Assessment and Conservation of Playas in Eastern Colorado

Final Report to the
Colorado Division of Wildlife,
Playa Lakes Joint Venture,
United States Environmental Protection Agency,
and the United States Fish and Wildlife Service

December 2008

Alison Banks Cariveau, Research Division Director
David Pavlacky, Spatial Ecologist

Rocky Mountain Bird Observatory
P.O. Box 1232
14500 Lark Bunting Lane
Brighton, CO 80603
303.659.4348
www.rmbo.org

ROCKY MOUNTAIN BIRD OBSERVATORY

***Mission**: To conserve birds and their habitats*

***Vision**: Native bird populations sustained in healthy ecosystems*

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

1. ***Science** provides the foundation for effective bird conservation.*
2. ***Education** is critical to the success of bird conservation.*
3. ***Stewardship** of birds and their habitats is a shared responsibility.*

RMBO accomplishes its mission by:

***Partnering** with state and federal natural resource agencies, private landowners, schools, and other nonprofits for conservation.*

***Studying** bird responses to habitat conditions, ecological processes, and management actions to provide scientific information that guides bird conservation efforts.*

***Monitoring** long-term trends in bird populations for our region.*

***Providing** active, experiential, education programs that create an awareness and appreciation for birds.*

***Sharing** the latest information in land management and bird conservation practices.*

***Developing** voluntary, working partnerships with landowners to engage them in conservation.*

***Working** across political and jurisdictional boundaries including counties, states, regions, and national boundaries. Our conservation work emphasizes the Western United States including the Great Plains, as well as Latin America.*

***Creating** informed publics and building consensus for bird conservation needs.*

Suggested Citation:
Cariveau, A.B. and D. Pavlacky. 2008. *Assessment and Conservation of Playas in Eastern Colorado: Final Report to the Colorado Division of Wildlife, Playa Lakes Joint Venture, United States Environmental Protection Agency, and United States Fish and Wildlife Service,* Rocky Mountain Bird Observatory, Brighton, CO, 117 pp.

Cover Photos:
All photos courtesy of Tony Leukering or RMBO.

Contact Information:
Alison Cariveau alison.cariveau@rmbo.org
David Pavlacky david.pavlacky@rmbo.org

ACKNOWLEDGEMENTS

Rocky Mountain Bird Observatory (RMBO) thanks the Colorado Division of Wildlife, Playa Lakes Joint Venture, United States Environmental Protection Agency, and United States Fish and Wildlife Service for funding this project.

We gratefully acknowledge all of the private landowners who allowed us access to their land and provided us with valuable information regarding their playas. We appreciate the contributions of Ducks Unlimited, Inc. and PLJV in providing base GIS layers for the study. Karin Callahan and Megan McLachlan of PLJV provided valuable help in updating our GIS as new data became available. We thank the CDOW personnel in eastern Colorado who volunteered to collect data on playas they encountered in the field. Field accommodations were provided by CDOW and The Nature Conservancy (TNC). We also appreciate the contribution of playa locations by TNC. We appreciate assistance with vegetation identification and sampling methodology from Denise Culver and Dave Anderson of the Colorado Natural Heritage Program. We also thank Don Hazlett for providing botanical expertise and identifying plant specimens collected by our field crews. At RMBO, Kelly Hutton and Lacrecia Johnson supervised the project, Michele Shimomura provided database expertise, Robert LeClair provided GIS support, Ben Risk assisted with data analysis, Rob Sparks provided GIS assistance, statistical analyses, and reviewed a draft of this report, and Sarah Manor assisted in data summaries and formatting of the report. Tony Leukering shared bird photos that are included throughout this report. We especially thank Crystal Bechaver, Carmen Blumberg, Brian Gibbons, Victor Gibbs, Kathy Herbener, Derek Hill, Marie Kalamaras, Tony Leukering, Ross Lock, Andrew Logsden, Sarah Manor, Chris Nicholson, Dave Rouse, Jennifer Scott, Jennifer Thieme, Molly Tranel, Chris Warren, and Deneb Woods for their hard work in the field collecting the data presented in this report.

EXECUTIVE SUMMARY

This is the Final Report for the project entitled *Survey and Assessment of Playa Wetlands in Eastern Colorado*, funded by the United States Environmental Protection Agency (EPA), with matching funds provided by the Colorado Division of Wildlife (CDOW). Earlier phases of the project were supported by a United States Fish and Wildlife Service (USFWS) Neotropical Migratory Bird Conservation Act grant, a CDOW State Wildlife Grant, and a Playa Lakes Joint Venture (PLJV) Conoco-Phillips Research Grant.

