proportions of sites that were classified as vegetated and unvegetated within each of the water depth classes. We combined water depths and percent vegetated to describe habitat conditions for shorebirds and waterfowl, based on previous research on migrating shorebirds and waterfowl that we conducted on the South Platte River in Colorado (Cariveau and Risk 2007).

2.4.5 Vegetation

Plants were classed as annual or perennial, native or exotic, and according to their wetland indicator status as defined in the United States Department of Agriculture national PLANTS database http://plants.usda.gov/ (USDA NRCS, 2007). Wetland indicator statuses were OBL = obligate wetland, FACW = facultative wetland, FAC = facultative, FACU = facultative upland, and UP = obligate upland) as defined in the 1987 *Wetland Delineation Manual* (Environmental Laboratory 1987) and listed in the *National List of Vascular Plant Species that Occur in Wetlands* (Reed 1988) in the PLANTS database (USDA NRCS 2007). If available, we used the USDA Region 5 indicator status rather than the national status. We also used the USDA PLANTS Database to categorize the status of plants as annual or perennial, native or introduced, and noted if they were invasive or noxious weeds. Because some plants were identified only to genus, not all plants were categorized. We calculated mean percent cover for each species within each playa using cover class midpoints.

2.4.6 At-risk species

At-risk species were Tier 1 and Tier 2 species, as reported in the Nebraska Natural Legacy Project: A Comprehensive Wildlife Conservation Strategy (Schneider et al. 2005).

2.4.7 Avian habitat and survey type models

We selected several guilds and the overall species count to model responses to basin effects such as playa size, hydrological modifications, distance to road, percent of the basin flooded, percent vegetated, as well as landscape effects including dominant surrounding landuse, road density, and relative abundance of playas. We were interested in migrant shorebirds with common habitat requirements, so we analyzed "typical shorebirds" as all shorebirds except for Killdeer, Wilson's Snipe, and phalarope species. However, because sample sizes for shorebirds were limited, we also present a habitat use model for the larger group of all shorebirds. Because of many zero counts in the dataset, we used a negative binomial count model appropriate for over-dispersed data.

Our research objective was to discover which playa attributes were important predictors of landbird and migratory waterbird abundance. We analyzed count models for the abundance of landbirds separately for wet and dry playas because the species composition of wet and dry playas was considerably different. Count models for the abundance of shorebirds and dabbling ducks, as well as species count, were considered for wet playas only. The data are represented by 227 wet playas with 2,619 surveys and 381 dry playas with 619 surveys.

We modeled the count of individuals for landbirds, typical shorebirds, total shorebirds and dabbling ducks as a function of covariates using a generalized linear mixed model (McCulloch 2003; PROC GLIMMIX, SAS Institute 2008). We investigated the suitability of the Poisson and negative binomial family distributions for each response variable by fitting the full model and examining the quasi-likelihood over-dispersion parameter (McCullagh and Nelder 1989; Pearson X^2 statistic / DF). We used the over-dispersion parameter as an indication of variation in excess of the mean and we selected the negative binomial distribution when the over-dispersion parameter was > 1.2 (Anderson et al. 1994). All models used the log link function and the parameters were estimated using maximum likelihood with Adaptive Quadrature (SAS Institute 2008).

We followed a sequential model building strategy that first determined the structure for the random effects, followed by the migratory chronology and habitat model and then determined the inclusion of basin and landscape covariates. The structure of the random effects was determined by including Playa ID or Cluster, Year, and Playa ID or Cluster nested within Year into the full model one at a time. The migration chronology part of the model was built using all subsets of the Season, Date and Season*Date covariates. In addition, we evaluated the threshold ($\log_e$*Date) and quadratic (Date + Date^2) functional forms of the Date covariate. We standardized the Date covariate using the *z*-transformation to improve model convergence (Sokal and Rohlf 1981). All subsets of the migration chronology covariates were forced into the full model one at a time. After arriving at the migration chronology part of the model, the habitat model was constructed using all subsets of the Full and Vegetated or Open Water and Wet Unvegetated variables (Table 1). In addition to the linear effect of Playa Size, we evaluated the threshold functional form ($\log_e$*Size) to evaluate the evidence for curvilinear relationships between the response variables and playa size. After assembling a base model with an appropriate structure for the random effects and fixed effects of migration chronology and habitat, we evaluated all subsets of two variable models for the basin and landscape variables (Table 1).

To assess potential bias of using vantage counts to represent all birds present, we compiled the vantage survey observations and flush survey observations into a “full survey” of all birds detected during both periods. Because our primary interest was evaluating the efficacy of the vantage survey, we excluded birds that arrived at or flew by the wetland during the flush survey period, which we assumed were not present during the vantage period. For descriptive purposes, we summarized the raw data reported by each method as a set of ratios (vantage survey/full survey), for numbers and species counts of all birds, waterfowl, and shorebirds. For this, we analyzed only playas with at least three surveys including the group of interest (e.g., at least three surveys with waterfowl to be incorporated into the waterfowl summary); sample sizes therefore varied with each group and are presented in Table 13 in Results. In this way, the ratio calculations did not incorporate many of the zero counts. We calculated mean vantage:full ratios across dates for each playa and then calculated a second mean and standard error across playas.

We investigated the differences between the survey types for species count, as well as abundance of shorebirds and waterfowl, in models containing survey date, season, playa size, and percentage vegetated. We were primarily interested in whether vantage and full counts for waterfowl, shorebirds and total bird species responded to factors thought to influence the detection of individuals and species: playa size and percent vegetated. This analysis involved 29 playas with 198 visits. The count of waterfowl, shorebirds and total species were modeled as a function of covariates using a generalized linear mixed model with an over-dispersed Poisson distribution and log link function (McCulloch 2003; PROC GLIMMIX, SAS Institute 2008). The parameters were estimated using maximum likelihood with Adaptive Quadrature (SAS Institute 2008). Again we followed a sequential model building strategy that first determined the structure for the random effects and then determined the inclusion of the detection covariates (Table 1). The structure of the random effects was determined by including Playa ID, Year, and Playa ID nested within Year into the full model one at a time. We parameterized the count models with vantage and flush counts as a categorical variable in an Analysis of Covariance design. We considered additive (Survey Type + covariate x_i) and multiplicative (Survey Type + covariate x_i + Survey Type*covariate x_i) models for the $\log_e$*Playa Size and Vegetated continuous covariates. The additive model specified parallel effects of the covariate for each Survey Type and the multiplicative model allowed different effects of the covariate for each Survey Type.

2.4.8 Anuran habitat models

We were interested in which playa attributes were important predictors of anuran occurrence, as determined by nocturnal surveys. Our dataset was built from 227 visits to 95 playas; data across visits were summed into presence or absence of each species for each playa. The playas were mostly in cropland, with only 3 in grassland. Twelve had been hydrologically modified and 22 were impacted by the road.

The presence or absence of each species was then modeled as a function of covariates using a generalized linear model (PROC GENMOD, SAS Institute 2008), using the binomial distribution and logit link function as previously described.

We followed a sequential model building strategy that first determined the habitat model and then determined the inclusion of basin and landscape covariates. The habitat model was constructed using all subsets of the Full, Vegetated, and Playa Size variables (Table 1). In addition to the linear effect of Playa Size, we evaluated the threshold functional form (log_e*Size) to evaluate the evidence for curvilinear relationships between the response variables and playa size. We then evaluated all subsets of three variable models for the basin and landscape variables (Table 1). We present only competing models within ΔAICc < 2 because of model selection uncertainty generating many competing models.

3 RESULTS

3.1 GIS Dataset

The net result of all revisions to the GIS dataset created a set of 15,812 potential playas in the Southwest Playa Complex of Nebraska, representing 21,976 ac (8,893 ha) of potential playa habitat (excludes 37 locations determined to be "other waterbodies"; shapefile available upon request). This represents a 6% increase over the original model in the number of playas and a 5% increase in playa area. This dataset includes 12% more playas and 34% more area than the original NWI dataset. The numbers of playas and their area by data source are depicted in Table 2.

Table 2. Current GIS dataset, including numbers and areas of playas by data source.

Data Source	Number	Percent	Total ha (ac)	Avg. ha (ac)	SD[1]
Aerial Photography 8/14/06	185	1.17	26 (65)	0.14 (0.35)	0.17
Aerial Photography 5/31/08	219	1.39	24 (60)	0.11 (0.27)	0.15
Fieldwork	40	0.25	34 (84)	0.85 (2.09)	0.99
LANDSAT	232	1.47	191 (473)	0.82 (2.04)	1.03
LANDSAT, NWI	409	2.59	357 (883)	0.87 (2.16)	0.83
LANDSAT, NWI, SSURGO	546	3.45	1200 (2966)	2.20 (5.43)	2.56
LANDSAT, SSURGO	119	0.75	379 (936)	3.18 (7.87)	2.84
NWI	11621	73.49	3757 (9284)	0.32 (0.80)	0.47
NWI, SSURGO	1255	7.94	1469 (3629)	1.17 (2.89)	1.23
PLJV Landcover	750	4.74	241 (596)	0.32 (0.79)	0.36
SSURGO	436	2.76	1214 (3000)	2.78 (6.88)	2.96
Totals/Averages	**15812**	**100.00**	**8894 (21976)**	**1.16 (2.87)**	

[1]SD = standard deviation in ha

We visited 769 potential playa locations in ten counties (Table 3 Figure 3). We visited the greatest number in Perkins County, the county accounting for the greatest percentage of playas in the Southwest Complex. We visited the highest proportion of the potential playa locations in the GIS dataset for Kimball County (14%). The proportions of locations confirmed as playas ranged from 0.5 to 0.93 among counties, but these are not strictly comparable because of different levels of rainfall and effort across the study area.

Playa in cropland, Southwest Nebraska.

Table 3. Potential playa locations in Southwest Complex of Nebraska by county; indicating the numbers in the GIS dataset and field-visited 2006-2008.

County	In GIS	Total Visited	Playa	% of GIS	% visited
Banner	196	1	1	1	1
Chase	1878	102	58	12	5
Cheyenne	2182	19	16	14	1
Deuel	1393	15	14	9	1
Dundy	45	3	2	0	7
Garden	886	0		6	0
Hayes	725	1		5	0
Keith	1811	89	80	11	5
Kimball	1069	145	73	7	14
Lincoln	471	6	5	3	1
Perkins	5197	388	305	33	7

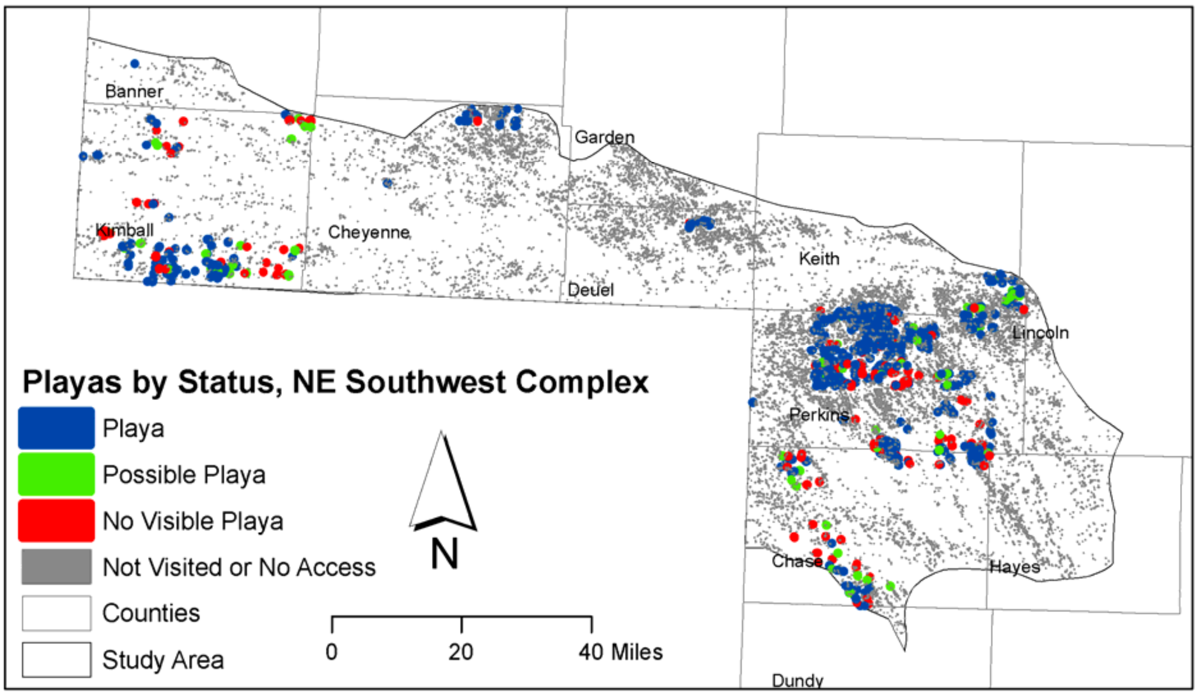


Figure 3. Field-visited playas in blue, possible playas in green, and locations where no playa could be confirmed in red, Southwest Playa Complex of Nebraska.

Overall, we confirmed playas in 72% of the potential playa locations; if "possible playas" were included, the confirmation rate increased to 80% (Table 4). Other waterbodies, representing true misclassifications, accounted for 5% of potential playa locations. Thirty-eight new locations were discovered by field crews; two were classified as "possible playas" and two were later determined to be other waterbodies. Locations where no playas were confirmed accounted for 15% of potential playa locations.

Table 4. Tabulation of field status reported for potential playa locations, by data source.

Data Source	Playa	Possible Playa	No Visible Playa	Other Waterbody	Total	Proportion Confirmed
Fieldwork	38	2		2	42	0.90
Aerial Flights CIR Imagery	10			1	11	0.91
PLJV Landcover	3	1	8	1	13	0.23
LANDSAT	6				6	1.00
LANDSAT, NWI	23				23	1.00
LANDSAT, NWI, SSURGO	69	1	1		71	0.97
LANDSAT, SSURGO	14	1	1		16	0.88
All LANDSAT	***112***	***2***	***2***	***0***	***116***	***0.97***
NWI	266	44	100	27	437	0.61
NWI, SSURGO	92	6	7	2	107	0.86
All NWI	***450***	***51***	***108***	***29***	***638***	***0.71***
SSURGO	33	4	2	4	43	0.77
All SSURGO	***208***	***12***	***11***	***6***	***237***	***0.88***
Total	**554**	**59**	**119**	**37**	**769**	**0.72**

When locations were predicted by more than one data source, confirmation rates were generally much higher than for single data sources (except for Landsat, with small sample size; Table 4). The data source with the lowest confirmation rate (23%) was the PLJV Landcover, which represented potential locations generated by review of imagery during an update to the landcover, but this was based on a small sample size.

We compared the confirmation rates of the two dominant data sources, NWI and SSURGO, in a model containing data source, playa size, distance to road, county, and dominant land use surrounding the playa. Potential playa locations predicted by both NWI and SSURGO were confirmed at a higher rate than locations predicted by either data source alone (Figure 4; see these and all subsequent statistical tables in Appendix C, Tables C-1, C-2, and C-3). In addition, confirmation rates increased with playa size (Table C-2). Confirmation rate was also higher in grassland than in cropland and was higher in both cropland and grassland than in CRP (Figure 5; Table C-3).

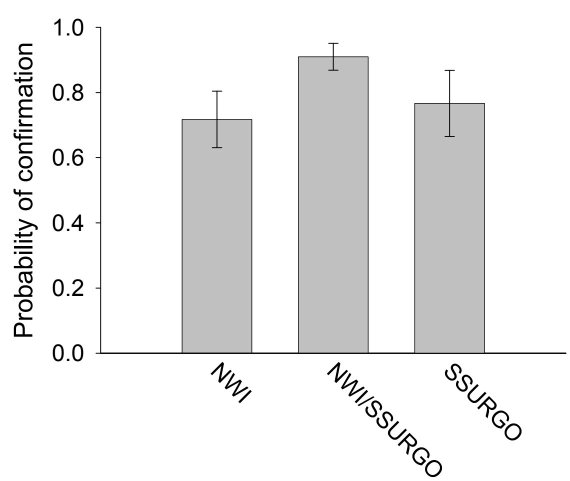


Figure 4. Confirmation rates of potential playa locations by major data source.

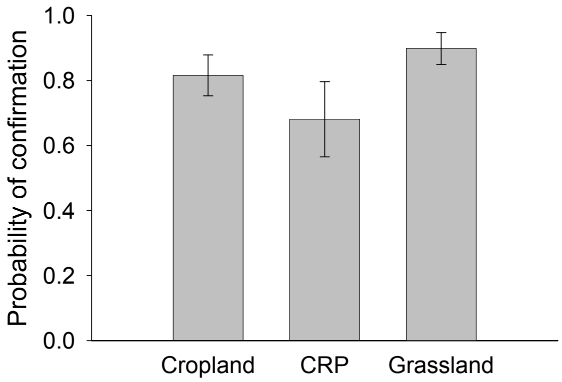


Figure 5. Confirmation rates of potential playa locations by dominant surrounding landcover.

One could revise the estimate of functioning playas in the Southwest Playa Complex by applying a 72-80% confirmation rate to the full GIS dataset (n = 15,849, including those determined to be other waterbodies), which would yield 11,411– 12,679. This rough estimate would be considered minimal as it assumes that the model is not missing any real playas, which we know is not true based on this project. If all "no confirmed playa" locations turned out to be functioning playas, the estimate would be 15,056.

3.2 Human Modifications

Across both flights, 124 pits were delineated from the aerial photography, which totaled 11.7 ha (29 ac; Table 5; 7% of playas were pitted). Pits accounted for 5% of the wet acres or 2% of the mapped potential playa acres overall.

In the field, we recorded hydrological modifications (excluding sedimentation) for 9.65% of the playas we visited (of n = 549 visited). Pits or excavations were most commonly reported (n = 34), followed by berms or terraces (n = 20), and constricted inlets or outlets (n = 10). Most hydrologically-modified playas had one modification recorded (n = 44); seven had two modifications and two playas had three.