Playas are shallow, depressional wetlands fed exclusively by rainfall and runoff, and are found throughout much of the Great Plains. These wetlands are vital to biodiversity in this ecoregion, but are threatened by agriculture and development. While attention has been focused on playas in other regions, such as the High Plains of Texas (Haukos and Smith 2003), prior to this study, playa wetlands in Colorado were relatively unknown. This study provides basic playa distribution and ecological information to facilitate conservation efforts of playas in eastern Colorado.

A fundamental goal of this project was to provide conservation practitioners with information important to playa conservation in eastern Colorado. We conducted analyses that translated playa attributes of conservation importance into spatially explicit maps. These data layers may be used by partners to guide conservation efforts and identify particular regions of the study area best suited for accomplishing specific conservation goals. In addition, we synthesized the findings of this project into a set of conservation recommendations.

Our random sample of playas within the study area provided the first empirical estimate of playa density and abundance within the BCR 18 of Colorado. Including all sizes of playas, our model estimated a range of approximately 14,000 – 23,000 playas within the study area. These numbers are two to three times the number occurring within the GIS database, and far exceed previous estimates of playa numbers in this region. Therefore, continued work to locate additional playas is warranted. We suggest that using aerial photography such as the NAIP may be an effective way to identify potential playa locations. In addition, private landowners are an excellent source of knowledge about the locations and histories of playas in eastern Colorado.

In this study, we documented within Colorado playas 245 species of plants including 85 wetland species, 148 species of birds including 27 Colorado Species of Greatest Conservation Need, as well as other species of wildlife including black-tailed jack rabbit (*Lepus californicus*), coyote (*Canis latrans*), horned lizards (*Phrynosoma* spp.), spadefoot toad (*Spea hammondii*), Woodhouse's toad (*Bufo woodhousii*), lesser earless lizard (*Holbrookia maculate*), snakes, damselflies, butterflies, and clams. We also documented vegetation and soils on playa restoration projects.

Our analyses indicated that several characteristics of playas are related to plant distribution and use by birds. Plant species richness was higher in playas within grasslands than playas within cropland. Landbirds were also more abundant in grassland playas than in farmed playas. Grassland playas are also valuable because they are not at direct risk for filling in due to sedimentation, and the native vegetation surrounding them facilitates inundation by sheet flows during heavy rainfall events. We also found the

abundance of landbirds, shorebirds, and waterfowl responded positively to playa area. Shorebird and waterfowl abundance also increased with the percent of playa cover in the surrounding landscape. Furthermore, smaller playas are much more common than larger ones, so prioritizing the conservation of larger playas may be an effective conservation strategy.

Our work also highlights conservation opportunities for playas in eastern Colorado. We found evidence for greater shorebird numbers in playas without hydrologic modifications. Therefore, pit removal and other hydrologic restorations may provide shallow water foraging habitats for migrating shorebirds. These projects are also relatively affordable, and, when done with the development of alternative water sources, provide landowners with more reliable, cleaner alternative for watering their livestock. In addition, farmed playas present conservation opportunities because retiring and buffering farmed playas is an effective way to reduce the likelihood they will fill in by sedimentation. We are encouraged to see the numbers of such projects on the rise both here in Colorado as well as in other states within the range of playas. Care should be taken when selecting buffer plantings to ensure that the vegetation stature is appropriate for the site and does not impede natural flows of water to the playas.

Here we summarize our accomplishments according to the four primary objectives set forth in our EPA grant, *Survey and Assessment of Playa Wetlands in Eastern Colorado*:

Objective 1.A. Verify the location and condition of at least 1,000 playas. We collected location and field condition information for 1,087 playas. 657 of these were predicted by the GIS database and 430 were newly discovered in the field by RMBO staff. All of these playas are portrayed in the GIS dataset provided to EPA as "Verified." These playas are found in 27 counties of eastern Colorado, throughout the entirety of the study area. Our playa confirmation analysis indicated the Soils Survey Geographic Database (SSURGO; 77%) data source was more accurate than the LANDSAT satellite imagery (55%) and National Hydrography Dataset (34%) data sources. Within the SSURGO data, the confirmatation rate of the Apishapa soil series was greater than the intermittent water and playa types. As an indication of playa condition, we recorded information about anthropogenic disturbances including farming, hydrologic alterations including excavation, and hydrologic impacts of roads. We found that 29% were tilled, 45% were grazed, and 25% had no agricultural use reported. We detected hydrologic modifications including pits, berms, levees, wells, or constricted inlets or outlets at 13% of the playas surveyed. In addition, 15% of the playas were directly impacted by roads: 9% split into two sides and 6% bordered on one side by the road. Looking across all forms of conditional information, 34% could be classified as in high condition, with the rest in categories of moderately to severely impacted. The estimated mean density of playas was 0.46 playas/mi^2 and the average playa size was 6.68 ac. We projected the number of playas in Colorado to be 14,597 – 22,623, with 8,357 – 14,922 playas greater than 1 acre in size.