Hydrologically modified playa, Southwest Playa Complex, Nebraska.

Table 5. Pits and ponded water delineated from aerial flight photos for 2006 and 2008.

	2006	**2008**	**Total**
Potential Playas within Flight Area (N)	850	890	1,740
Total Area of Potential Playas within Flight Area (ac)	1,039	849	1,889
Wet Acres delineated as Pits	23	6	29
Wet Acres delineated as Playa	364	141	505
Wet Acres delineated as Sheetwater	11	6	17
Total Acres Delineated as Wet	398	153	551
proportion of acres that were wet	0.38	0.18	0.29
proportion of wet acres that are pits	0.06	0.04	0.05
proportion of all acres that are pits	0.02	0.01	0.02

We recorded direct impact by the road for 25% of the playas in the set; this figure is high due to our protocol of primarily investigating playas within 100 m of the road. When combined with the other hydrological modifications, 32% of the playas we studied were hydrologically impacted.

We recorded tillage at 53% of the playas visited; grazing at 5%, and haying at 1%. When combined with the hydrological modification data; 74% of the playas we studied had a hydrological modification, agricultural use, or road impact associated with them.

3.3 Landcover

Eighty percent of the playas we visited in the field were predominantly surrounded by cropland; 1% was surrounded by CRP and 9% by grassland.

We found an overall 83% concurrence in our field characterizations of landuse when compared to the dominant adjacent landuse extracted from the PLJV Landcover in GIS (Table 6).

Playa in cropland, Southwest Playa Complex, NE.

Table 6. Concurrence of surrounding landuse for potential playa locations as determined by extraction from the PLJV Landcover and by field characterization.

	PLJV Landcover Type			
Field Landuse	Crop	CRP	Grass	Grand Total
Crop	416	18	18	452
CRP	34	22	9	65
Grass	15	1	34	50
Grand Total	465	41	61	567

3.4 Playa Inundation

In 2006, 42% of playas became wet following heavy rainfall; in 2008 53% became wet. Including dry playas, the average percent full was 29 (SE = 1.36) in 2006 and 43 (SE = 1.53) in 2008. When depicting the percent full for only the wet playas, the averages were 70 (SE = 1.57) and 81 (SE = 1.30) for 2006 and 2008, respectively.

To verify the accuracy of our interpretation of the aerial imagery for inundation, we determined the concurrence of our field assessments of playa hydrology with interpretation of the aerial photography. Combining 40 playas from 2006 and 49 playas from 2008 that were field-visited within 11 days of the flights, we found 74% concurrence for categories of dry, less than 50% wet, and more than 50% wet (Table 7). Concurrence was 84% for whether a playa was wet or dry.

Table 7. Comparison of field characterization of playa hydrology to classification by interpretation of aerial photography.

	Aerial Photography Classification		
Field Characterization	> 50% full	1-50% full	dry
> 50% full	38	9	2
1-50% full	3	6	4
dry	1	4	22

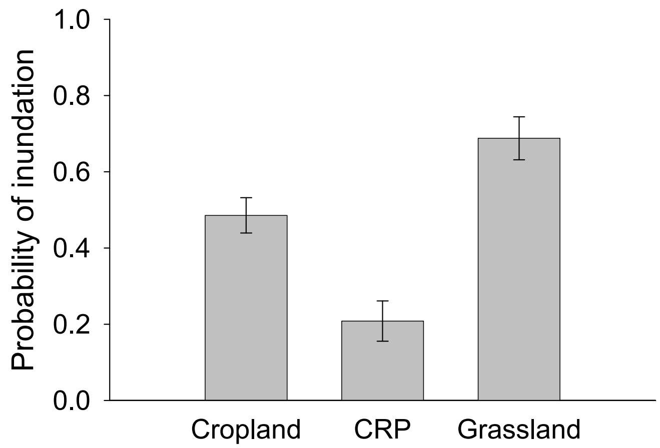


Figure 6. Probability of playa inundation following heavy rain, by surrounding landcover type.

The best approximating model for playa inundation in response to heavy rainfall contained amount of initial precipitation, playa size, dominant adjacent landuse, as well as a random effect of flight area within year. The probability a playa would become inundated was highest for playas in grassland, followed by those in cropland; playas in ungrazed grasslands such as those in soil conservation programs (termed “CRP” hereafter) were least likely to flood (Tables C-4, C-5, and C-6; Figure 6). All three cover classes were considerably different (Table C-6). The odds of inundation were 87% greater in grassland than in CRP and 53% greater in grassland than in cropland (Table C-6). In addition, probability of inundation was positively related to amount of precipitation and playa size (Figures 7-8; Tables C-4, C-5, and C-6). The odds of inundation increased by 15% for every hectare (approximately 2.5 ac) increase in playa size (Table C-6).

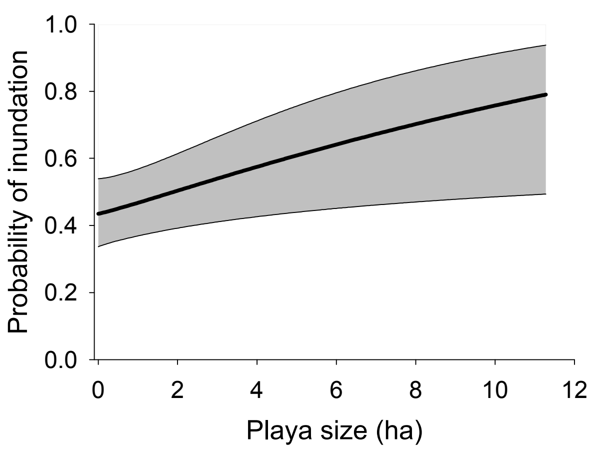


Figure 7. Probability of playa inundation in relation to playa size.

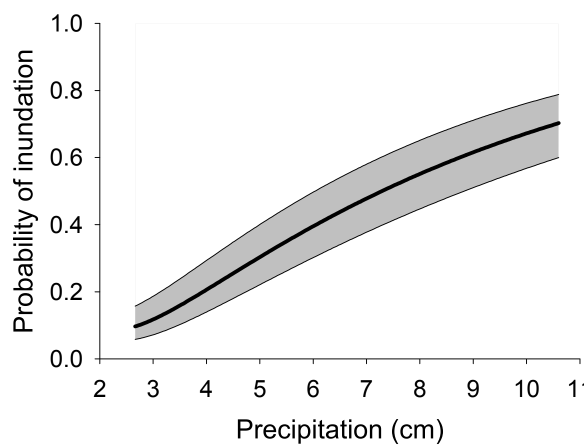


Figure 8. Probability of playa inundation in response to amount of precipitation.

The competing model of playa inundation included the proportion of the watershed in less permeable soils (loamy and sandy loams), but the 95% confidence interval for that effect showed considerable overlap of zero, (CV = 0.8) which did not meet our criteria for a large effect size. The cumulative AIC_c weights showing the importance of these factors were as follows: natural log of precipitation (1.00), surrounding landcover (0.96), playa size (0.83), and less permeable soils (0.38).

3.5 Hydroperiod Lengths

In 2006, following the August 8 rain event, we documented hydrology for 44 playas (Figure 9). Fifteen playas remained wet from August 8 through October 31, representing a hydroperiod length of at least 84 days. Twelve playas were not monitored through drying or the end of the season. For 17 that dried during the study the mean hydroperiod length was 49 days (SE = 5.25).

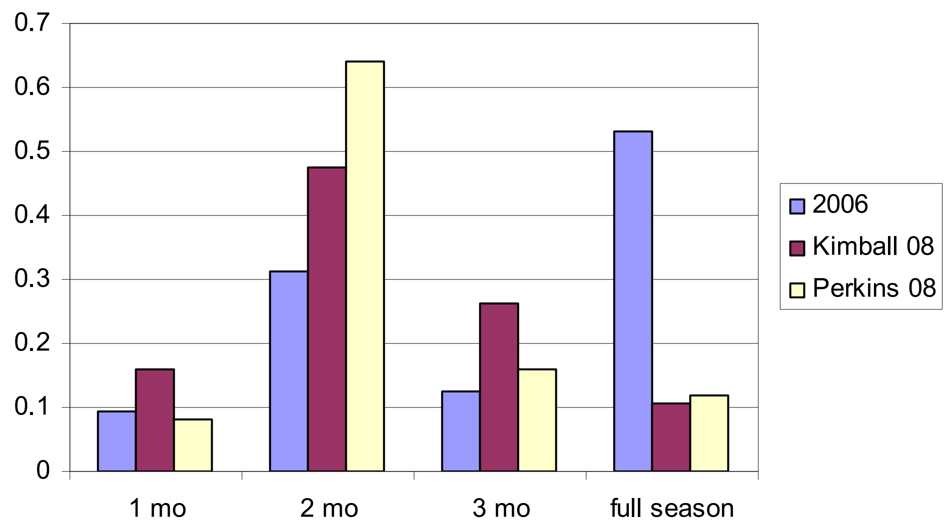


Figure 9. Proportions of playas that dried within the month indicated following heavy rain. "Full season" indicates playas that did not dry during the study period (Oct 31 2006 and Sep 4 2008).

In the 2008 flight area, following late May rain, we documented hydroperiods for 26 playas. Three stayed wet for the duration of the monitoring season, which was late August. One was not monitored for the full duration and did not dry. The average hydroperiod for 22 that dried was 53 days (SE = 4.10).

In Kimball County in 2008, 19 playas were monitored semi-weekly from August until dry or through the end of October. Two playas retained water through October 31 (95 days). Hydroperiods ranged from 27 to 95 days, with an average of 52 d (SE = 5.84; Figure 9).

Our model of playa survival incorporated data for both flight areas, and this model accounted for the fact that some playas remained inundated throughout the study periods.

The model indicated that the amount of ensuing rainfall (subsequent to the initial event) was a strong predictor of hydroperiod length (Tables C-7 and C-8). Playas that were bisected by the road or which were hydrologically modified also held water longer on average than undisturbed playas (we did not test a model containing both bisection and hydrological modifications, Tables C-7 and C-8). In addition, playas in 2006 held water longer on average than playas in 2008 (Tables C-7 and C-8).

3.6 Hydrological and Habitat Profiles

The average hydrologic characteristics of all playas throughout all seasons (2,929 surveys of 299 playas) was 32% unvegetated open water, 12% water with emergent vegetation, 8% unvegetated wet mud, 12% vegetated wet mud, 8% unvegetated dry mud, 11% vegetated dry mud, 3% unvegetated dry, and 15% vegetated dry. Summarizing, playas typically were 50% vegetated, 44% flooded, 64% composed of water and wet mud, and 39% open wet mud or water without vegetation.

Considering only playas with at least some standing water (2,587 surveys of 284 playas), the averages were similar: 36% unvegetated open water, 14% water with emergent vegetation, 7% unvegetated wet mud, 13% vegetated wet mud, 6% unvegetated dry mud, 10% vegetated dry mud, 1% unvegetated dry, and 12% vegetated dry. These playas averaged 50% vegetated, 51% flooded, 71% composed of water and wet mud, and 43% open wet mud or water without vegetation.

Sampled water depths ranged from 1 cm to greater than 100 cm. At four playas we recorded water depths in excess of 100 cm. Two of these playas were substantially comprised of deeper water (35% and 37%, respectively) and were excluded from these calculations of water depth averages. Two playas were mostly (at least 97%) characterized by shallow water measurements; for these we substituted values of 150 cm as estimates for the several missing deep measurements (total n = 7 substitutions). Average water depths ranged from an average of 4 to 24 cm per playa, with a mean of 15 cm (5.7 in; SE = 1.31; n = 30 playas). For open water, the average was slightly higher (mean = 17.66 cm; 6.95 in; SE = 1.51). The average proportion of the playa basin that was wet, vegetated or not, in various water depth classes, is depicted in Figure 5.

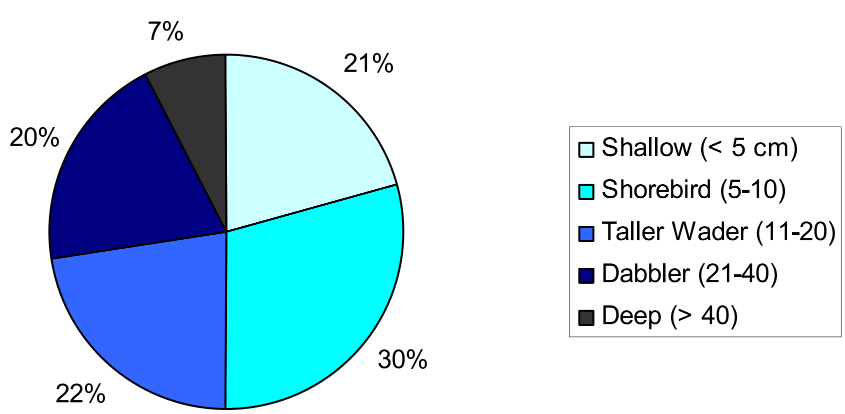


Figure 5. Average proportions of wet playas by water depth classes, labeled by bird guilds for interpretive purposes (guilds not limited to labeled depths) from 30 playas sampled 2006-2008.

When considering playa areas consisting of only unvegetated, open water, then the proportions were as follows: 14% less than 5 cm deep, 24% 5-10 cm, 26% 11-20 cm, 25% 21-40 cm, and 11% > 40 cm deep.

To characterize habitat for various guilds of waterbirds, we summed unvegetated open mud and shallow, open water using several water depth thresholds. We calculated the proportion of all playa habitat (wet or dry, from visits with at least some water) for various guilds. Values ranged from 12% of the playa acres being suitable for the smallest sandpipers to 39% for waterfowl (Table 8). A more liberal estimate for waterfowl, including all wet mud and water regardless of vegetation, would indicate an average habitat suitability proportion of 66% of all mapped acres.

Table 8. Average proportions of wet playas providing appropriate habitat conditions for several waterbird guilds. All values include mud and water, unvegetated.

Guild	Max depth	Average % of Acres Suitable
Calidrid shorebird (e.g., Least Sandpiper)	4 cm	12.04
Larger-bodied shorebirds (Baird's Sandpiper)	10 cm	17.08
PLJV shorebird planning (5 inches)	12.7 cm	20.09
Wading shorebirds (e.g., yellowlegs)	20 cm	30.04
Dabbling ducks	40 cm	39.04

Combining these figures with an average rate of playa inundation of 47% (averaged for 2006 and 2008), we would calculate that for the season ensuing after heavy rainfall, on average 9% and 18% of playa area could be expected to provide conditions for foraging shorebirds and waterfowl, respectively. If one were able to predict the proportion of area in the PLJV that receives heavy rainfall each year or migratory season, then one could further model the total amount of habitat available to migratory birds.

3.7 Vegetation

We documented 70 plant species and five genera for which no species were identified (see Appendix A). Two-thirds of the plants were native (47 species); one-third were exotic. None of the species were considered noxious weeds or state watch-list species (www.agr.state.ne.us). Thirty-four of the species were wetland plants (obligate, facultative wetland, or facultative), of which 32 were native. Forty species were classified as annuals; 27 were perennials.

The most frequently encountered plant, barnyard grass (*Echinochloa crus-galli*), was found in 58% of the 24 playas sampled (Table 9). We found 12 plant species that were not reported by Haukos and Smith in their book "Common Flora of the Playa Lakes" (1997; Table 10). Three of these species were also not detected on our 2004-2007 surveys of 116 playas in Colorado (Table 10; Cariveau and Pavlacky 2008).

Relative cover of playas ranged in values of open ground/water from 0 – 98%, with an average of 42% (SE = 8.50). Dead plant material accounted for another 15% on average (SE = 3.86). Western wheatgrass (*Pascropyron smithii*) was the most dominant plant, accounting for 12% of playa cover on average (SE = 4.22), followed by spikerush

(*Eleocharis* sp.; mean = 6%; SE = 2.95), and curly dock (*Rumex crispus;* mean = 5%; SE = 1.80). Across all playas, native plants comprised 25% cover while exotics accounted for 9% of cover.

Table 9. Most common plant species and genera, found in at least 25% of 24 playas surveyed in Chase, Perkins, and Kimball counties during the falls of 2006-2008.

Scientific Name	Common Name	N playas	Nativity	WIS[1]
Echinochloa crus-galli	barnyard grass	14	Exotic	FACW
Eleocharis sp.	spikerush	14		
Marsilea vestita	western water clover, pepperwort	12	Native	OBL
Rumex crispus	curly dock	12	Exotic	FACW
Bassia scoparia	kochia	11	Exotic	FACU
Ammannia auriculata	eared redstem	10	Native	OBL
Oenothera canescens	spotted evening primrose	10	Native	FACW-
Pascopyrum smithii	western wheatgrass	10	Native	FACU
Coreopsis tinctoria	golden tickseed	9	Native	FAC
Heteranthera limosa	blue mud plantain	8	Native	OBL
Polygonum sp.	smartweed	8		
Ambrosia grayi	woollyleaf bursage, woollyleaf burr ragweed	7	Native	FAC
Carex sp.	sedge	7		
Eleocharis palustris	common spikerush	7	Native	OBL
Mollugo verticillata	green carpetweed	7	Native	FAC
Polygonum pensylvanicum	Pennsylvania smartweed	7	Native	FACW+
Amaranthus sp.	pigweed	6		
Ambrosia tomentosa	skeletonleaf bursage, skeletonleaf burr ragweed	6	Native	
Eragrostis cilianensis	stinkgrass	6	Exotic	FACU
Panicum capillare	witchgrass	6	Exotic	FAC

1. Wetland Indicator Status, see Methods (USDA NRCS 2007).

Table 10: Plant species we found that were not listed by Haukos and Smith (1997).