Objective 1.B. Document the surrounding landuse, playa alterations, surface hydrology, wildlife habitat quality, bird use, hydroperiod, and soils of at least 60 playas. Surrounding landuse, surface hydrology, wildlife habitat condition, bird use, and the presence of hydrologic alterations were recorded at all 1,087 playas visited. Fifty-two percent of playas were found in grassland, 28% were in cropland, 4% were in the USDA Conservation Reserve Program, and the rest were surrounded by multiple land uses. Playas were dry on nearly half of the surveys. During fall 2006, the observed hydroperiod ranged from 32 to 41 days, including playas that remained wet until the end of the fall migration season. The mean vegetation cover of the sampled playas was 50% with an average plant height of 26 cm. We documented 48,830 bird detections for 148 species using the playas. We sampled soils at 21 playas in the first year of work, indicating clay soils present in all playas and sedimentation, indicated by non-clay soils on top of the clay layer, at one playa. We did not continue sampling soils because of the limited amount of variation observed in our initial sample and time needed for other aspects of the project.

Objective 2. Implement playa conservation programs through cooperative efforts with other non-profit and government agencies and evaluate the effectiveness of various restoration techniques as they relate to hydrology, runoff, sedimentation, wetland quality, and wildlife use. RMBO delivered 19 playa conservation projects protecting or enhancing 1,039 playa acres, in partnership with the USFWS Partners for Wildlife, the Colorado Division of Wildlife, Playa Lakes Joint Venture, USDA Natural Resources Conservation Service, and National Fish and Wildlife Foundation. The conservation practices applied were fencing with grazing management, removal of pits, and development of alternate water sources for livestock. We visited each of the playas in this program as well as suitable controls annually to track changes in vegetation composition. Because of the short duration of this study, dominant drought conditions, and time constraints imposed by the multiple objectives of this project, we did not directly observe impacts of restoration on hydrology, runoff, sedimentation, wetland quality, or wildlife use. However, we relate vegetative conditions to these parameters and synthesize what has been found by other researchers on these topics. We found that restored playas did not differ from control playas in terms of percent cover of bare ground or grass, but that forbs were more prevalent in restored playas. We will further investigate the response of birds and vegetation to levels of human disturbance in the *Floristic Quality and Assessment Project* to be completed in 2009.

Objective 3. Create a comprehensive database integrating remotely-sensed data layers with site visit information and develop a spatial model identifying playas with the high conservation potential that are useful for prioritizing playa wetland conservation in eastern Colorado. Based on the July 2008 meeting with conservation partners, we determined that because stakeholders have different conservation priorities they require different inputs to meet their conservation goals. For instance, a land trust organization such as The Nature Conservancy may prioritize large tracts of native shortgrass prairie with relatively undisturbed playas for conservation, while an NRCS soils conservationist may prioritize farmed playas within their county for restoration. Therefore, we provided important data layers (playa locations, sizes, densities, human impacts) that can be tailored to the specific conservation goals of various stakholders. We presented these data layers, along with a set of conservation recommendations, in two formats. First, we posted an interactive, non-technical pdf document on-line to increase public awareness about playa wetlands, including their values, threats, and conservation opportunities. This document contained most of the map figures from this report and will be posted to the RMBO website (www.rmbo.org) in January 2009. The second way we disseminated the data is in an ESRI ArcGIS 9.x geodatabase, which provided the relevant datasets to conservation partners for use in their own GIS planning environments.

Objective 4. Generate a report that includes a summary of the data, results from the site assessments, recommendations for playa conservation and restoration techniques, and a model depicting playas of the highest conservation value. This report, the pdf product for the public posted to the web, the geodatabase dispersed on CD, and a scientific manuscript (to be submitted to *Wetlands*) together fulfill this objective.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION AND OBJECTIVES

Introduction

Playas are shallow depressional wetlands of the Great Plains that fill periodically from heavy rainfall and associated runoff (Smith 2003). These clay-lined wetlands occur in closed watersheds and are thought to have formed through a collaboration of wind, wave, and dissolution processes (Smith 2003). While the greatest concentration of playas is in the Southern High Plains of Texas, playas are distributed across northern Texas, western Oklahoma, Kansas, Nebraska, and eastern New Mexico and Colorado (Smith 2003). Playa wetlands provide important ecological and societal functions (Haukos and Smith 1994), including water storage during flood events, irrigation water for crops, recharge to the Ogallala aquifer (Zartman 1994, Wood 2000), and water for livestock (Ostercamp and Wood 1987).