Scientific Name (PLANTS)	**Common Name**	**Nativity**	**WIS**
Ambrosia artemisiifolia[1]	annual ragweed	Native	FACU
Ambrosia tomentosa	skeletonleaf bursage	Native	
Bromus inermis	smooth brome		
Chamaesyce glyptosperma	ribseed sandmat	Native	
Cycloloma atriplicifolium[1]	winged pigweed	Native	FAC
Cyperus squarrosus	bearded flatsedge	Native	OBL
Descurainia sophia	herb sophia	Exotic	
Eragrostis trichodes[1]	sand lovegrass	Exotic	
Glycyrrhiza lepidota	American licorice	Native	FACU
Polygonum arenastrum	oval-leaf knotweed	Exotic	NI
Polygonum convolvulus	black bindweed	Exotic	FACU
Verbascum thapsus	common mullein	Exotic	NI

[1]Plant species that were also not found by RMBO during Colorado playa surveys 2004-2007 (Cariveau and Pavlacky 2008).

3.8 Species of Conservation Concern

Of the six plant species specified for survey effort, we located one: *Ammannia auriculata* (slender toothcup or eared redstem; S1), at ten playas (42% of playas surveyed). In addition, we found three other at-risk plant species (NGPC 2005): *Oenothera canescens* (spotted evening primrose; S3) in ten playas; and *Sagittaria longiloba* (longbarb arrowhead; S1) and *Eleocharis parvula* (dwarf spikerush; S1) in three playas each. Of these, only specimens of *Oenothera canescens* were collected and confirmed by our botanist; the other three species cannot be verified at this time.

We detected 29 avian species of concern according to the Nebraska Natural Legacy Project, including five at-risk (Tier I) species (Table 11).

Table 11. Tier I and Tier II avian species observed in the Southwest Playa Complex, 2006-2008.

Tier	Common Name	Scientific Name	Number Observed	Count of Playas[1]
I	Bald Eagle	*Haliaeetus leucocephalus*	1	1
	Burrowing Owl	*Athene cunicularia*	49	5
	Long-billed Curlew	*Numenius americanus*	14	3
	McCown's Longspur	*Calcarius mccownii*	1908	11
	Short-eared Owl	*Asio flammeus*	2	1
II	American Avocet	*Recurvirostra americana*	114	15
	American Bittern	*Botaurus lentiginosus*	10	2
	American Wigeon	*Anas americana*	3210	47
	Black-crowned Night-Heron	*Nycticorax nycticorax*	5	2
	Canvasback	*Aythya valisineria*	579	6
	Chestnut-collared Longspur	*Calcarius ornatus*	790	27
	Cooper's Hawk	*Accipiter cooperii*	6	5
	Double-crested Cormorant	*Phalacrocorax auritus*	123	1
	Lesser Scaup	*Aythya affinis*	72	4
	Merlin	*Falco columbarius*	6	3
	Northern Bobwhite	*Colinus virginianus*	2	1
	Northern Harrier	*Circus cyaneus*	231	82
	Peregrine Falcon	*Falco peregrinus*	5	3
	Prairie Falcon	*Falco mexicanus*	10	7
	Savannah Sparrow	*Passerculus sandwichensis*	925	53
	Sharp-shinned Hawk	*Accipiter striatus*	5	2
	Swainson's Hawk	*Buteo swainsoni*	58	12
	Swamp Sparrow	*Melospiza georgiana*	2	1
	Western Grebe	*Aechmophorus occidentalis*	33	4
	White-breasted Nuthatch	*Sitta carolinensis*	1	1
	White-faced Ibis	*Plegadis chihi*	45	5
	Willet	*Tringa semipalmata*	9	5
	Wilson's Snipe	*Gallinago delicata*	512	48
	Wood Duck	*Aix sponsa*	18	9

[1]Of 558 playas surveyed.

We also documented several species rare for the area, including American Golden-plover (*Pluvialis dominica*) and Yellow-crowned Night-heron (*Nyctanassa violacea*) using playas, as well as Buff-breasted Sandpiper (*Tryngites subruficollis*) in the uplands of the study area.

3.9 Avian Use

We detected 158,232 birds comprising 140 species on playa surveys (Appendix B; n = 558 playas surveyed). We recorded 20 species of waterfowl, 14 species of waterbirds, 25 species of shorebirds, 9 species of other wetland dependent birds and 81 species of landbirds, of which nine we considered to be wetland-dependent (e.g., Bald Eagle, Yellow-headed Blackbird). Waterfowl were most numerous, contributing 79% to the total birds recorded, followed by landbirds (13%), shorebirds (6%), and waterbirds (2%). The most abundant birds throughout the study were Snow Goose, Mallard, and Northern Pintail (Table 12). The species we observed most frequently were Mallard (on 9% of surveys) and Killdeer (7%), followed by Blue-winged Teal, Horned Lark, and Red-winged Blackbird at 5% each. On 1,306 of 9,362 visits (14%), no birds were recorded.

Table 12. The five most abundant bird species, by guild, in southwest NE Playas, 2006-2008.

Guild	Common Name	Scientific Name	Number
Waterfowl	Snow Goose	*Chen caerulescens*	37208
	Mallard	*Anas platyrhynchos*	26824
	Northern Pintail	*Anas acuta*	9764
	Green-winged Teal	*Anas crecca*	8558
	Blue-winged Teal	*Anas discors*	4333
Shorebird	Killdeer	*Charadrius vociferus*	3108
	Wilson's Phalarope	*Phalaropus tricolor*	1853
	Lesser Yellowlegs	*Tringa flavipes*	767
	Baird's Sandpiper	*Calidris bairdii*	631
	Wilson's Snipe	*Gallinago delicata*	336
Waterbird	American Coot	*Fulica americana*	2692
	Sandhill Crane	*Grus canadensis*	607
	Black Tern	*Chlidonias niger*	136
	Double-crested Cormorant	*Phalacrocorax auritus*	123
	Pied-billed Grebe	*Podilymbus podiceps*	108
Landbird	Horned Lark	*Eremophila alpestris*	4015
	Red-winged Blackbird	*Agelaius phoeniceus*	3094
	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	1153
	American Pipit	*Anthus rubescens*	1107
	Barn Swallow	*Hirundo rustica*	1106

We found that the overall species count of birds (combining all guilds) varied with playa basin attributes as well as landscape effects. The best approximating model of species count exhibited positive effects of playa size (natural log) and proportion wet, and a negative effect of the proportion of the playa vegetated (Figure 6; Tables C-9 and C-10).

For an average size playa (1.16 ha), 2.2 species were predicted, at 10 ac, 3.7 species were predicted, and at 25 acres 5.5 species were predicted.

At the landscape scale, species count responded positively to the density of playas in the surrounding landscape and negatively to the proportion of cover in cropland (Figures 7 and 8; Tables C-9 and C-10). Species count also varied within the migratory season, showing different patterns in the spring and fall (not shown).

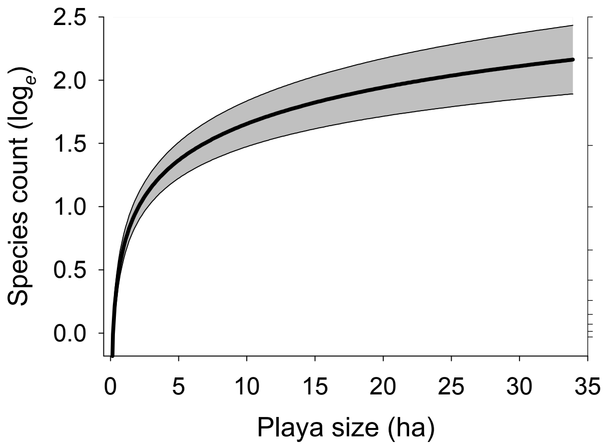


Figure 6. Relationship of overall avian species count to playa size.

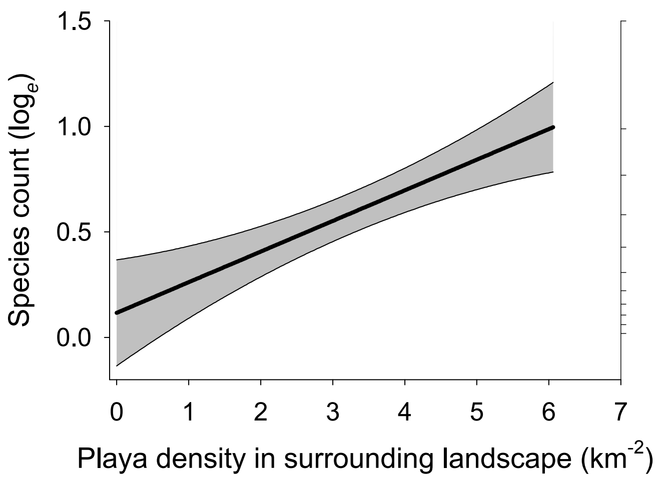


Figure 7. Relationship of overall avian species count to density of playas in the landscape.

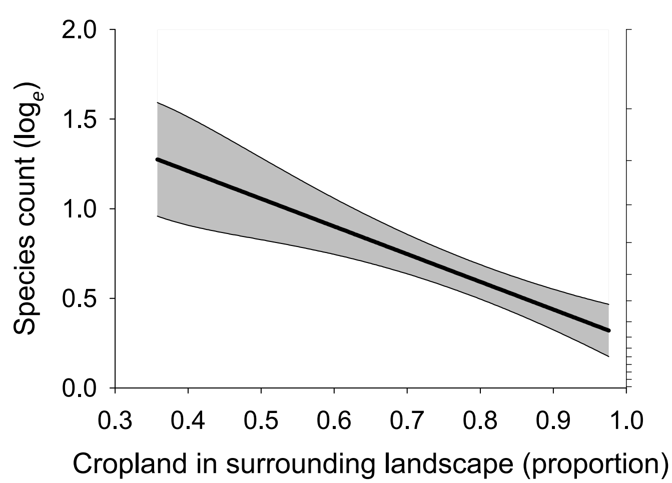


Figure 8. Relationship of overall avian species count to proportion of cropland in the landscape.

Dabbling ducks

Dabbling ducks were found in the greatest numbers during spring, with the highest counts in early March, when we began monitoring in earnest (Figure 9; ordinal date 80 = March 21). The abundance of dabbling ducks was lower in the fall but the chronology was similarly shaped, with numbers tapering off late in the season.

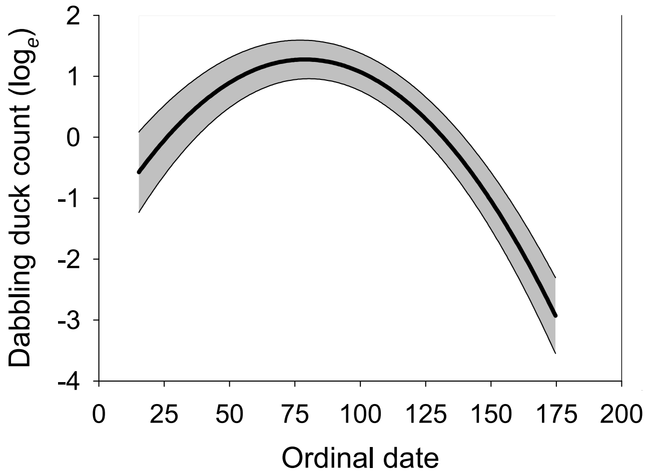


Figure 9. Chronology of dabbling duck nbers observed on playas in SW NE during the spring, compiling data from 2007 and 2008.

The best model for dabbling ducks showed that abundance was positively related to the natural log of playa area, proportion full, and negatively related to proportion of the playa vegetated at the basin level (Figure10; Tables C-11 and C-12). Dabbling duck abundance increased sharply up to approximately 12 ac (5 ha), after which abundance leveled off (Fig 10).

Dabbling duck abundance also responded positively to the proportion of CRP in the landscape (2 km-radius; Figure 11; Tables C-11 and C-12).

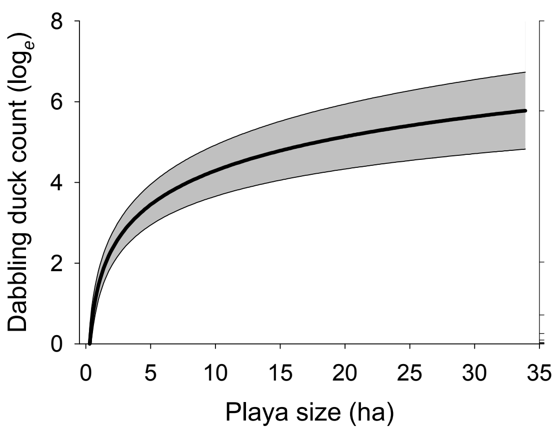


Figure 10. Dabbling duck numbers increase with playa size, rapidly at small playa sizes, after which the relationship becomes less

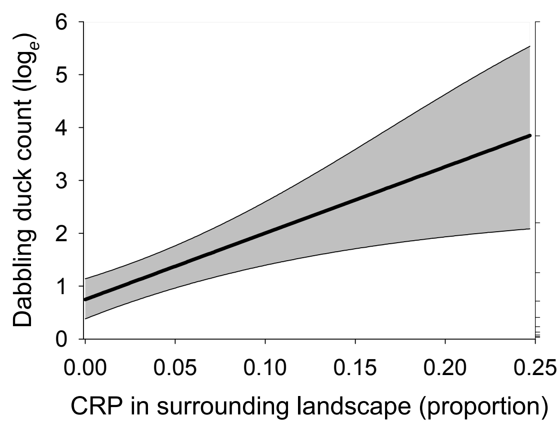


Figure 11. Relationship of dabbling duck numbers to amount of Conservation Reserve Program (CRP) in the landscape.

Shorebirds

Shorebirds were found in greatest abundance early in the spring, with diminishing numbers into summer (Figure 12). In the fall, shorebird numbers peaked in mid-September (ordinal date 255 = September 12) and dropped off steeply through the fall (Figure 13).

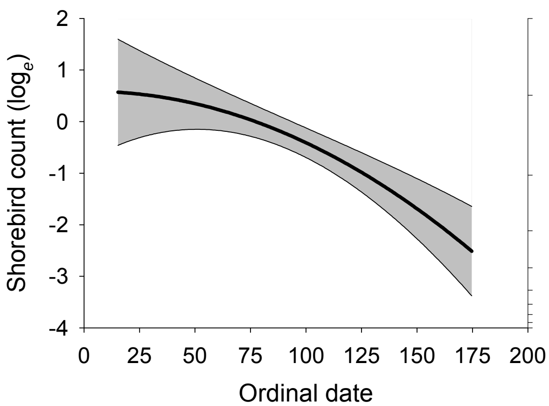


Figure 12. Chronology of spring use of playas by shorebirds in SW NE, 2007-2008.

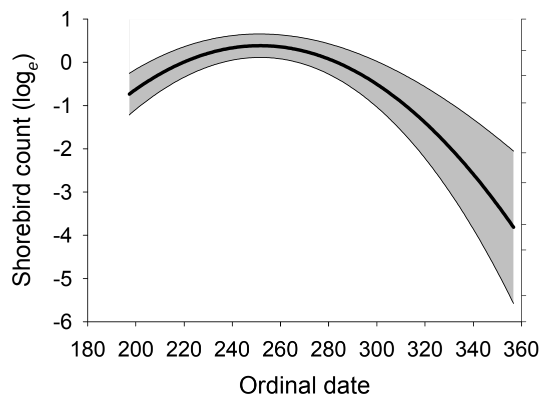


Figure 13. Chronology of fall use of playas by shorebirds in SW NE, 2006-2008.

Our best habitat model indicated that shorebird abundance was positively related to playa size (natural log; Figure 14) and negatively related to percent of the playa vegetated (Tables C-13 and C-14). Shorebird abundance increased dramatically up to about 12 ac (5 ha) and then leveled off thereafter (Fig. 14). At the landscape scale, shorebirds became more abundant with increasing densities of playas in the landscape and also more abundant as the distance to non-playa wetlands increased (Figure 15; pattern for distance to wetlands similar but not shown; Tables C-13 and C-14).

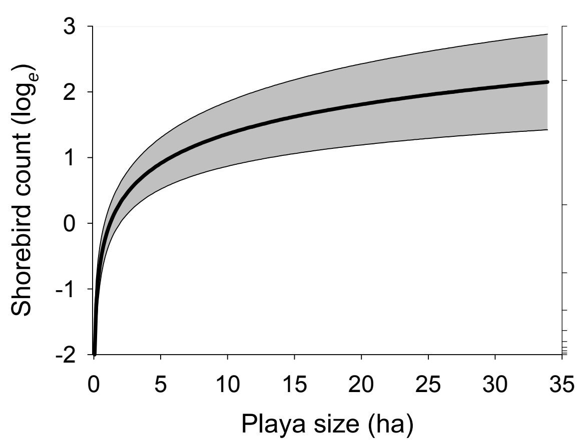


Figure 14. Relationship of shorebird numbers to playa size.

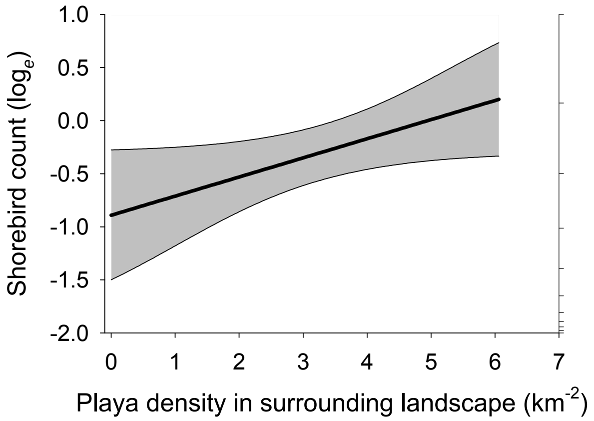


Figure 15. Relationship of shorebird numbers to playa density in surrounding landscape.

A large number of competing models with moderate levels of support (18 models with ΔAICc < 4) indicate a high degree of model selection uncertainty. The low AICc weight of the top model indicates uncertain effect sizes and low probability that the selected variables would occur in the top model if the analysis were to be conducted again. Future effort to model average the parameter estimates could improve inference in the presence of high model selection uncertainty.