The total number of playas in the Great Plains has not been well estimated, but 25,000 - 37,000 have been estimated for the Southern High Plains alone (Smith 2003), and Playa Lakes Joint Venture estimates 60,000 in the Joint Venture region (www.pljv.org). Playas are one of the most numerous wetland types in the region. Ecologically, playas provide vital habitat for a wide variety of wildlife and plant species, including over 185 avian species, 13 amphibian species, 37 mammal species, and 124 aquatic invertebrate species (Haukos and Smith 2003). In addition, playas are recognized to provide a key component of the "stepping stone" habitat mosaic used by shorebirds during migration between the Arctic and South America (Skagen and Knopf 1993, Davis and Smith 1998).

Playas are frequently dry for extended periods of time, typically located in flat to gently rolling landscapes, and often surrounded by agricultural land use. Playas receive surface water inflows only from precipitation events and overland flow, and fill periodically following heavy rainfall events. Due to the sporadic, localized rainfall patterns common to the eastern Colorado plains, most playas characteristically exhibit prolonged wet-dry cycles, which can extend up to 10 years or longer (Smith 2003). These factors combined can make recognition of a playa difficult, which can increase susceptibility to alteration.

Today, playas are primarily found in working landscapes of farm and ranch land, and many have been affected by sedimentation, pit excavation, road construction, urban development, feedlot runoff, livestock grazing, and deliberate filling (Haukos and Smith 1994). In the Great Plains region, where wetlands and rivers have been significantly altered to provide arable farmland and irrigation for crops, playas represent a valuable wetland resource and a conservation opportunity. In some areas, playa distribution and condition has been well-studied (Bolen et al. 1989, Guthery and Bryant 1982, Nelson et al. 1983). However, the status of playas in Colorado was relatively unknown before this study began.

In Colorado, interest in protecting these isolated, temporary wetlands has been strong, particularly by wildlife constituents. Wildlife conservation groups including the U.S. Fish and Wildlife Service (USFWS) Partners for Fish and Wildlife Program, the Colorado Division of Wildlife (CDOW), Playa Lakes Joint Venture (PLJV), Colorado Wetland Partnership's (CWP) Prairie and Wetlands Focus Area (PWFA), and Rocky Mountain Bird

Observatory (RMBO) have begun protecting, enhancing, and restoring playas through voluntary programs. The United States Congress has also demonstrated its commitment to protect and restore this resource by creating the Wetlands Restoration Initiative (CP23a) of the USDA Farm Bill Conservation Reserve Program (USDA 2004). Throughout much of the playa lakes region, CP23a efforts have focused on playa wetlands.

Due to the importance of playas to the people and wildlife of the plains and the threats posed to these wetlands, basic information is needed regarding the distribution and condition of playas in this region. To provide these data to conservation partners, RMBO initiated this study in 2004, which has taken place in several phases.

Study Objectives

The goal of the overall study is to contribute to the scientific understanding of playas within the Shortgrass Prairie Bird Conservation Region 18 in eastern Colorado, using a combined approach of GIS mapping and field surveys. We originally identified four primary objectives:

1. Verify the location and condition of at least 1,000 playas in eastern Colorado; and document the soils, surface hydrology, hydroperiod, surrounding landuse, playa alterations, wildlife habitat quality, and bird use of at least 60 randomly sampled playas.
2. Implement playa conservation programs through cooperative efforts with other non-profit and government agencies and evaluate the effectiveness of various restoration techniques as they relate to hydrology, runoff, sedimentation, wetland quality, and wildlife use.
3. Create a comprehensive database that integrates remotely-sensed data layers with site visit information and apply the data into a spatial model that identifies playas with the highest conservation potential in order to prioritize wetland conservation efforts in eastern Colorado.
4. Generate a report that includes a summary of the data, results from the site assessments, recommendations for playa conservation efforts and restoration techniques, and a model depicting playas of the highest conservation value.