When restricting our analysis to "typical shorebirds" (excluding phalaropes, Wilson's Snipe, and Killdeer), the best approximating model indicated that shorebird numbers were higher on playas without hydrological modifications, and were also more abundant closer to roads (Figure 13; Tables C-15 and C-16). In addition, the migration chronology and association with playa size for typical shorebirds were similar to the model for total shorebird abundance. There was nearly equal support (ΔAICc = 0.42) for a competing model without the effects of hydrological modification. The 95% confidence interval for effect of hydrological modification was covered by zero (CV = 0.64), but the narrow coverage by the interval was suggestive of a moderate effect. Typical shorebird abundance was also related to the proportion of the playa that was unvegetated and wet (either standing water or wet mud).

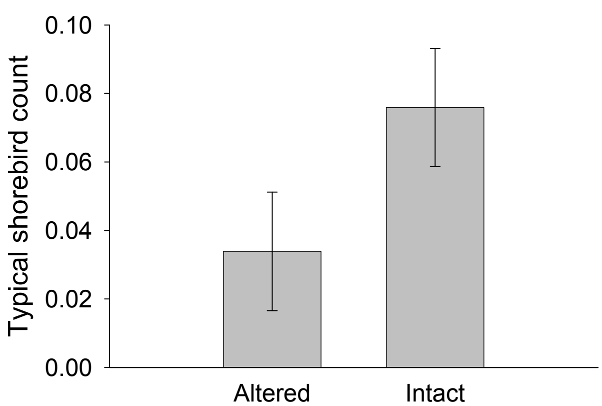


Figure 16. Numbers of "typical shorebirds" in hydrologically modified or intact playas.

Landbirds

The best model for landbird abundance on wet playas (at least 1% standing water at the survey) included the effects of date, season (higher in fall), playa size (Figure 17), percent full of water (positive) and percent vegetated (negative; Tables C-17 and C-18). As in the models for other species groups, landbird numbers leveled off for playas greater than approximately 12 ac (5 ha).

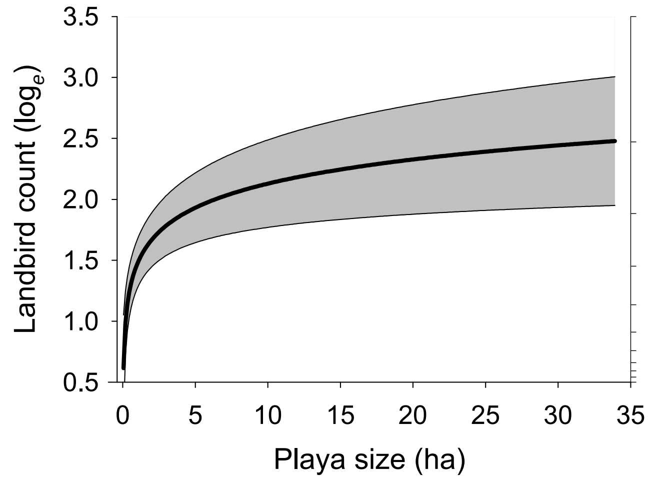


Figure 17. Relationship of landbird numbers to size (ha) of wet playas.

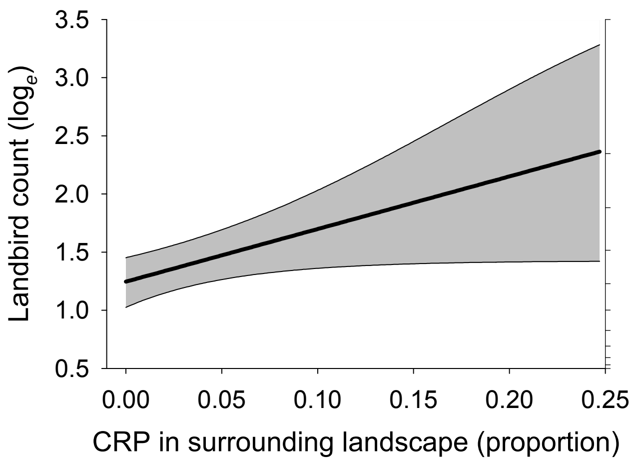


Figure 18. Numbers of landbirds on wet playas in relation to amount of CRP in landsca

Numbers of landbirds also increased with proportion of landscape in CRP and decreased with road density in the surrounding landscape (Figures 18 and 19; Tables C-17 and C-18).

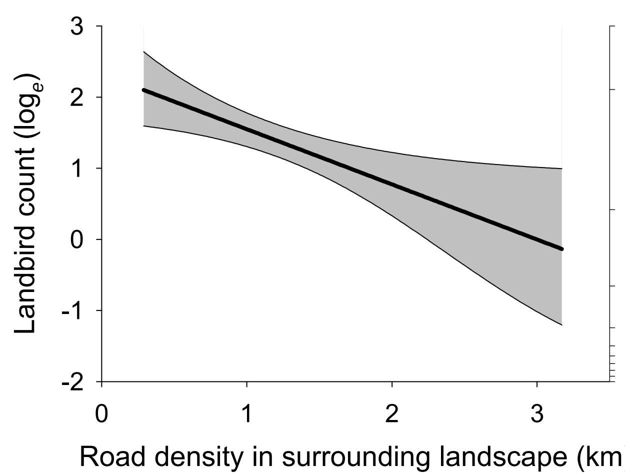


Figure 19. Numbers of landbirds on wet playas in relation to density of roads in landscape.

The best approximating model for landbird abundance on dry playas included the effects of survey date and season (higher in spring), playa size (natural log; Figure 20), playa density and proportion of CRP in the landscape. Similar to landbirds in wet playas, abundance reached a plateau for playas greater than approximately 12 ac (5 ha). Landbird abundance increased with the density of playas in the landscape as well as the proportion of CRP in the landscape (Figures 21 and 22).

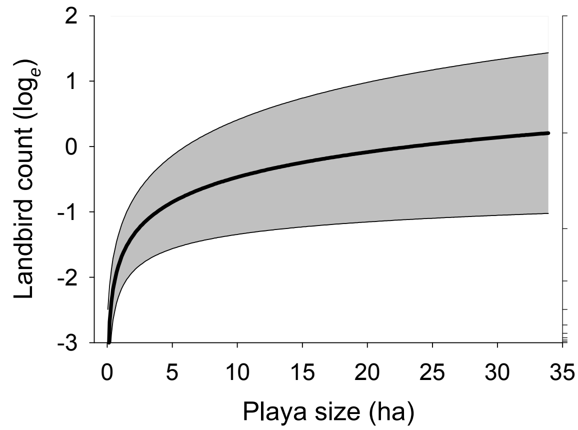


Figure 20. Relationship between playa size and numbers of landbirds on dry playas.

Although the 95% confidence interval narrowly covered zero (CV = 0.52), the model with CRP was 2.3 times more likely than the model without this effect (Tables C-19 and C-20).

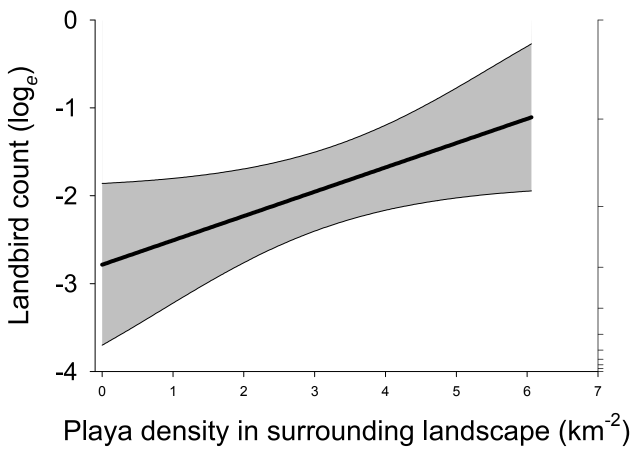


Figure 21. Numbers of landbirds on dry playas in relation to density of playas in landscape.

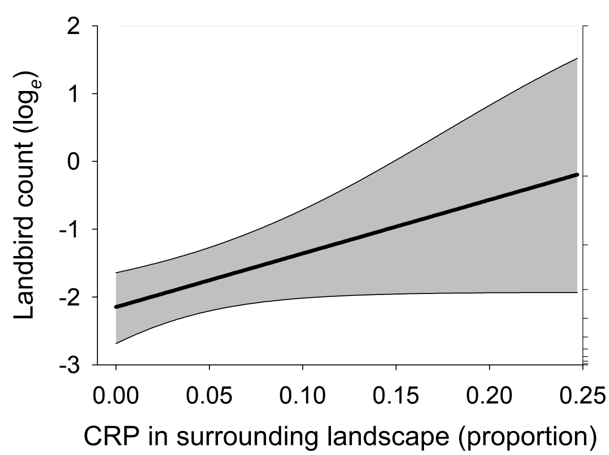


Figure 22. Numbers of landbirds on dry playas in relation to proportion of landscape in CRP.

Survey methods

The ratios of counts by vantage surveys contrasted to full surveys (including flush counts) are summarized in Table 13. The lowest ratio was noted for shorebirds; for 66 visits (46%), the vantage count indicated zero shorebirds but full counts resulted in up to 30 individuals of 1-2 species. Detection ratios of numbers of birds and numbers of species were similar, suggesting that in many cases we were missing all individuals of some species during vantage counts.

Vantage survey preceding a flush survey for birds on a playa in southwest Nebraska.

Table 13. Ratios of numbers of birds and numbers of species detected using vantage surveys as compared to full surveys that included flush counts, for playas surveyed 2006-2008 in the Southwest Playa Complex, Nebraska.

Bird Group	N Playas (surveys)	Metric	Mean Ratio	SE
All birds	27 (239)	numbers	0.57	0.05
		species	0.57	0.04
Waterfowl	15 (101)	numbers	0.71	0.08
		species	0.73	0.09
Shorebirds	20 (129)	numbers	0.31	0.07
		species	0.32	0.07

The best approximating model for species count included date, season, survey type and the natural log of playa size (Tables C-21 and C-22). We found that full surveys generated higher species counts (mean = 1.3, SE = 1.04) than vantage surveys (mean = 0.8, SE = 0.59). The additive model, which suggested that counts in both surveys responded to playa size in the same fashion, was 1.5 times more likely than a multiplicative model. The 95% confidence interval for the interaction between survey type and playa size was well covered by zero (CV = 0.81), indicating that the effect of playa size was similar for both surveys. There was considerable support (ΔAICc = 1.94) for a competing model containing an interaction between survey type and the proportion of the playa that was vegetated (Tables C-21 and C-22). This model indicated the negative effect of percent vegetated on species count was stronger for vantage surveys than for full surveys. Although the confidence interval for the interaction term contained zero (CV =

0.58), the multiplicative model was 1.5 times more likely than the additive model. There is also some evidence for the competing model without the interaction effect. The 95% confidence interval for the additive effect of vegetated narrowly covered zero (CV = 0.54), which is indicative of a marginal effect.

For shorebirds, the best approximating model indicated that shorebird numbers responded to date, season, and the natural log of playa area. There was no evidence for an effect of survey type, and there were no evidence for an interaction between survey type and playa size or percent of the playa vegetated (Tables C-23 and C-24). These results indicate the effect of playa size (CV = 0.57) on shorebird count was similar for both survey types.

For waterfowl, the best approximating model indicated that waterfowl numbers responded to date, season, and negatively to percent of the playa vegetated (Table C-25). The model with the additive effect of percent vegetated was 2.8 times more probable than the model with the interaction between survey type and percent vegetated (Table C-25). There was no evidence for an effect of survey type, playa size, or an interaction between survey type and percent vegetated or playa size (Tables C-25 and C-26). These results indicate the negative effect of percent vegetated on waterfowl count was similar for both the vantage and full surveys. There was little evidence for models including the effects of survey type and playa size or the interaction effect between survey type and playa size.

3.10 Anuran Use

We detected frogs and toads at 88 of 95 (93%) playas surveyed nocturnally; we identified four species. Great Plains Toad and Western Striped Chorus Frog were most commonly detected, followed by Plains Spadefoot and Woodhouse’s Toad (Table 14). We found all four species in Chase, Keith, and Perkins counties; we found Great Plains Toad and Western Striped Chorus Frog in Lincoln County, where we surveyed only four playas.

Table 14. Percent of playas in the Southwest Complex of Nebraska at which four frog and toad species were detected using nocturnal and daytime surveys.

Common Name	Scientific Name	Nocturnal	Daytime
Great Plains Toad	*Bufo cognatus*	77	14
Western Striped Chorus Frog	*Pseudacris triseriata*	73	36
Plains Spadefoot	*Spea bombifrons*	51	9
Woodhouse's Toad	*Bufo woodhousei*	48	2

We detected all four species at much higher rates during nocturnal surveys than diurnal surveys (Table 14). Forty percent of playas with anurans recorded on nocturnal surveys had no anurans detected during the day, while at only two playas did we detect anurans during daytime surveys when we failed to detect anurans at night. For each species individually, nocturnal surveys increased detections dramatically.

Habitat use models indicated different patterns of occurrence among species. The best approximating model for occurrence of Great Plains Toad indicated positive effects of playa size (natural log) and predominance of playas in the surrounding landscape (percent of 2 km radius in playas; see Tables C-27 and C-28).

The occurrence of Western Striped Chorus Frogs was positively related to several basin effects, including proportion of the playa that was wet (percent full), proportion that was vegetated, and playa size (natural log; Tables C-29 and C-30). In addition, the best approximating model included road impacts, suggesting that Western Striped Chorus Frogs were less likely to occur in playas that had been bisected or otherwise directly impacted by a road (Tables C-29 and C-30). The coefficient of variation (CV) for this variable was 0.61, and its 95% confidence interval contained zero, so this should be considered a weak effect. In addition, it should be noted that sixteen models fell within $\Delta AICc < 2$, suggesting a high degree of model selection uncertainty.

Plains Spadefoots responded positively to playa size (natural log; Tables C-31 and C-32). The best approximating model also indicated a positive effect of percent of the playa that was wet, although its CV was 0.9 and its confidence interval substantially covered zero in this model. The best competing model indicated a positive effect of percent full, as well as negative effects of playa density in the surrounding landscape and proportion of the landscape in CRP. In this model the CV for percent full dropped to 0.45, but the effect sizes for the landscape variables were weak (CV = 0.54 for playa density and CV = 0.63 for CRP in the landscape; Table C-32). This suggested a possible effect of greater probability of occurrence of Plains Spadefoots in more isolated playas with less CRP in the landscape.

The best approximating model for Woodhouse's Toad indicated greater probability of occurrence with playa size (natural log), percent full, and in playas impacted by roads (Tables C-33 and C-34). However, the CV for road impacts was 0.62, suggesting a marginal effect size.

We summarized call frequencies as an index to the relative abundance of species across the season (Figure 12). Great Plains Toad and Plains Spadefoots appeared to be most abundant in April and decreased in abundance as the season advanced. Indeed, Plains Spadefoots were entirely undetected during the final window of observation. Woodhouse's Toad and Western Striped Chorus Frog were more steadily detected throughout the season, although the calling rates of Western Striped Chorus Frogs were slightly higher in May than in April and June.

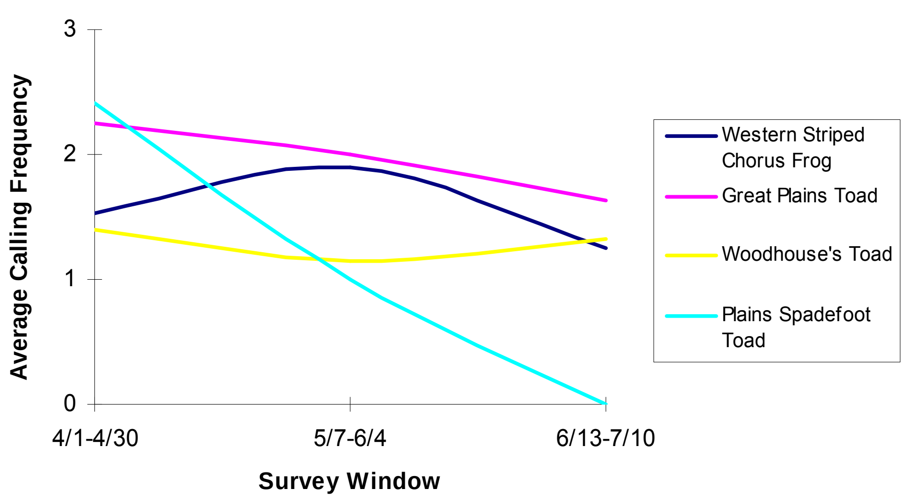


Figure 12. Calling frequencies of frogs and toads throughout spring 2007.

3.11 Outreach Activities


Playa in pivot corner showing sediment input

In addition to the research work outlined above, we conducted outreach as part of the project. We presented information about playas, conservation practices and opportunities, and our research through oral presentations to conservation partners, including the NGPC's Wildlife Division Meeting, the Natural Resource Conservation Service (NRCS) Leadership Meeting, and the NRCS Area Two Meeting. We gave a presentation at a workshop hosted by NRCS and designed for landowners. We also spoke and interacted with private landowners interested in playa conservation at several landowner workshops hosted by Nebraska Prairie Partners. We gave an update on the project to the PLJV Monitoring, Evaluation and Research Team and a talk for 2007 Nebraska Chapter of the Wildlife Society meeting. Ted LaGrange gave presentations at the 2008 EPA Regional Wetlands & Watershed Conference and the 2009 Rainwater Basin Joint Venture Information Seminar. In addition, we gave a poster presentation at the national 125th American Ornithologists' Union Meeting. Future presentations include the Society of Wetland Scientists (June 2009; T. LaGrange) as well as the 126th meeting of the American Ornithologists Union (A. Cariveau; August 2009).

Written outreach from this project included a one-page fact sheet about the project that we gave to all landowners contacted in the field for access to playas. These landowners were also given a copy of *The Playas: Reflections of Life on the Plains* video or DVD. For all participating landowners, we sent follow-up letters including lists of the birds and plants observed on their properties. This project was featured in the RMBO newsletter in August 2007. In addition, we helped to write a press release with NGPC in April 2007, which was sent to local and regional newspapers. This report as well as photographs are posted on the RMBO webpage. Finally, we are developing manuscripts depicting the playa hydroperiod information as well as the avian habitat use models for publication in peer-reviewed scientific journals.