In our most recent update to the Scope of Work for the final phase of this project, we identified two summarizing objectives:

1. Create a comprehensive database that integrates remotely-sensed data layers with site visit information, and application of the data into a spatial model that identifies playas with the highest conservation potential in order to prioritize wetland conservation efforts in eastern Colorado.
2. Generate a report including a summary of the data, results from the site assessments, and baseline data on the effects of playa restoration and/or enhancement; and generate a manuscript for peer-reviewed publication.

In addition to these objectives, this report addresses the following questions that were raised through the course of our study, some of which are of particular interest to other funding partners:

1. How many playas are estimated to exist in eastern Colorado?
2. Do the proportion of playas confirmed (verified) vary according to surrounding landuse?
3. What is the relative effectiveness of each of the three primary data sources in predicting playas within the GIS database?
4. Because some conservation partners, notably NRCS, work at the county scale, what are the known locations, predicted numbers, and known number of playas with conditions that may be restored within each county?
5. Do playa attributes vary spatially in a way that can be used to guide conservation efforts?

This report compiles findings for each of the four original objectives as well as the additional questions. In addition, we provide a conservation model in two modules: an informative, interactive .pdf format report for the general public to be posted on our website (www.rmbo.org) in January 2009; and for our conservation partners an ESRI ArcGIS geodatabase that contains the same spatial data within a GIS environment.

CHAPTER 2. PLAYA ABUNDANCES AND CONDITIONS

The conservation of playa wetlands in eastern Colorado requires knowledge of the abundance and spatial distribution of the resource. However, the abundance, distribution, and general conditions of playa wetlands in eastern Colorado were poorly understood prior to this study. Previous playa studies focused on the Southern High Plains including sites in southeastern Colorado (Guthery and Bryant 1982, Hoagland and Collins 1997, Smith and Haukos 2002, Smith 2003), but did not encompass the extent of the state's playa region. We developed a Geographic Information System (GIS) database depicting the location and size of known and potential playa wetlands. In addition, we conducted field surveys and developed statistical models to estimate the density, abundance, and condition of playa wetlands in eastern Colorado.

The accuracy of the playa locations in our GIS database was assessed by estimating the classification rate from field surveys. Our objective was to compare the confirmation rates of the three primary data sources: National Hydrogrgaphy Dataset (NHD; USGS 2000), the Duck's Unlimited and PLJV interpretation of satellite imagery (LANSAT; DU 2003), and Soil Survey Geographic Database (SSURGO; USDA 1995). We hypothesized the confirmation rate of playa wetlands would vary by the source of thematic data, further predicting the SSURGO data may perform best because these data were field-derived. Further, because the SSURGO data source was compiled at the county level using different soil types (USDA 1995), we predicted that the confirmation rate of this data source would vary by county.

Methods

Study Area

The study area encompassed 113,404 km^2 (43,786 mi^2) of eastern Colorado (102^{o}3'1"-105^{o}16'15"W, 36^{o}59'34"- 41^{o}0'6"N) within the South-central Semi-arid Prairies Ecological Region (CEC 1997, Gauthier and Wilken 1998) and Shortgrass Prairie Bird Conservation Region 18 (US NABCI Committee 2000a, b). This region consisted of flat to gently rolling topography, with occasional canyons and bluffs. The dominant native vegetation was shortgrass prairie composed of blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*) and western wheatgrass (*Pascopyrum smithii*). Livestock grazing and irrigated and dry-land agriculture were the primary land uses. Elevation ranged from 975 m (3,200 ft) to 1800 m (6,000 ft), mean monthly temperature from -12^{o}C (10^{o}F) to 38^{o}C (100^{o}F) and mean annual precipitation from 250 mm (10 in) to 750 mm (30 in).

GIS Database Development

The initial model of potential playa locations was built from a GIS database created by Ducks Unlimited, Inc. (DU) for PLJV in 2003. We utilized three datasets in the PLJV GIS database: (1) DU's satellite imagery (LANDSAT; DU 2003), (2) the U.S. Geological Survey/EPA National Hydrography Database (NHD; USGS 2000), and (3) the Natural Resource Conservation Service's (NRCS) Soils Survey Geographic Database (SSURGO; USDA 1995). The LANDSAT dataset was developed to serve as a catalog of hydrologically functioning playa lakes present during periods of peak precipitation between 1986 and 2000 (DU 2003). The NHD was a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. The NHD layer used in the current model was a subset of *lake/pond* and *playa* features extracted from the larger dataset by DU. SSURGO data were available for 23 counties in our study area (Table 1). These potential playa locations were deliniated by PLJV staff from mapped soil units. The USFWS National Wetlands Inventory data were not utilized because less than 1% of the area in eastern Colorado was available in digital format at the outset of this project.

Table 1. Summary of features extracted in September 2005 as possible playas from SSURGO data, by county.

County	Soil Type Interpreted as Playas	Potential Playas (N)	Playa Acres
Adams	Intermittent Water	160	994
Arapahoe	Intermittent Water	41	447
Baca	Playas	182	1574
Bent	Playas	20	576
Boulder	Playas	9	36
Broomfield	Intermittent Water; Playas	2	9
Cheyenne	Apishapa family, ponded	156	2209
Crowley	Intermittent Water; Playa beaches	75	1222
Denver	Intermittent Water	4	16
Douglas	Intermittent Water	13	53
Elbert	Playas	235	1818
El Paso	Playas	63	597
Kiowa	Playas	187	9195
Kit Carson	Pleasant silty clay loam 0-1%	899	8233
Larimer	Playas	20	199
Lincoln	Apishapa clay loam 0-3% rarely	573	4230
Logan	Intermittent Water	104	859
Phillips	Intermittent Water	235	1688
Prowers	Playas	53	806
Pueblo	Playas	19	470
Sedgwick	Scott silt loam	335	1286
Washington	Pleasant silty clay	852	10072
Weld	Playas	197	2943
Total		4,434	49,532

We made several modifications to the data layers to improve the accuracy of the playa model. From the NHD dataset and DU LANDSAT imagery, we removed features that were identified as a reservoir, saline lake, riparian corridor, stock tank, or well. We also removed features within 150 m of riparian corridors. Because features within riparian zones were probably not hydrologically isolated, these features were not considered to be playas. We also extracted all features that were within 8.5 km of major metropolitan areas (with 1990 populations greater than 50,000) to minimize misclassifications of urban ponds or impoundments. We did not remove features in the SSURGO database identified as *intermittent water* or *playa*, as they were field-derived and therefore expected to be more accurate. The above revisions resulted in the removal of 1,607 features. Beginning in 2008, we used the National Agricultural Inventory Photography (NAIP) July 2005 aerial photography to review several sets of potential playa polygons that we suspected were not playas. We examined: 1) polygons greater than 40 acres (removed 33 of 95 inspected); 2) polygons with area-adjusted perimeter to area ratios greater than 2 (e.g., non-circular shapes; removed 14 of 19 inspected); 3) polygons intersecting suspect PLJV landcover types (reservoirs, lakes, ponds; other waterbodies; reservoirs; exotic riparian shrubland; native riparian shrubland; riparian canopy; wet meadow; stock ponds; floodplain marsh; removed 31 of 94 inspected). In addition, we visually examined the NAIP imagery for all playas that were either field-reported as bisected by a road or that intersected the TIGER road layer (US Census Bureau 2007) in GIS. The above polygons were redrawn to reflect the road impacts using the Editor tool in ArcGIS (ESRI 2005). We then classified each of these polygons as “split” if a playa was split into two wetlands by a road or “clipped,” if the playa was truncated or skirted by the road on one edge but no basin was visible across the road. We drew adjoining polygons for split playas when they were missing, sometimes by splitting the original polygon and sometimes by digitizing a new shape.

When potential playa locations were determined to be other types of water bodies (e.g., reservoir, stock tank, farm pond) either by field-visits or by examination of aerial photography, these polygons were removed from the final playa layer (287 removed in 2008, including those in the preceding paragraph). Similarly, a smaller number of potential locations were determined not to indicate wetlands of any type, indicating upland features instead (e.g., feedlots, farm buildings); these polygons were also removed from the final layer (29). Data regarding these polygons are available upon request.

Playa found in eastern Colorado during roadside field surveys 2004-2007

We incorporated new playas into the GIS database that were discovered during fieldwork and were not captured in any of the SSURGO, NHD, or LANDSAT imagery datasets. The new polygons were drawn by overlaying the triangulated field locations on the NAIP imagery and tracing the playa footprint using the Editor tool in ArcGIS (ESRI 2005). In addition, we incorporated a set of playas delineated by The Nature Conservancy that were field-documented from one of their conservation land holdings (216; 198 of which did not overlap with any other data source and were therefore new in the dataset).

Field Survey Methods

We conducted roadside surveys on playas close to roads across the study area to ground-truth the potential playas predicted by our GIS database. Roadside surveys were designed as a rapid assessment technique, with each survey taking an observer approximately 15 minutes. This methodology allowed us to efficiently determine the accuracy of each source dataset and to document playa locations and conditions. Surveys were conducted between March and November each year. In addition, we visited a subset of playas to sample vegetation and soils; information regarding the condition of these playas is also incorporated as appropriate within this section.