4 Discussion

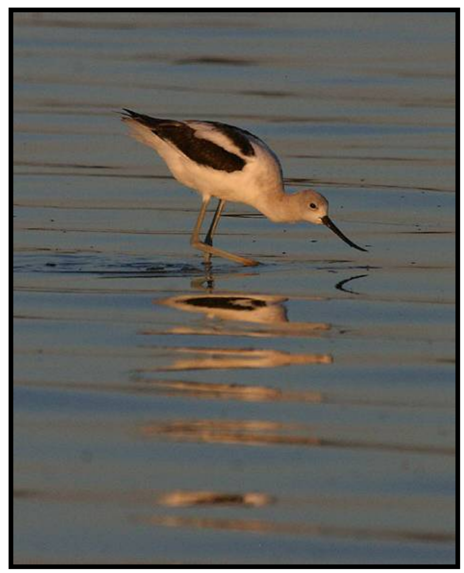
Aerial view of playas in Southwest Complex

We found that landscape composition and human alterations to playas in the Southwest Playa Complex of Nebraska significantly affect both the wetlands and their use by migrating birds.

Following heavy rainfall, playas directly surrounded by tall, dense, and undisturbed grasslands characterizing soil conservation programs, primarily the Conservation Reserve Program (CRP), were less likely to become inundated than playas in cropland or grassland. Playas in native grassland were 7.7 times more likely to become inundated than a playa in a soil conservation program, all other factors held constant. Playas in native grassland were also more likely to become inundated than playas in cropland. In western Nebraska, many of the CRP fields are planted to species that are not native species characteristic of mixed or shortgrass prairie, which have taller stature and perhaps greater water requirements than native species. Similar effects have been noted in other wetland systems and could also apply to playas (Skagen and Melcher 2005; Skagen et al. 2008). Isolated pothole wetlands in Saskatchewan dried out following conversion of surrounding cropland to waterfowl nesting habitat dominated by brome grass and alfalfa (Van der Kamp et al. 1999 and 2003). Similarly, in North Dakota, following heavy rainfall, the maximum depths of seasonal prairie pothole wetlands in native prairie exceeded those surrounded by buffer strips in cropland and those in watersheds restored to provide dense waterfowl nesting cover (Detenbeck et al. 2002). Such effects could to be due to a higher density of vegetation impeding water flow to the wetlands as has been found experimentally with grass filter strips (Van Dijk et al. 1996, Abu-Zreig et al. 2004). In addition, native prairie, cropland, and restored areas may differ in infiltration rates. Indeed, runoff coefficients, watershed areas, and evapo-transpiration rates were similar among the native prairie and restored grassland sites, supporting the conclusion that restored areas had a higher infiltration rate than native prairie, presumably because of a history of tillage (Detenbeck et al. 2002). Van der Kamp et al (2003) also concluded that interception of snows by the upland vegetation and greater infiltration in the nesting cover areas were responsible for reducing runoff to wetlands in the restored areas. Collectively these findings suggest that restored areas, either due to vegetation composition or soil characteristics due to tillage history, do tend to show reduced levels of runoff in comparison to native prairie sites.

We also considered that relationships between landuse and soil types could drive patterns in runoff or infiltration; for instance, CRP might be more prevalent on more erosive soils that were also more permeable. We did find a weak effect of soil particle size in our model, but it was not statistically significant. Van der Camp commented that the differences in hydrology among wetlands observed in their study were not due to soil particle size, but these data were not presented (2003). Future studies should continue to consider both soils and landcover in analyses. In addition, future work should examine the variation among buffered playas, incorporating information about the seed-mixes used in the buffer strips, the stature and density of the standing vegetation, and contrasting playas with buffer strips from those in larger tracts of ungrazed grassland.

We found another strong effect of CRP at the landscape level. Two very different guilds of birds, dabbling ducks and landbirds, increased with the proportion of the surrounding landscape in CRP. Similarly, overall species count of birds was negatively associated with the proportion of cropland in the landscape. These effects suggest that CRP plays a significant role in the suitability of habitat for landbirds and dabbling ducks. Birds may use CRP grasslands directly for foraging opportunities or for roosting cover, or there may be indirect effects of CRP in a landscape otherwise dominated by farming. Naugle et al. (1999) found Black Terns were more abundant in prairie pothole wetlands with more grassland surrounding them, postulating that there may have been indirect effects of grassland on the water quality and invertebrate levels in the wetlands of the area.



American Avocet foraging

Shorebirds, which we might expect to remain more focused on wetlands for feeding, responded to the density of playas in the landscape rather than to land use. Similarly, shorebirds in Colorado playas were positively associated with the proportion of the landscape in playas (Cariveau and Pavlacky 2008). These findings support a hypothesis that shorebirds select stopover locations as complexes, rather than single wetlands (Skagen and Knopf 1993 and 1994, Farmer and Parent 1997, Niemuth et al. 2006). Niemuth et al. (2006) found that shorebirds were more abundant in landscapes with a greater percent of area covered by semi-permanent and permanent wetlands. We also found that the abundance of typical migrant shorebirds (excluding Killdeer, snipe, and phalaropes) was negatively related to proximity to nearest non-playa wetland. This could indicate a preference for playa wetlands, which provide exceptional habitat quality: 50% unvegetated, with an average water depth of 15 cm (6 in). Alternatively, there could be a “magnet effect” of other preferred waterbodies that creates a pattern of lower usage on playas in their vicinity. Third, there could be some other unmeasured aspect of landscape suitability that varies in association with other waterbodies, such as higher levels of recreational or agricultural use associated with reservoirs. An integrated study of various wetland types and their use by shorebirds would be an interesting follow-up to this study.

Typical migrant shorebirds, (excluding Killdeer, Snipe, and phalarope species which have different habitat profiles) were more prevalent in intact playas that had not been excavated or otherwise hydrologically modified. Similarly, shorebirds in Colorado were more abundant in unexcavated playas, and spring migrant shorebirds preferred prairie potholes without evidence of drainage (Cariveau and Pavlacky 2008; Niemuth et al. 2006).

Excavations increase the slope of the shoreline and amount of deeper water, decreasing the availability of preferred shallow, sparsely vegetated habitat with substantial mudflats (Colwell and Oring 1998, Helmers 1993). These findings underscore the importance of playas in providing shallow water habitat. Niemuth et al (2006) also found shorebirds selected temporary wetlands over seasonal wetlands, which they attributed to a preference for shallower water. Indeed, the average water depth of playas in this study was 6 inches and playas in our study were on average half unvegetated, providing for good visibility.

Direct measures of water depths in a sub-sample of playas within our study area indicated water depths providing excellent foraging conditions for shorebirds and waterfowl during the migratory season. Considering only wet playas, we found that 12% of the playa habitat we profiled was unvegetated and less than 5 cm deep; 30% was unvegetated habitat less than 20 cm deep, and 39% unvegetated and 40 cm or less deep. A recent study shows that migrating shorebirds in the South Platte River corridor in Colorado were associated with unvegetated mudflat and open water less than 4 cm deep (and to a lesser extent, 20 cm deep; Cariveau and Risk 2007). Brennan also found a negative association between water depths and shorebird use in the Rainwater Basin (Brennan 2006). Waterfowl in the South Platte River corridor were associated with water depths less than 40 cm (Cariveau and Risk 2007). When averaging conditions of all playas for the entire the season, we found that 51% of the habitat was flooded to 40 cm deep.

These data may be applied to refine some of the parameters used by the PLJV biological planning models. PLJV estimates the suitability of wet playa habitat as 10% for shorebirds and 100% for waterfowl. Our data indicate that 20% of the habitat was suitable for shorebirds and 39% was suitable for waterfowl. This approach excludes the part of the playas that was dry each week from the percent suitable, taking into account that “wet” playas will not be full throughout the season. However, if one simply classifies playas as wet or dry, then our data indicate that 89% of the wet habitat is suitable for waterfowl and 38% for shorebirds.

Combining these figures with an average rate of playa inundation of 47%, we would calculate that for the season ensuing after heavy rainfall, on average 9% or 18% of playa acres could be expected to provide conditions for foraging shorebirds and waterfowl, respectively. If one were able to predict the proportion of area in the PLJV that receives heavy rainfall each year or migratory season, then one could further model the total amount of

Shallow, open habitat provided by a southwest Nebraska playa.

habitat typically available to migratory birds. The conservation message for those not familiar with playas is that it takes a lot of acreage to provide wetland habitat in any given season, but that the habitat provided is of high quality.

Playa size was a significant factor in all bird use models, and it was always a natural log function that fit best. This indicated a threshold effect. At smaller sizes, bird use increased rapidly with playa size, and at larger sizes these gains leveled off. For waterbirds, approximately 5 ha (12 ac) appeared to be a point after which gains due to size slowed down; this point was a bit lower for landbirds, approximately 3 ha (7.5 ac). As a complement to this finding, we also found that larger playas were also more likely to fill by rain than smaller playas. In addition, larger playas in the Southern High Plains supported more wetland plant species (Smith and Haukos 2002) and held water for longer durations (Smith and Haukos 2002; Howard et al. 2003). However, it should be noted that all playas, regardless of size, provide numerous benefits, including recharge, biodiversity, habitat for plants, invertebrates, etc (Ostercamp and Wood 1987, Bolen et al. 1989, Haukos and Smith 1994, Zartman 1994, Wood 2000). Furthermore, these playas increase the acreage and density of playas at the landscape level, creating wetland complexes preferred by some species of frogs and toads, as well as shorebirds and landbirds alike.

4.3 GIS Dataset

Using field and aerial flight data, we can make recommendations to refine the Playa Lakes Joint Venture GIS dataset for playas in the Southwest Complex of Nebraska. Our revised GIS dataset estimates 15,812 playa locations (21,976 ac) in the Southwest Playa Complex. This is a 12% increase in the number of playas and 34% increase in acreage over a dataset including National Wetland Inventory data alone, which has been used to depict Nebraska playas in the past (Karin Callahan, PLJV, pers. comm.). The largest increase in acreage was gained by including potential playa locations predicted by soils data (SSURGO), which are larger than those from other data sources. This is particularly significant because larger playas are both more likely to fill by rainfall as well as are preferred by migratory birds. Therefore, we recommend that playa conservation partners include potential playa locations predicted by soils data when possible.

Our field confirmation rate of playas predicted in the GIS (72 - 80%; the latter when including “possible playas”) would adjust the estimated number of functioning playas in the Southwest Playa Complex to 11,411– 12,679 (15,885 – 17,650 ac). This is a bit lower than the 21,680 ac estimated by LaGrange (2005) using NWI data alone. Uncertainty surrounds our estimates however, because we do not know what proportion of unconfirmed mapped playas exist but were missed during field surveys, and we do not know how many more are missing from the GIS dataset. Due to repeated failed efforts to find playas at a number of mapped potential playa locations, we do believe some proportion of the locations in the model have been lost or at least should be considered non-functional. Whether they represent historic wetland locations that could be restored or whether they were improperly mapped originally is the subject of future investigations. A large-scale effort, perhaps involving a re-analysis of the 1980’s NWI imagery and/or field-based soils work, would be helpful to determine if playas are truly being lost from the landscape and if so, relating that rate of loss to different land management practices. In addition, a random or systematic survey, (either field based such as in Cariveau and Pavlacky 2008 or using aerial photography such as the National Agricultural Imagery Program) could be used to determine the rate of omission of playas from the current GIS dataset.

Modeling the confirmation rates of various potential playas locations was informative. We found that potential playa locations predicted by more than one data source (e.g., NWI, SSURGO, and Landsat) were more likely to be confirmed as playas than locations predicted by one data source alone (see also Cariveau and Pavlacky 2008). We also found that locations predicted by Landsat were also confirmed at a high rate. This might have been due to the specific objective of the Landsat project to delineate playas, and/or due to the use of more recent imagery (1990's rather than the early 1980's for NWI). Incorporating playa size was important; we found that confirmation rates increased with playa size, either indicating that larger playas are easier to detect or that they are more likely to persist through time, perhaps better able to persist despite sedimentation or other anthropogenic impacts. After accounting for playa size, playas predicted by SSURGO were no more likely to be confirmed than were those predicted by NWI.

Playa with a water concentration pit

We found a lower incidence of pits in playas than estimated previously by the PLJV biological planning models, although the impacts of pits were still quite considerable in the landscape. PLJV estimated that for BCR 18 in Nebraska, on average, 85% of playa acres were dry, 9% were wet and unexcavated, and 6% were wet in the pit only, representing a 60:40 ratio of unpitted to pitted acres (PLJV 2007). Interpretation of aerial photography suggested that only 5% of the wet habitat was in pits. It is possible that we under-represented pits in our interpretation of the aerial photography, or that the flight areas were not representative of the entire study area. However, we found similar proportions of playas with pits (6%) in our field visits throughout the study area as in the aerial photography (7%). Thus, we recommend that the estimates of playa acres in pits be reduced in the PLJV biological planning models. This concurs with the observations of LaGrange, who notes that the Southwest Playas are less likely to be drained than wetlands in many of the other Nebraska complexes, probably due to the lesser amounts of rainfall typically received in this part of the state (2005).

Another contribution of this project was investigating watershed sizes for playas. Thanks to cooperators at NRCS, we employed empirical delineations of playa watersheds in a mathematical model to predict watershed sizes for the rest of the playas in our study area. Many factors affecting the hydrology of playas (e.g., runoff, sedimentation) should be expected to scale at the watershed: cover types, soil types. This approach might be of use for other GIS practitioners within the PLJV.

4.4 Vegetation and Habitat Characteristics

The plants we found were most similar to the plants of heavily disturbed playas described by Rolfsmeier, who documented the flora of playas in Deuel, Keith, and Perkins counties in 1992. The plant we encountered most commonly, *Echinochloa crus-gallii*, Rothsmeier (1992) noted was dominant in recently tilled playas. We also found seven of the eight plants he associated with larger, periodically tilled playas (Rothsmeier 1992). However, we found few of the plants he associated with the “least-disturbed playas”. This could be due to our sampling of only two playas in native prairie by a single visit in late fall. A few of those species (*Lippea cuniefolia*, *Myosurus minimus,* and *Veronica peregrina)* we found in our more extensive Colorado surveys (Cariveau and Pavlacky 2008).

Of the three rare species noted by Rolfsmeier (*Amaranthus californicus, Oenothera canescens,* and *Plagiobothrys scouleri;* 1992), we detected only *O. canescens* in our surveys of playas in Nebraska and Colorado (Cariveau and Pavlacky 2008). Interestingly, *P. scouleri* (popcorn flower) was considered to be “ubiquitous in undisturbed playas in the study area” and Rolfsmeier recommended it be monitored as an indicator of well-preserved playa wetlands (1992). It is possible that this plant is still present in the study system and we did not detect it. It is a small-statured annual, and we conducted our surveys late in the fall when perhaps it is less readily identified. Alternatively, it could be that this plant is less abundant in the study area than it was fifteen years ago, which could be the subject of future investigations. *A. californicus* was found only once by Rolfsmeier, and we found plants within *Amaranthus* that we did not identify, so we cannot comment on this species.

Relative to the current list of species of concern, we found *Ammannia auriculata* (slender toothcup or eared redstem) and *O. canenscens* at more than a third of the playas we visited, although samples of *A. auriculata* were not collected. We also reported *Sagittaria longiloba* (longbarb arrowhead) and *Eleocharis parvula* (dwarf spikerush), but these were also not verified. Thus, our work should be regarded as preliminary, and perhaps will lead the way for follow-up work, should there be an interest in any of these species.

The productivity of playas in producing seeds and invertebrates is well-recognized as important for supporting migrating waterfowl (Anderson and Smith 2000). Based on their analysis of Northern Pintail (*Anas acuta*) crop contents, Sheeley and Smith (1989) found that barnyard grass, curly dock, spikerush, and smartweed were important food resources for migratory waterfowl. We observed all of these plants on at least a third of the playas we surveyed, with barnyard grass as the most commonly encountered plant in our study. In addition, seeds can complement invertebrates in the diets of migrating shorebirds, comprising approximately 20% of the dietary mass for five species using playas in Texas (Baldassarre and Fisher 1984).

Seeds from alfalfa and curly dock, good seed sources for waterfowl.

4.5 Avian Use

Mallard, a common playa species

We detected 158,232 birds comprising 140 species on playas in the Southwest Complex. Our observations add to the body of knowledge regarding the use of playas by migrating birds, already well-documented for the Rainwater Basin of Nebraska (Brennan 2006, Jorgensen 2004) and the High Plains of Texas (Davis and Smith 1998, Smith 2003). The Southwest playas were heavily used by waterfowl. We recorded 20 waterfowl species, and they comprised 79% of all the birds we counted. The most abundant birds for the study were Snow Goose, Mallard, and Northern Pintail. Notably, several aggregations of Snow Geese exceeded estimates of 10,000 birds in single playas. Most of the use of playas appeared to be for migration, and the highest numbers were noted in spring, as also found recently in the Texas High Plains (Baar et al. 2008).

Playas appear to be an important part of the stepping stone mosaic of habitat utilized by transcontinental shorebirds stopping over in the Great Plains (Skagen and Knopf 1993). Two spring surveys and three fall surveys in the Southwest Complex generated a species list of 25 species of shorebirds. For comparison, 40 species are known for the Eastern Rainwater Basins (Jorgensen 2004). The most common shorebirds differed in the two studies: we found higher numbers of Killdeer, Wilson's Phalarope, and Wilson's Snipe than in the Rainwater study (Jorgensen 2004). Of the dominant species reported from the Rainwater Basins for spring, we found only White-rumped Sandpiper and Baird's Sandpiper in our top six species; for fall, of their top five species we found only Lesser Yellowlegs and Least Sandpiper were within our top six species.

Our models indicated no difference in waterfowl abundance relative to distance from roads, in contrast to LaGrange and Dinsmore (1989) who found a negative effect of roads on the use of sheetwater wetlands by Mallards during spring migration. One difference in our studies is in the amount of vegetation present on the wetlands sampled; because our study spanned the springtime, summer, and fall, we were observing waterfowl in more heavily vegetated conditions than was likely in the earlier study. These conditions may have impaired our ability to detect greater numbers of waterfowl at greater distances from roads. We did find an effect of distance from roads on shorebirds (excluding phalarope, snipe, and Killdeer), but it was positive; that is, shorebirds in our study appeared to be more abundant closer to the road. It is possible that this was caused by a greater detectability of shorebirds closer to the road.

Our comparison of vantage surveys and full surveys incorporating flush counts indicated gains in the number of species detected with full surveys and a negative association of species count with vegetation, suggesting that vegetation may have been affecting detectability. However, our statistical model did not find significant differences in waterfowl or shorebird numbers by survey type, even though the detection ratios were approximately 71% and 31%, respectively. This might be because the model incorporated more zero counts, many of which were corroborated with a zero count in the full survey. The ratio summary had no way to incorporate the zero:zero ratios. The mixed model allows for each survey (including those with no birds) to exist within the analysis, in contrast to the ratio calculations in which zero counts really have no impact. To summarize, in the analytical framework we employed, we did not find evidence that survey type affected our analyses of waterfowl and shorebird use of playas relative to their basin and landscape characteristics. However, the detection ratios we observed suggest that detectability be considered and accounted for in future studies of playa wetlands. Investigators will need to evaluate the increases in sample sizes afforded by more cost-effective and efficient vantage counts posed against the increases in accuracy afforded by flush surveys which require landowner permission to access and more sampling effort. In addition, we will pursue other analytical approaches to our dataset, such as occupancy modeling, to better account for detectability.

4.6 Anuran Use

Our data suggest that playas in this region were well-utilized by frogs and toads. We found four species in Chase, Keith, and Perkins counties where we sampled most intensively. Nocturnal call surveys were much more effective than daytime surveys, particularly for the Woodhouse's Toad, which was only detected at 2% of playas surveyed during the day. Our highest diurnal encounter rate was of Western Striped Chorus Frogs, which are more active during the day than the other species (Hammerson 1999).

We found some common habitat associations across all species. All four species had a higher probability of occurrence with greater playa size (logarithmic threshold shape) and percent of the playas that were wet. This underscores the importance of hydroperiods sufficient to support the anuran lifecycle (Gerlanc and Kaufman 2003). A study of bison wallows in Kansas found that only in 20% of the years did buffalo wallows provide habitat of sufficient duration for breeding Western Chorus Frogs (*Pseudacris triseriata*; Gerlanc and Kaufman 2003). We found evidence that anurans might have been selecting playas for longer hydroperiods. Woodhouse's Toad was more abundant in playas impacted by roads, and playas bisected by roads held water longer than intact playas. Thus, Woodhouse's Toad may select for playas impacted by roads as a means for selecting for prolonged hydroperiods. In contrast, we found that Chorus Frogs were less likely to occur in playas impacted by roads, the effect one would predict if roads are seen as a form of human disturbance. This could be due to a sensitivity of chorus frogs to water quality (*Pseudacris* clarkia; Anderson et al. 1999), although we did not measure water quality in our study. More detailed study of the effects of human impacts, including surrounding landuse (e.g., tillage, which we could not address) on anuran abundance in the Southwest Playas should be promising. Others have found no effect (Anderson et al 1999) or higher densities of some species of anurans in more fragmented landscapes (Gray et al. 2004a). Furthermore, studies could incorporate postmetamorphosis size, which can have strong fitness consequences and vary with dominant land use (Gray and Smith 2005).

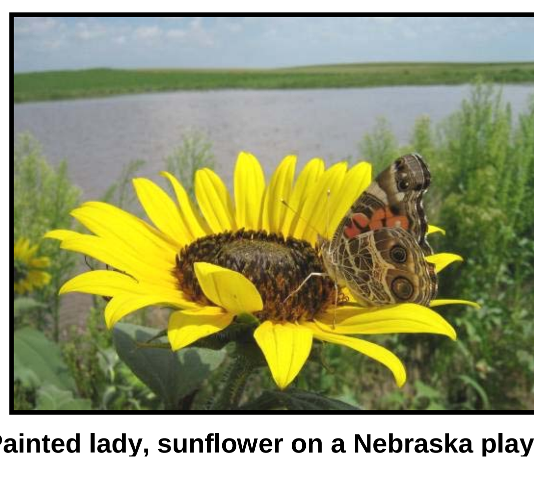
We also found some interesting effects of landscape on the occurrence of anurans. Great Plains Toads were more common in playas with more playa cover in the surrounding landscape, suggesting that this species prefers playas in complexes. We found the opposite effect in Plains Spadefoots, which had a slight affinity for more isolated playas, although the effect size was marginal. These results directly contrast with a similar study of Texas playas in which Plains Spadefoots were positively and Great Plains Toads negatively associated with the prevalence of playas in the landscape (Gray et al. 2004b). Gray et al. report a negative association between occurrence of Plains Spadefoots and Great Plains Toads, which they suggest could be due to better competitive ability or predatory behavior of young spadefoots (2004a and 2004b). They further note that spadefoots are more abundant where tiger salamanders are not (playas in cropland), perhaps because salamanders control their populations (Gray et al. 2004a). Whether these types of antagonistic interactions could be occurring in the Southwest Playas is not something we can address currently but could be the subject of future investigation.

Additional analysis incorporating data from repeat visits may improve our ability to understand relationships of anuran species to habitat and landscape characteristics. We may be better able to describe possible variation due to detectability in an occupancy theoretical framework. In addition, we may be better able to account for uneven effort through time due to the different hydroperiod lengths of the playas surveyed, which may be important because calling frequency varied through the season for some species.

4.7 Conservation Implications

Sedimentation remains a negative effect for many playas, reducing the water holding capacity of playas and likely reducing hydroperiod lengths as well. We found ample opportunity for conservation practices in this region. Nearly three-fourths of the playas we visited were hydrologically modified, directly impacted by a road, or in agricultural production. Previous work describes the typical playa in the Southwest Complex as farmed in most years (LaGrange 2005); in this study, we classified 53% as tilled. Retiring these playas from production, or at a minimum protecting them from sedimentation with buffers or other watershed soil conservation measures, will ensure their persistence through time as valuable wetland resources on the landscape. The other conservation practice that would be most beneficial to birds is removing pits, which reduce the availability of shallow water habitats so valuable for foraging shorebirds and waterfowl. Sediment removal likely would also be a beneficial conservation practice, but was not evaluated as part of this study.

This study highlighted the importance of playas in native grasslands and the importance of CRP in the landscape. Protecting playas from reduction in function due to sedimentation remains the highest priority for the region, and playas in both grassland and CRP will be protected from the soil inputs generated by tilled ground. We also found that larger playas are likely more valuable for migratory birds, because they are both more likely to become flooded and also sustain higher levels of use by waterfowl and shorebirds. Finally, we found evidence that bird use was also higher for playas found in proximity to other playas, suggesting that playas in complexes be prioritized in conservation planning.



Painted lady, sunflower on a Nebraska playa

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APPENDIX A. PLANT SPECIES DOCUMENTED ON PLAYAS OF SOUTHWEST NEBRASKA, 2006-2008.

Scientific Name	Common Name	Nativity	Reg 5 WIS*	# of Playas
Agropyron cristatum	crested wheatgrass	Exotic		1
Amaranthus albus	prostrate pigweed	Native	FACU	5
Amaranthus retroflexus	redroot pigweed	Exotic	FACU	5
Amaranthus sp.	pigweed			6
Ambrosia artemisiifolia	annual ragweed	Native	FACU	1
Ambrosia grayi	woollyleaf bursage, woollyleaf burr ragweed	Native	FAC	7
Ambrosia psilostachya	Cuman ragweed	Native	FAC	1
Ambrosia tomentosa	skeletonleaf bursage,skeletonleaf burr ragweed	Native		6
Ammannia auriculata	eared redstem	Native	OBL	10
Andropogon gerardii	big bluestem	Native	FAC-	2
Aster sp.	aster sp.			1
Bacopa rotundifolia	disk waterhyssop	Native	OBL	4
Bassia scoparia	kochia	Exotic	FACU	11
Brassica sp.	mustard sp.			2
Bromus inermis	smooth brome	Exotic		1
Bromus japonicus	Japanese brome	Exotic	FACU	4
Bromus sp.	brome sp.			3
Bromus tectorum	cheatgrass	Exotic		4
Buchloe dactyloides	buffalograss	Native	FACU	3
Carex sp.	sedge sp.			7
Cenchrus longispinus	mat sandbur	Native		4
Chamaesyce glyptosperma	ribseed sandmat	Native		2
Chenopodium berlandieri	pitseed goosefoot	Native		2
Chloris verticillata	tumble windmill grass	Native		2
Convolvulus arvensis	field bindweed	Exotic		1
Convolvulus sp.	bindweed sp.			1
Conyza canadensis	Canadian horseweed	Native	FACW	3
Coreopsis tinctoria	golden tickseed	Native	FAC	9
Cycloloma atriplicifolium	winged pigweed	Native	FAC	1
Cyperus esculentus	yellow nutsedge	Native	FACW	5
Cyperus sp.	sedge sp.			1
Cyperus squarrosus	bearded flatsedge	Native	OBL	5
Descurainia sophia	herb sophia	Exotic		1
Echinochloa crus-galli	barnyard grass	Exotic	FACW	14
Eleocharis palustris	common spikerush	Native	OBL	7
Eleocharis parvula	dwarf spikerush	Native	OBL	3
Eleocharis sp.	spikerush sp.			14
Eragrostis cilianensis	stinkgrass	Exotic	FACU	6
Eragrostis trichodes	sand lovegrass	Native		1

Scientific Name	Common Name	Nativity	Reg 5 WIS*	# of Playas
Glycyrrhiza lepidota	American licorice	Native	FACU	1
Helianthus annuus	common sunflower	Native	FACU	2
Helianthus sp.	sunflower sp.			1
Heteranthera limosa	blue mud plantain	Native	OBL	8
Hordeum jubatum	foxtail barley	Native	FACW	3
Juncus sp.	rush sp.			2
Lepidium sp.	pepperweed sp.			2
Leptochloa fusca ssp. fascicularis	bearded sprangletop	Native	OBL	2
Marsilea vestita	western water clover, pepperwort	Native	OBL	12
Medicago sativa	alfalfa	Exotic	NI	2
Melilotus officinalis	yellow sweetclover	Exotic	FACU	1
Melilotus sp.	sweetclover sp.			1
Mollugo verticillata	green carpetweed	Native	FAC	7
Oenothera canescens	spotted evening primrose	Native	FACW-	10
Oenothera sp.	evening-primrose			1
Panicum capillare	witchgrass	Native	FAC	6
Panicum miliaceum	wild proso millet, broomcorn millet	Exotic		2
Panicum virgatum	switchgrass	Native	FAC	3
Pascopyrum smithii	western wheatgrass	Native	FACU	10
Phyla cuneifolia	frog-fruit, fogfruit	Native	FAC	1
Polygonum amphibium var. stipulaceum	water smartweed	Native	OBL	4
Polygonum arenastrum	oval-leaf knotweed	Exotic	NI	1
Polygonum convolvulus	black bindweed	Exotic	FACU	1
Polygonum pensylvanicum	Pennsylvania smartweed	Native	FACW+	7
Polygonum ramosissimum	bushy knotweed	Native	FAC	1
Polygonum sp.	knotweed sp.			2
Polygonum sp.	smartweed sp.			8
Populus deltoides	eastern cottonwood	Native	FAC	1
Populus sp.	cottonwood sp.			4
Portulaca oleracea	common purslane	Native	FAC	1
Portulaca sp.	purslane sp.			2
Potentilla rivalis	brook cinquefoil	Native	FACW+	1
Ranunculus cymbalaria	alkali buttercup	Native	OBL	1
Rorippa sinuata	spreading yellowcress	Native	FACW	2
Rumex crispus	curly dock	Exotic	FACW	12
Sagittaria longiloba	longbarb arrowhead	Native	OBL	3
Sagittaria sp.	arrowhead sp.			1
Salsola tragus	Russian thistle	Exotic	FACU	5
Setaria pumila ssp. pumila	yellow foxtail	Exotic		1

Scientific Name	Common Name	Nativity	Reg 5 WIS*	# of Playas
Setaria viridis	green bristlegrass	Exotic		2
Solanum rostratum	buffalobur nightshade	Native		5
Spartina pectinata	prairie cordgrass	Native	FACW	1
Taraxacum officinale	common dandelion	Exotic	FACU	2
Tragopogon dubius	yellow salisfy	Exotic		2
Tragopogon sp.	goatsbeard			1
Tribulus terrestris	puncturevine	Exotic		2
Typha latifolia	broadleaf cattail	Native	OBL	4
Verbascum thapsus	common mullein	Exotic	NI	1
Verbena bracteata	prostrate vervain,bigtract verbena	Native	FACU	3
Xanthium strumarium	rough cockleburr	Native	FAC	1

***As defined in PLANTS database; see http://plants.usda.gov/wetinfo.html.**

APPENDIX B. BIRD SPECIES DOCUMENTED ON PLAYAS OF SOUTHWEST NEBRASKA, 2006-2008.

Common Name	Scientific Name	Total Observed	Number Of Playas*
American Avocet	*Recurvirostra americana*	114	15
American Bittern	*Botaurus lentiginosus*	10	2
American Coot	*Fulica americana*	2827	34
American Crow	*Corvus brachyrhynchos*	317	12
American Golden-Plover	*Pluvialis dominica*	7	5
American Goldfinch	*Carduelis tristis*	38	7
American Kestrel	*Falco sparverius*	3	3
American Pipit	*Anthus rubescens*	1740	68
American Robin	*Turdus migratorius*	83	21
American Tree Sparrow	*Spizella arborea*	47	5
American Wigeon	*Anas americana*	3210	47
Baird's Sandpiper	*Calidris bairdii*	851	48
Bald Eagle	*Haliaeetus leucocephalus*	1	1
Baltimore Oriole	*Icterus galbula*	1	1
Bank Swallow	*Riparia riparia*	6	4
Barn Swallow	*Hirundo rustica*	1871	77
Black Tern	*Chlidonias niger*	138	10
Black-bellied Plover	*Pluvialis squatarola*	9	4
Black-crowned Night-Heron	*Nycticorax nycticorax*	5	2
Blue Grosbeak	*Passerina caerulea*	3	1
Blue Jay	*Cyanocitta cristata*	12	2
Blue-winged Teal	*Anas discors*	5605	104
Brewer's Blackbird	*Euphagus cyanocephalus*	585	44
Brewer's Sparrow	*Spizella breweri*	2	1
Brown Thrasher	*Toxostoma rufum*	2	2
Brown-headed Cowbird	*Molothrus ater*	477	10
Buff-collared Nightjar	*Caprimulgus ridgwayi*	2	1
Bufflehead	*Bucephala albeola*	50	8
Bullock's Oriole	*Icterus bullockii*	1	1
Burrowing Owl	*Athene cunicularia*	49	5
Canada Goose	*Branta canadensis*	3047	15
Canvasback	*Aythya valisineria*	579	6
Chestnut-collared Longspur	*Calcarius ornatus*	790	27
Chipping Sparrow	*Spizella passerina*	9	4
Cinnamon Teal	*Anas cyanoptera*	17	6
Clay-colored Sparrow	*Spizella pallida*	16	4
Cliff Swallow	*Petrochelidon pyrrhonota*	8	4
Common Goldeneye	*Bucephala clangula*	1	1
Common Grackle	*Quiscalus quiscula*	675	32
Common Nighthawk	*Chordeiles minor*	4	3
Common Yellowthroat	*Geothlypis trichas*	5	3
Cooper's Hawk	*Accipiter cooperii*	6	5

Common Name	Scientific Name	Total Observed	Number Of Playas*
Dark-eyed Junco	*Junco hyemalis*	8	1
Dickcissel	*Spiza americana*	14	9
Double-crested Cormorant	*Phalacrocorax auritus*	123	1
Eared Grebe	*Podiceps nigricollis*	21	6
Eastern Kingbird	*Tyrannus tyrannus*	8	5
Eastern Phoebe	*Sayornis phoebe*	5	3
European Starling	*Sturnus vulgaris*	439	11
Gadwall	*Anas strepera*	2897	57
Grasshopper Sparrow	*Ammodramus savannarum*	24	11
Great Blue Heron	*Ardea herodias*	56	19
Great Horned Owl	*Bubo virginianus*	12	7
Greater White-fronted Goose	*Anser albifrons*	871	8
Greater Yellowlegs	*Tringa melanoleuca*	323	46
Green-winged Teal	*Anas crecca*	9909	96
Horned Lark	*Eremophila alpestris*	6392	190
House Sparrow	*Passer domesticus*	14	2
House Wren	*Troglodytes aedon*	1	1
Killdeer	*Charadrius vociferus*	4114	175
Lapland Longspur	*Calcarius lapponicus*	521	8
Lark Bunting	*Calamospiza melanocorys*	72	13
Lark Sparrow	*Chondestes grammacus*	6	2
Least Sandpiper	*Calidris minutilla*	279	22
Lesser Scaup	*Aythya affinis*	72	4
Lesser Yellowlegs	*Tringa flavipes*	860	46
Lincoln's Sparrow	*Melospiza lincolnii*	4	1
Loggerhead Shrike	*Lanius ludovicianus*	1	1
Long-billed Curlew	*Numenius americanus*	14	3
Long-billed Dowitcher	*Limnodromus scolopaceus*	234	12
Mallard	*Anas platyrhynchos*	33140	164
Marbled Godwit	*Limosa fedoa*	6	2
Marsh Wren	*Cistothorus palustris*	7	5
McCown's Longspur	*Calcarius mccownii*	1908	11
Merlin	*Falco columbarius*	6	3
Mourning Dove	*Zenaida macroura*	348	71
Northern Bobwhite	*Colinus virginianus*	2	1
Northern Flicker	*Colaptes auratus*	13	7
Northern Harrier	*Circus cyaneus*	231	82
Northern Pintail	*Anas acuta*	11099	91
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	4	3
Northern Shoveler	*Anas clypeata*	3285	73
Northern Shrike	*Lanius excubitor*	1	1
Pectoral Sandpiper	*Calidris melanotos*	107	22
Peregrine Falcon	*Falco peregrinus*	5	3
Pied-billed Grebe	*Podilymbus podiceps*	128	22
Prairie Falcon	*Falco mexicanus*	10	7