In 2004, we targeted potential playa locations within .05 mi. (80 m) of the road, and in subsequent years we expanded our selection to locations within 0.5 mi. (800 m) of the road, based on our experience that visibility to one half-mile is possible in the generally flat terrain of eastern Colorado. Survey routes were selected to correspond with locations of playas being characterized in other facets of this study, thus maximizing the number of potential playas surveyed each day. Potential playa locations were visited up to three times for verification purposes; for instance, we re-visited many locations where playas could not initially be verified due to dry conditions or cover by crops.

Playa confirmed and surveyed from roadside

For each potential playa location visited, we assigned one of several status categories: playa, possible playa, other waterbody, no access, or no visible playa. For this study, we define a playa as a depressional wetland fed by rainfall and runoff that is hydrologically isolated from other natural water bodies in the landscape, particularly stream beds and creeks (Hutton and Cariveau 2005). 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 water bodies included reservoirs, feedlot ponds, or stock dams within creek drainages. No access indicated that the road was not passable or was private, or for some other reasons the surveyor was not able to view the potential playa location (e.g., a house or windrow obscured their view). No visible 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, possible playa, or other waterbody, we collected the following information using a standardized field form:

- We recorded the Universal Transverse Mercator (UTM) coordinates marked by a handheld Garmin eTrex® Global Positioning System (GPS) unit;
- 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 converting diameter to area (assuming playas were circular) to classify playas into one of the three size classes (<2 ac, 2-12 ac, or >12 ac);
- We documented the relative wetness of playas by classifying the extent of standing water within the playa basin (> or <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 agriculture, USDA Conservation Reserve Program (CRP), and/or grassland;
- We noted any of the following agricultural uses in the playa basin: farmed, grazed, or hayed;
- We noted hydrologic modifications to the playa: pitted/excavated, constructed inlet or outlet, impounded/bermed/terraced, 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; and
- 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.

GIS database Verification

We brought together data derived from multiple field visits and GIS work to a final status field. When playas were visited in multiple field seasons, we used the highest level of confirmation for each playa. For example, if a potential playa was not visible on one occasion but was later verified as a playa it became verified in our database. The categories in the final status field of the playa database were as follows:

- “Confirmed” indicated that a potential playa polygon was field-verified, typically visited by RMBO staff and judged to be present. In rare cases a playa was confirmed by the landowner observing the playa in GIS (n = 5).

- “Highly Probable” was used primarily for locations that appeared like playas in the NAIP imagery but did not receive a field visit to confirm. In addition this was applied to playas contributed by The Nature Conservancy. This was also applied to a small group of playas that were noted as “possible playas” in the field.

- “Probable” was applied to locations predicted by SSURGO (or SSURGO and other data sources) that had not been field-visited or examined in aerial photography.

- “Possible” was applied to locations predicted by LANDSAT (or LANDSAT and NHD) that had not been field-visited or examined in aerial photography.

- "Low Potential" was applied to locations in the dataset predicted by NHD that had not been field-visited or examined in aerial photography; OR locations predicted by source which RMBO staff determined to be "no visible playa" during one or more field visits.

In addition, we re-classified visited playas that had been called "not visible" but which were greater than 400 m of the road to "no access" because of uncertainty in the ability to view areas at that distance from the road.

The accuracy of the playa locations in the PLJV GIS database (PLJV 2006) was assessed by estimating the confirmation rate, or the proportion of field-visited playas that were confirmed to be playas. Our main objective was to compare the confirmation rates of the primary data sources (NHD, LANDSAT, SSURGO), landcover types (grassland, farmland, CRP) and counties in the study area. A second objective was to investigate the confirmation rates for the different soil types in the SSURGO database by county. We selected the visited playa locations within 400 m of the road and discarded the playas with uncertain classification. The sample size for the classification analysis consisted of 997 potential playa locations within 19 counties. We represented playa confirmation as a binary variable with verified playas coded by 1, and unverified playa locations and other waterbodies coded as 0. Confirmation rate was modeled as a function of data source, landcover type, and county using a generalized linear model (Nelder and Wedderburn 1972) with the binomial distribution and logit link function (PROC GENMOD, SAS Institute 2008). In addition to the covariates listed above, we modeled confirmation rate as a function of playa area (ha) and distance to road (m) as these variables were expected to influence the estimation of the confirmation rate. A non-linear threshold relationship between confirmation rate and playa area was investigated by the $\log_e$ transformation of playa area.