Common Name	Scientific Name	Total Observed	Number Of Playas*
Redhead	*Aythya americana*	1420	18
Red-headed Woodpecker	*Melanerpes erythrocephalus*	4	1
Red-necked Phalarope	*Phalaropus lobatus*	10	4
Red-tailed Hawk	*Buteo jamaicensis*	26	16
Red-winged Blackbird	*Agelaius phoeniceus*	3603	163
Ring-billed Gull	*Larus delawarensis*	29	5
Ring-necked Duck	*Aythya collaris*	74	5
Ring-necked Pheasant	*Phasianus colchicus*	132	61
Rock Pigeon	*Columba livia*	58	7
Rock Wren	*Salpinctes obsoletus*	2	1
Ross's Goose	*Chen rossii*	56	4
Rough-legged Hawk	*Buteo lagopus*	2	2
Ruby-crowned Kinglet	*Regulus calendula*	3	1
Ruddy Duck	*Oxyura jamaicensis*	489	14
Rusty Blackbird	*Euphagus carolinus*	56	5
Sandhill Crane	*Grus canadensis*	846	11
Savannah Sparrow	*Passerculus sandwichensis*	925	53
Say's Phoebe	*Sayornis saya*	3	1
Semipalmated Plover	*Charadrius semipalmatus*	9	4
Semipalmated Sandpiper	*Calidris pusilla*	169	12
Sharp-shinned Hawk	*Accipiter striatus*	5	2
Short-billed Dowitcher	*Limnodromus griseus*	16	4
Short-eared Owl	*Asio flammeus*	2	1
Snow Goose	*Chen caerulescens*	37213	18
Snowy Owl	*Bubo scandiacus*	1	1
Solitary Sandpiper	*Tringa solitaria*	128	36
Song Sparrow	*Melospiza melodia*	56	11
Sora	*Porzana carolina*	8	5
Spotted Sandpiper	*Actitis macularia*	39	15
Spotted Towhee	*Pipilo maculatus*	3	1
Stilt Sandpiper	*Calidris himantopus*	40	8
Swainson's Hawk	*Buteo swainsoni*	58	12
Swamp Sparrow	*Melospiza georgiana*	2	1
Upland Sandpiper	*Bartramia longicauda*	11	6
Vesper Sparrow	*Pooecetes gramineus*	1592	42
Western Bluebird	*Sialia mexicana*	1	1
Western Grebe	*Aechmophorus occidentalis*	33	4
Western Kingbird	*Tyrannus verticalis*	18	12
Western Meadowlark	*Sturnella neglecta*	1525	180
Western Sandpiper	*Calidris mauri*	17	6
White-breasted Nuthatch	*Sitta carolinensis*	1	1
White-crowned Sparrow	*Zonotrichia leucophrys*	51	11
White-faced Ibis	*Plegadis chihi*	45	5
White-rumped Sandpiper	*Calidris fuscicollis*	98	12
Willet	*Tringa semipalmata*	9	5

Common Name	Scientific Name	Total Observed	Number Of Playas*
Wilson's Phalarope	*Phalaropus tricolor*	1934	48
Wilson's Snipe	*Gallinago delicata*	512	48
Wilson's Warbler	*Wilsonia pusilla*	1	1
Wood Duck	*Aix sponsa*	18	9
Yellow Warbler	*Dendroica petechia*	3	2
Yellow-crowned Night-Heron	*Nyctanassa violacea*	1	1
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	1325	25
Yellow-rumped Warbler	*Dendroica coronata*	11	4

***Of n = 558 playas surveyed.**

APPENDIX C. STATISTICAL TABLES.

Table C-1. Model selection results for the effects of data source and basin variables on the probability of confirmation of playas from potential playa locations predicted in GIS.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random effects					
County	8	-330.29	676.8	0.00	1.000
Basin					
Source + Playa size + Landcover	7	-330.33	674.83	0.00	0.681
Source + Playa size + Landcover + Road distance	8	-330.29	676.80	1.97	0.254

Table C-2. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating for the effects of data source and basin variables on the probability of confirmation of playas from potential playa locations predicted in GIS.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Intercept	2.17	0.636	0.72	3.61
$\log_e$*Playa size	0.41	0.107	0.20	0.63
NWI	-0.26	0.422	-1.09	0.58
NWI/SSURGO	1.12	0.452	0.23	2.01
SSURGO	-	-	-	-
Crop	-0.70	0.349	-1.39	-0.01
CRP	-1.43	0.471	-2.36	-0.50
Grass	-	-	-	-
Random effect of County	0.93	0.574	0.31	3.54

Table C-3. Effect sizes, standard errors (SE) and 95% confidence limits (CL), and odds ratios and 95% confidence limits (CL) from the best approximating model for the effects of data source and basin variables on the probability of playa confirmation.

Parameter	*Parameter*	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*	*Odds ratio*	*Lower 95% CL*	*Upper 95% CL*
$\log_e$*Playa size		0.41	0.107	0.20	0.63	1.510	1.224	1.863
NWI	NWI/SSURGO	-1.38	0.329	-2.03	-0.73	0.252	0.132	0.481
NWI	SSURGO	-0.26	0.422	-1.09	0.58	0.772	0.337	1.767
NWI/SSURGO	SSURGO	1.12	0.452	0.23	2.01	3.063	1.261	7.437
Cropland	CRP	0.73	0.350	0.04	1.42	2.077	1.044	4.131
Cropland	Grass	-0.70	0.349	-1.39	-0.01	0.499	0.251	0.989
CRP	Grass	-1.43	0.471	-2.36	-0.50	0.240	0.095	0.605

Table C-4. Model selection results for the random effects of year and flight area, and fixed effects of basin and watershed variables on the probability of playa inundation after rain.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random effects					
Flight(year)	8	-1089.57	2197.23	0.00	1.00
Basin and watershed					
$\log_e$*Precip + Landcover(100) + Playa size	6	-1094.18	2200.40	0.00	0.493
$\log_e$*Precip + Landcover(100) + Playa size + loam	7	-1093.67	2201.40	1.00	0.299
$\log_e$*Precip + Landcover(100)	5	-1096.79	2203.61	3.21	0.099

Table C-5. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of basin and watershed factors on probability of inundation.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-1.556	0.3263	-2.462	-0.649
$\log_e$*Precipitation	2.283	0.2138	1.864	2.703
Playa size	0.136	0.0595	0.019	0.253
Cropland - 100m	-0.763	0.1944	-1.145	-0.381
CRP - 100m	-2.044	0.3231	-2.678	-1.410
Grass - 100m	-	-	-	-
Flight (Year)	0.136	0.0991	0.039	0.700
Competing model				
Intercept	-1.633	0.3326	-2.557	-0.709
$\log_e$*Precipitation	2.301	0.2146	1.880	2.723
Playa size	0.134	0.0596	0.016	0.251
Cropland - 100m	-0.830	0.2058	-1.234	-0.426
CRP - 100m	-2.082	0.3258	-2.721	-1.442
Grass - 100m	-	-	-	-
Loam	0.002	0.0016	-0.002	0.005
Flight (Year)	0.127	0.0936	0.036	0.656

Table C-6. Effect sizes, standard errors (SE) and 95% confidence limits (CL), and odds ratios and 95% confidence limits (CL) from the best approximating models for the effects of basin and watershed factors on probability of inundation.

Parameter	*Parameter*	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*	*Odds ratio*	*Lower 95% CL*	*Upper 95% CL*
$\log_e$*Precip		2.28	0.214	1.86	2.71	9.80	6.44	14.92
Playa size		0.14	0.059	0.01	0.26	1.15	1.01	1.29
Cropland	CRP	1.28	0.271	0.75	1.82	3.60	2.11	6.13
Cropland	Grass	-0.76	0.194	-1.15	-0.38	0.47	0.31	0.69
CRP	Grass	-2.04	0.323	-2.68	-1.41	0.13	0.06	0.25

Table C-7. Model selection results for the effects of year and basin variables on playa hydroperiod length, as surveyed in 2006 and 2008.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Precipitation					
Ensuing	8	-173.73	365.82	0.00	0.590
Total	8	-174.74	367.85	2.03	0.214
Preceding + Ensuing	9	-173.51	368.01	2.20	0.197
Basin and watershed					
Year + Road impact	5	-177.34	365.62	0.00	0.416
Year + Hydro	5	-178.28	367.50	1.88	0.163

Table C-8. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best two models for effects of basin variables on playa hydroperiods in 2006 and 2008.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best Model				
Intercept	-29.9	8.52	-46.6	-13.1
Ensuing precip.	10.4	1.07	8.2	12.6
2006	48.2	5.82	36.8	59.7
2008	-	-	-	-
Road impact	13.4	4.85	3.9	23.0
Not impacted	-	-	-	-
Standard deviation	14.6	1.75	11.5	18.5
Competing model				
Intercept	-28.8	9.06	-46.6	-11.0
Ensuing precip.	10.3	1.15	8.0	12.6
2006	51.3	5.93	39.7	63.0
2008	-	-	-	-
Hydro Altered	20.6	9.64	1.70	39.50
Intact	-	-	-	-
Standard deviation	15.3	1.82	12.1	19.4

Table C-9. Model selection results for the random effects and fixed effects of migration chronology, local habitat, and basin and landscape variables on the count of avian species.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random Effects					
Playa ID (Year)	23	-4469.91	8986.23	0.00	1.000
Migration Chronology					
$Date^2$*Season	19	-4528.81	9057.61	0.00	0.976
Local Habitat					
log_e*Size + full + vegetated	18	-4501.87	9037.97	0.00	0.992
Basin and Landscape					
Cropland + Playa density	11	-4505.64	9035.39	0.00	0.993

Table C-10. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best model for the effects of basin and landscape impacts on the count of avian species.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Intercept	**1.30**	**0.292**	**0.72**	**1.88**
Date	-0.20	0.059	-0.33	-0.08
Date2	-0.01	0.048	-0.11	0.09
Autumn	-0.03	0.089	-0.21	0.15
Spring	-	-	-	-
Date2*Autumn	-0.28	0.079	-0.44	-0.12
Date2*Spring	-	-	-	-
Vegetated	-0.28	0.088	-0.46	-0.11
Full	0.58	0.100	0.38	0.78
log_e*Playa size	0.42	0.035	0.34	0.49
Cropland	-1.54	0.356	-2.25	-0.84
Playa density	0.15	0.035	0.07	0.22
Playa ID (Year)	0.30	0.046	0.23	0.40
Dispersion	0.27	0.027	0.21	0.32

Table C-11. Dabbling duck abundance model selection results for the effects of migration chronology, local habitat, and basin and landscape variables on dabbling duck abundance.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random Effects					
Playa ID (Year)	23	-5150.07	10346.57	0.00	1.000
Migration Chronology					
$Date^2$ + Season	19	-5148.00	10332.25	0.00	0.716
$Date^2$*Season	18	-5147.91	10334.10	1.85	0.284
Local Habitat					
log_e*Size + Full + Vegetated	19	-5139.59	10317.46	0.00	0.999
Basin and Landscape					
CRP	10	-5144.15	10308.38	0.00	0.248
CRP + Wetland Distance	11	-5143.31	10308.72	0.34	0.210
CRP + Adjacent Landuse	12	-5142.85	10309.81	1.43	0.122
CRP + Road Distance	11	-5143.88	10309.85	1.47	0.119
CRP + Road Density	11	-5143.90	10309.91	1.53	0.116
CRP + Road impact	11	-5144.15	10310.40	2.02	0.090

Table C-12. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating model for basin and landscape effects on dabbling duck abundance.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Intercept	0.79	0.389	0.02	1.56
Date	-0.59	0.107	-0.80	-0.37
$Date^2$	-0.73	0.064	-0.86	-0.60
Autumn	-1.25	0.275	-1.79	-0.70
Spring	-	-	-	-
Vegetated	-1.15	0.278	-1.70	-0.60
Full	2.63	0.335	1.97	3.30
log_e* Playa Size	1.22	0.125	0.97	1.47
CRP	12.54	4.016	4.66	20.43
Playa ID (Year)	3.88	0.593	2.97	5.10
Dispersion	5.12	0.247	4.66	5.62

Table C-13. For all shorebirds, model selection results for effects of migration chronology, local habitat, and basin and landscape variables on the abundance of shorebirds.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random Effects					
Playa ID (Year)	23	-3167.51	6381.43	0.00	1.000
Migration Chronology					
Date^2*Season	18	-3184.25	6402.74	0.00	0.963
Local Habitat					
$\log_e$*Size + Vegetated	18	6407.26	-3203.63	0.00	0.435
Size + Vegetated	18	6407.61	-3203.81	0.34	0.367
$\log_e$*Size + Vegetated + Open water	19	6407.21	-3203.61	1.97	0.162
Basin and Landscape					
Playa density + Wetland distance	11	-3205.29	6432.68	0.00	0.158
Playa density	10	-3207.16	6434.40	1.72	0.067
Wetland distance	10	-3207.43	6434.95	2.27	0.051
Wetland distance + Road distance	11	-3206.47	6435.04	2.36	0.049
Playa density + Road impact	11	-3206.50	6435.09	2.41	0.047
Playa density + Hydro	11	-3206.55	6435.19	2.51	0.045
Wetland distance + Hydro	11	-3206.61	6435.31	2.63	0.042
Playa density + Road distance	11	-3206.63	6435.35	2.67	0.042
Road distance + Hydro	11	-3206.88	6435.86	3.18	0.032
Wetland distance + Road impact	11	-3206.91	6435.92	3.24	0.031
Road distance	10	-3207.95	6435.98	3.30	0.030
Playa density + Adjacent CRP	11	-3206.96	6436.03	3.35	0.030
Road impact	10	-3208.04	6436.16	3.48	0.028
Hydro	10	-3218.12	6436.24	3.56	0.027
Playa density + Cropland	11	-3207.12	6436.33	3.65	0.025
Wetland distance + Cropland	11	-3207.14	6436.37	3.69	0.025
Playa density + Road density	11	-3207.14	6436.38	3.70	0.025
Wetland distance + Adjacent CRP	11	-3207.20	6436.50	3.82	0.023
Road impact + Hydro	11	-3207.27	6436.64	3.96	0.022

Table C-14. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating model for the effects of basin and landscape impacts on the abundance of shorebirds.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-1.02	0.440	-1.89	-0.15
Date	-0.77	0.208	-1.18	-0.36
Date2	0.27	0.165	-0.06	0.60
Autumn	0.90	0.246	0.41	1.38
Spring	-	-	-	-
Date2*Autumn	-0.88	0.262	-1.40	-0.36
Date2*Spring	-	-	-	-
Vegetated	-1.26	0.237	-1.73	-0.79
$\log_e$*Playa size	0.65	0.094	0.46	0.84
Playa density	0.18	0.086	0.01	0.36
Wetland distance	0.05	0.024	0.00	0.10
Playa ID (Year)	1.69	0.286	1.24	2.29
Dispersion	4.89	0.300	4.35	5.49

Table C-15. Model selection results for the random effects and fixed effects of migration chronology, local habitat, and basin and landscape variables on the abundance of typical shorebirds.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random Effects					
Playa ID (Year)	23	-1510.52	3067.46	0.00	0.998
Migration Chronology					
Date^2*Season	19	-1518.29	3072.83	0.00	1.000
Local Habitat					
$\log_e$*Size + wet unvegetated	18	-1515.60	3069.49	0.00	0.901
Basin and Landscape					
Road Distance + Hydro	11	-1544.60	3111.29	0.00	0.163
Road Distance	10	-1545.81	3111.71	0.42	0.132
Road Distance + Road impact	11	-1545.40	3112.89	1.60	0.073
Road Distance + Playa in landscape	11	-1545.61	3113.32	2.03	0.059
Road Distance + Cropland	11	-1545.66	3113.42	2.13	0.056
Road Distance + Road Density	11	-1545.68	3113.46	2.17	0.055
Road Distance + Adjacent Cropland	11	-1545.78	3113.65	2.36	0.050
Road Distance + Wetland Distance	11	-1545.79	3113.68	2.39	0.049
Road impact	10	-1546.84	3113.76	2.47	0.047
Hydro	10	-1557.10	3114.19	2.90	0.038
Hydro + Road impact	11	-1546.09	3114.27	2.98	0.037
Road Density	10	-1547.27	3114.61	3.32	0.031
Road Distance + Road Density	11	-1546.30	3114.70	3.41	0.030
Playa_landscape	10	-1547.58	3115.24	3.95	0.023

Table C-16. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating model for the effects of basin and landscape impacts on the abundance of typical shorebirds.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-4.01	0.454	-4.91	-3.11
Date	-1.58	0.327	-2.23	-0.94
Date2	1.06	0.278	0.51	1.61
Autumn	2.60	0.417	1.78	3.43
Spring	-	-	-	-
Date2*Autumn	-2.29	0.446	-3.17	-1.41
Date2*Spring	-	-	-	-
Wet unvegetated	1.78	0.410	0.97	2.59
$\log_e$*Playa size	1.03	0.164	0.71	1.36
Hydro altered	-0.81	0.518	-1.83	0.22
Intact	-	-	-	-
Road distance	-2.23	1.000	-4.20	-0.26
Playa ID (Year)	3.33	0.712	2.39	4.67
Dispersion	7.03	0.696	5.86	8.47

Table C-17. Model selection results for the random and fixed effects of chronology, local habitat, and basin and landscape variables on landbird abundance in wet playas.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random Effects					
Playa ID (Year)	23	-5075.55	10197.53	0.00	0.997
Migration Chronology					
Date*Season	16	-5086.11	10206.45	0.00	1.000
Local Habitat					
$\log_e$*Size + full + vegetated	17	-5090.17	10214.56	0.00	0.556
$\log_e$*Size + full	16	-5091.88	10215.96	1.40	0.276
Basin and Landscape					
Road density + CRP	10	-5094.28	10208.65	0.00	0.272
Road density + wetland distance	10	-5095.12	10210.31	1.66	0.118
Road density + Hydro	10	-5095.45	10210.98	2.33	0.085
Road density	9	-5096.51	10211.08	2.43	0.081
Road density + Road impacts	10	-5095.60	10211.27	2.62	0.073

Table C-18. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of basin and landscape impacts on landbird abundance in wet playas.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	1.54	0.358	0.83	2.25
Date	-0.24	0.094	-0.43	-0.05
Autumn	1.30	0.180	0.94	1.66
Spring	-	-	-	-
Date*Autumn	1.05	0.136	0.78	1.33
Date*Spring	-	-	-	-
Full	0.12	0.059	0.00	0.24
$\log_e$*Size	0.29	0.068	0.15	0.42
Road density	-0.78	0.278	-1.33	-0.23
CRP	4.52	2.153	0.30	8.75
Playa ID (Year)	0.79	0.129	0.57	1.07
Dispersion	4.06	0.174	3.73	4.41
Competing model				
Intercept	1.26	0.412	0.44	2.08
Date	-0.24	0.094	-0.43	-0.05
Autumn	1.28	0.180	0.93	1.64
Spring	-	-	-	-
Date*Autumn	1.04	0.135	0.77	1.31
Date*Spring	-	-	-	-
Full	0.11	0.059	-0.01	0.24
$\log_e$*Size	0.26	0.070	0.12	0.41
Road density	-0.66	0.279	-1.22	-0.11
Wetland distance	0.03	0.017	-0.01	0.07
Playa ID (Year)	0.81	0.131	0.59	1.10
Dispersion	4.05	0.174	3.73	4.40

Table C-19. Model selection results for the random and fixed effects of chronology, local habitat, and basin and landscape variables on landbird abundance in dry playas.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Random Effects					
Playa ID (Year)	23	-692.24	1428.02	0.00	0.567
Playa ID	23	-692.53	1428.62	0.60	0.420
Migration Chronology					
Date*Season	15	-780.48	1589.65	0.00	1.000
Local Habitat					
$\log_e$*Size	15	-782.00	1592.7	0.00	0.995
Basin and Landscape					
Playa density + CRP	9	-783.66	1583.55	0.00	0.248
Playa density	8	-785.52	1585.22	1.67	0.107
Playa density + Adjacent grass	9	-784.88	1585.98	2.43	0.073
CRP	8	-786.10	1586.39	2.84	0.060
Playa density + Wetland distance	9	-785.09	1586.42	2.87	0.059
Playa density + Hydro	9	-785.14	1586.51	2.96	0.056
Playa density + Road impacts	9	-785.33	1586.90	3.35	0.046
Playa density + Road density	9	-785.47	1587.18	3.63	0.040
Playa density + Road distance	9	-785.52	1587.27	3.72	0.039
CRP + Road impacts	9	-785.57	1587.36	3.81	0.037

Table C-20. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating model for the effects of basin and landscape impacts on landbird abundance in dry playas.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-2.49	0.493	-3.46	-1.52
Date	0.39	0.172	0.05	0.73
Autumn	-0.80	0.355	-1.51	-0.10
Spring	-	-	-	-
Date*Autumn	-1.17	0.220	-1.61	-0.74
Date*Spring	-	-	-	-
$\log_e$*Size	0.55	0.147	0.26	0.85
Playa density	0.28	0.127	0.02	0.53
CRP	7.91	4.085	-0.15	15.96
Playa ID (Year)	5.93	0.908	4.84	7.34

Table C-21. Model selection results for the fixed effects of migration chronology and survey on the count of avian species.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Migration chronology					
$Date^2$*Season	10	-804.75	1630.06	0.00	0.912
Flush count surveys					
Survey type + $\log_e$(Playa size)	9	-806.87	1632.20	0.00	0.433
Survey type*$\log_e$(Playa size)	10	-806.20	1632.97	0.77	0.295
Survey type*Vegetated	10	-806.79	1634.14	1.94	0.164
Survey type + Vegetated	9	-808.26	1634.98	2.78	0.108

Table C-22. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of survey type and playa size on the count of avian species.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-1.63	1.737	-5.15	1.89
Date	-0.23	0.054	-0.35	-0.12
Date^2	0.31	0.181	-0.05	0.67
Autumn	2.30	1.745	-1.13	5.74
Spring	-	-	-	-
Date^2*Autumn	-0.47	0.186	-0.84	-0.10
Date^2*Spring	-	-	-	-
Flush	0.56	0.059	0.44	0.68
Vantage	-	-	-	-
$\log_e$(Playa size)	0.21	0.086	0.04	0.38
Playa ID (Year)	0.16	0.052	0.09	0.30
Dispersion	0.05	0.039	0.00	0.13
Competing Model 1 (for playa size)				
Intercept	-1.60	1.735	-5.11	1.92
Date	-0.23	0.054	-0.35	-0.12
Date^2	0.31	0.181	-0.05	0.67
Autumn	2.30	1.743	-1.13	5.74
Spring	-	-	-	-
Date^2*Autumn	-0.47	0.185	-0.84	-0.10
Date^2*Spring	-	-	-	-
Flush	0.51	0.076	0.35	0.66
Vantage	-	-	-	-
$\log_e$(Playa size)	0.16	0.095	-0.03	0.35
Flush*$\log_e$(Playa size)	0.08	0.065	-0.06	0.21
Vantage*$\log_e$(Playa size)	-	-	-	-
Playa ID (Year)	0.16	0.052	0.09	0.30
Dispersion	0.04	0.039	0.00	0.13
Competing Model 2 (vegetation)				
Intercept	-2.17	1.771	-5.75	1.42
Date	-0.21	0.058	-0.32	-0.09
Date^2	0.39	0.185	0.02	0.76
Autumn	3.26	1.799	-0.29	6.80
Spring	-	-	-	-
Date^2*Autumn	-0.53	0.188	-0.91	-0.16
Date^2*Spring	-	-	-	-
Flush	0.41	0.104	0.21	0.62
Vantage	-	-	-	-
Vegetated	-0.56	0.228	-1.01	-0.10
Flush*Vegetated	0.32	0.186	-0.05	0.69
Vantage*Vegetated	-	-	-	-
Playa ID (Year)	0.14	0.051	0.07	0.26
Dispersion	0.05	0.040	0.00	0.14
Competing Model 3 (vegetation)				
Intercept	-2.26	1.774	-5.86	1.33
Date	-0.20	0.058	-0.32	-0.09
Date^2	0.39	0.185	0.02	0.76
Autumn	3.26	1.803	-0.29	6.81
Spring	-	-	-	-
Date^2*Autumn	-0.53	0.189	-0.91	-0.15
Date^2*Spring	-	-	-	-

Flush	0.56	0.060	0.44	0.68
Vantage	-	-	-	-
Vegetated	-0.36	0.194	-0.74	0.03
Playa ID (Year)	0.13	0.050	0.07	0.26
Dispersion	0.06	0.040	0.00	0.14

Table C-23. Model selection results for the fixed effects of migration chronology and survey on shorebird abundance.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Migration chronology					
Date + Season	8	-473.61	963.59	0.00	0.401
Date*Season	9	-473.45	965.36	1.77	0.165
$\log_e$(Date) + Season	8	-474.57	965.50	1.91	0.154
Date^2 + Season	9	-473.61	965.68	2.09	0.141
Date^2*Season	10	-473.40	967.37	3.78	0.061
$\log_e$(Date)*Season	9	-474.52	967.50	3.91	0.057
Flush count surveys					
Survey type + Playa size	7	-473.48	961.25	0.00	0.629
Survey type*Playa size	8	-473.48	963.33	2.08	0.222
Survey type + Vegetated	7	-475.22	964.73	3.48	0.110

Table C-24. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best and competing models for the effects of survey type on shorebird abundance.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	3.79	0.921	1.92	5.66
Date	-1.24	0.190	-1.62	-0.86
Autumn	-4.98	0.985	-6.92	-3.04
Spring	-	-	-	-
Flush	0.01	0.166	-0.32	0.34
Vantage	-	-	-	-
$\log_e$(Playa size)	0.66	0.374	-0.08	1.41
Playa ID (Year)	2.88	1.119	1.58	5.80
Dispersion	1.43	0.136	1.20	1.71
Competing model				
Intercept	3.79	0.923	1.91	5.66
Date	-1.24	0.190	-1.62	-0.86
Autumn	-4.98	0.985	-6.92	-3.04
Spring	-	-	-	-
Flush	0.02	0.221	-0.42	0.46
Vantage	-	-	-	-
$\log_e$(Playa size)	0.67	0.384	-0.09	1.43
Flush*$\log_e$(Playa size)	-0.01	0.173	-0.35	0.34
Vantage*$\log_e$(Playa size)	-	-	-	-
Playa ID (Year)	2.88	1.119	1.58	5.80
Dispersion	1.43	0.136	1.20	1.71

Table C-25. Model selection results for the fixed effects of migration chronology and survey on waterfowl abundance.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Migration chronology					
Date^2*Season	10	-901.39	1823.35	0.00	0.510
Date^2 + Season	9	-903.16	1824.79	1.44	0.248
Date*Season	9	-903.79	1826.05	2.70	0.132
Date + Season	8	-905.22	1826.82	3.47	0.090
Flush count surveys					
Survey type + Vegetated	9	-903.25	1824.95	0.00	0.737
Survey type*Vegetated	10	-903.23	1827.02	2.07	0.262

Table C-26. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of survey type and proportion vegetated on waterfowl abundance.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-2.07	4.537	-11.25	7.11
Date	-0.82	0.151	-1.12	-0.51
Date^2	0.74	0.479	-0.21	1.69
Autumn	4.08	4.657	-5.07	13.25
Spring	-	-	-	-
Date^2*Autumn	-0.97	0.480	-1.92	-0.02
Date^2*Spring	-	-	-	-
Flush	0.09	0.126	-0.17	0.34
Vantage	-	-	-	-
Vegetated	-2.68	0.661	-3.99	-1.38
Playa ID (Year)	5.50	1.901	3.15	10.71
Dispersion	2.49	0.138	2.25	2.78
Competing model				
Intercept	-2.04	4.542	-11.23	7.16
Date	-0.82	0.152	-1.12	-0.51
Date^2	0.74	0.480	-0.21	1.69
Autumn	4.07	4.659	-5.10	13.23
Spring	-	-	-	-
Date^2*Autumn	-0.97	0.480	-1.92	-0.02
Date^2*Spring	-	-	-	-
Flush	0.05	0.228	-0.41	0.50
Vantage	-	-	-	-
Vegetated	-2.73	0.717	-4.15	-1.32
Flush*Vegetated	0.10	0.533	-0.95	1.15
Vantage*Vegetated	-	-	-	-
Playa ID (Year)	5.51	1.902	3.15	10.72
Dispersion	2.49	0.138	2.25	2.78

Table C-27. Model selection results for the effects of basin and landscape variables on the occurrence of Great Plains Toads in the Southwest Playa Complex, NE, spring 2007.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Local Habitat					
$\log_e$*Size	7	-42.47	100.23	0.00	0.273
$\log_e$*Size + Full	8	-41.53	100.72	0.50	0.213
$\log_e$*Size + Vegetated	8	-41.78	101.24	1.01	0.165
Basin and Landscape					
Playa Landscape	3	-42.82	91.91	0.00	0.224
Playa Landscape + Adjacent Grass	4	-42.55	93.55	1.64	0.098

Table C-28. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating model for the effects of basin and landscape impacts on the occurrence of Great Plains Toads in the Southwest Playa Complex, NE, spring 2007.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Intercept	1.03	0.649	-0.19	2.40
$\log_e$*Playa Size	0.85	0.277	0.34	1.45
Playa Landscape	0.56	0.281	0.04	1.16

Table C-29. Model selection results for the effects of basin and landscape variables on the occurrence of Western Striped Chorus Frogs in the Southwest Playas, NE, spring 2007.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Local Habitat					
Size + Full + Vegetated	9	-48.59	117.29	0.00	0.292
$\log_e$*Size + Full + Vegetated	9	-48.71	117.53	0.24	0.259
Full + Vegetated	8	-50.48	118.63	1.34	0.150
Basin and Landscape					
Rd. Impact	5	-51.61	113.89	0.00	0.089
Playa Density	5	-51.75	114.18	0.29	0.078
Size + Full + Vegetated only	4	-52.94	114.31	0.42	0.072
Rd. Impact + Hydro	6	-50.76	114.48	0.59	0.067
Playa Density + Grass landscape	6	-50.84	114.64	0.75	0.062
Rd. Impact + Playa Density	6	-50.85	114.65	0.76	0.061
Hydro	5	-52.12	114.92	1.03	0.053
Playa Density + Hydro	6	-50.99	114.93	1.04	0.053
Rd. Impact + Playa Density + Grass landscape	7	-50.04	115.37	1.48	0.043
Rd. Impact + Playa Density + Hydro	7	-50.04	115.37	1.48	0.043
Playa Density + Adjacent Crop + Grass landscape	7	-50.04	115.37	1.48	0.043
Rd. Impact + Adjacent Crop	6	-51.29	115.53	1.63	0.040
Playa Density + Hydro + Grass landscape	7	-50.13	115.54	1.65	0.039
Rd. Impact + Grass landscape	6	-51.38	115.72	1.83	0.036
Adjacent Crop	5	-52.55	115.77	1.88	0.035
Rd. Impact + Adjacent Crop + Grass landscape	7	-50.29	115.88	1.99	0.033

Table C-30. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of basin and landscape variables on the occurrence of Western Striped Chorus Frogs in southwest NE, spring 2007.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-3.74	1.568	-7.06	-0.85
$\log_e$*Size	0.65	0.363	0.08	1.50
Vegetated	0.03	0.013	0.00	0.06
Full	0.03	0.014	0.00	0.07
Intact	0.90	0.552	-0.19	2.01
Impacted	-	-	-	-
Competing model				
Intercept	-1.99	1.414	-4.92	0.71
$\log_e$*Size	0.65	0.352	0.07	1.46
Vegetated	0.03	0.013	0.00	0.06
Full	0.03	0.014	0.00	0.07
Playa Density	-0.23	0.152	-0.55	0.07

Table C-31. Model selection results for the effects of basin and landscape variables on the occurrence of Plains Spadefoots in the Southwest Playa Complex, NE, spring 2007.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Local Habitat					
$\log_e$*Size + Full	8	-56.06	129.79	0.00	0.385
$\log_e$*Size	7	-57.74	130.76	0.98	0.236
$\log_e$*Size + Full + Vegetated	9	-55.65	131.42	1.63	0.171
Basin and Landscape					
$\log_e$*Size + Full only	3	-58.92	124.09	0.00	0.110
Playa Density + CRP Landscape	5	-56.78	124.23	0.14	0.102
Hydro	4	-58.13	124.71	0.61	0.081
Playa Density	4	-58.20	124.85	0.75	0.075
Playa Density + Hydro	5	-57.09	124.85	0.75	0.075
Playa Density + CRP Landscape + Hydro	6	-56.08	125.11	0.23	0.098
CRP Landscape	4	-58.65	125.74	1.65	0.048
Adjacent Grass	4	-58.77	125.99	1.90	0.043
Rd. Impact	4	-58.84	126.12	2.02	0.040
Playa Density + CRP Landscape + Rd. Impact	6	-56.77	126.49	1.61	0.049
Playa Density + CRP Landscape + Adjacent Grass	6	-56.77	126.50	1.61	0.049

Table C-32. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of basin and landscape impacts on the occurrence of Plains Spadefoots in the Southwest Playas, NE, spring 2007.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	-0.41	0.565	-1.56	0.69
$\log_e$*Size	0.59	0.210	0.19	1.03
Full	0.01	0.009	-0.01	0.04
Competing model				
Intercept	1.15	0.965	-0.73	3.11
$\log_e$*Size	0.64	0.219	0.23	1.10
Full	0.02	0.009	0.00	0.04
Playa Density	-0.32	0.174	-0.69	0.01
CRP Landscape	-0.13	0.082	-0.31	0.03

Table C-33. Model selection results for the effects of basin and landscape variables on the occurrence of Woodhouse's Toad in the Southwest Playa Complex, NE, spring 2007.

Model	*K*	*log(L)*	*AICc*	*ΔAICc*	w_i
Local Habitat					
$\log_e$*Size + Full	8	-46.45	110.57	0.00	0.579
Basin and Landscape					
Rd. Impacts	4	-47.09	102.62	0.00	0.162
$\log_e$*Size + Full only	3	-48.44	103.14	0.53	0.125
Rd. Impacts + Adjacent Grass	5	-46.74	104.15	1.54	0.075

Table C-34. Parameter estimates, standard errors (SE) and 95% confidence limits (CL) from the best approximating and competing models for the effects of basin and landscape variables on the occurrence of Woodhouse's Toad in the Southwest Playas, NE, spring 2007.

Parameter	*Estimate*	*SE*	*Lower 95% CL*	*Upper 95% CL*
Best model				
Intercept	0.08	0.793	-1.47	1.69
$\log_e$*Size	1.17	0.280	0.66	1.78
Full	0.02	0.011	0.00	0.05
Intact	-0.93	0.574	-2.11	0.18
Impacted	-	-	-	-
Competing model				
Intercept	-0.59	0.650	-1.91	0.68
$\log_e$*Size	1.19	0.280	0.68	1.80
Full	0.02	0.010	0.00	0.05