The statistical models for data source and county were assembled using the ANOVA parameterization with source term followed by the 'county nested in source' term (county[source]). We also presented the results with the reverse parameterization to estimate confirmation rate by county. We used information-theoretic model selection (Burnham and Anderson 2002) to evaluate the predictive ability for models including all subsets of the predictor variables (source, county, county[source], landcover, playa area, road distance). 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 and evidence ratios were used as strength of evidence for the competing models (Burnham and Anderson 2002). We evaluated the fit of the selected model using the deviance goodness-of-fit test. The mean confirmation rates were estimated using the logit transformation of the least squares means (SAS Institute 2008) and the and standard errors were estimated using the delta method (Powell 2007). We conducted post-hoc tests for pairwise differences of the least squares means using sequential Bonferroni correction (Rice 1989). Only effects with statistical significance at the Bonferroni corrected level within each comparison group were reported (Appendix B).

Conditional Assessment

We report the proportion of playas visited that were modified hydrologically, in agricultural production, or impacted by roads. These measures of human impact may be used to estimate conditions of playas. We also report the surface hydrology of all playa surveys to describe the proportion of playas that were wet during our study. To describe hydroperiod lengths, we examined playas that became wet from rainfall in August 2006. We estimated the hydrology period for the dry sites by first calculating the midpoint of the date between the second-to-last survey and the last, and then subtracting the date of the first survey from this quantity. We excluded one site because there was a substantial gap in the time between surveys (25 days instead of 7 or 8 days). For playas that remained wet until the end of the migration season (October 31) and were sampled at least four times, we used the number of days between the first and last surveys (sampling period) to represent minimum hydroperiods.

Estimation of Playa Abundance

We overlaid the study area with a 6.44 x 6.44 km (41.4 km^2, 16.0 mi^2) sampling grid using ArcGIS (ESRI 2005). To arrive at the sampling frame, we overlaid the sampling grid with the boundaries of major metropolitan areas along the Front Range in ArcGIS (ESRI 2005). Of the 2,596 grid cells, 132 intersected the metropolitan areas and were removed from the sampling frame. A random sample of 130 grid cells were selected from the sampling frame of 2462 cells resulting in a sampling fraction of 5.2% (Figure 1). Within each grid cell, roadside surveys were conducted during 2004-2006 to discover new playas and verify the location of playas existing in the RMBO digital map. We drew the newly encountered playas into the digital map using the Editor tool and converted the polygons into point data using the Feature to Point tool in ArcGIS (ESRI 2005). The survey effort in each grid cell was quantified by measuring the length of road traveled (m) using the TIGER road layer (US Census Bureau 2007) and the Sum Length of Lines in Polygons tool, Hawths Tools extension (ArcGIS, ESRI 2005). We calculated distance (m) from the road to the center of each playa encountered using the Near proximity tool (ArcGIS, ESRI 2005). A total of 210 playas were encountered within the 130 randomly sampled grid cells. For the purpose of estimating playa numbers, we considered entire playa polygons not divided by roads (i.e., we used the polygons prior to splitting them across roads).

We estimated the density and abundance of playas in eastern Colorado using program DISTANCE (Thomas et al. 2006). This analysis used playa detections along roads in much the same way as observations along line transects are used in the typical DISTANCE sampling design. Because there was a long tail in the distribution of playa detections, we truncated the data at the recommended 15% of the data (Buckland et al. 2001), which corresponded to a maximum detection distance of 350 m. We binned the detections into one 100m and five 50m distance intervals to improve the fit of the detection function. The detection of playas was thought to be related to playa size. Therefore, when estimating overall playa density and abundance, we evaluated detection models post-stratified according to small (0.02 - 1.0 ac), intermediate (1.0 - 3.7 ac) and large (3.7 - 73.0 ac) playas. In addition, we estimated playa density and abundance by county using a global detection function, and estimated the variance assuming the counts followed a Poisson distribution. We considered the four robust detection models recommended for line transect data: uniform - cosine; uniform - simple polynomial; half-normal - hermite polynomial; and hazard-rate - cosine (Buckland et al. 2001). The models were ranked according to AICc, and the strength of evidence for the models was quantified using AICc weights and evidence ratios (Burnham and Anderson 2002). We used the highest ranking model for estimation when the ΔAICc of the competing models was >2 and used model averaged estimates when the ΔAICc of the competing models was <2. The chi-square goodness-of-fit test was used to evaluate the fit of the detection models (Buckland et al. 2001).

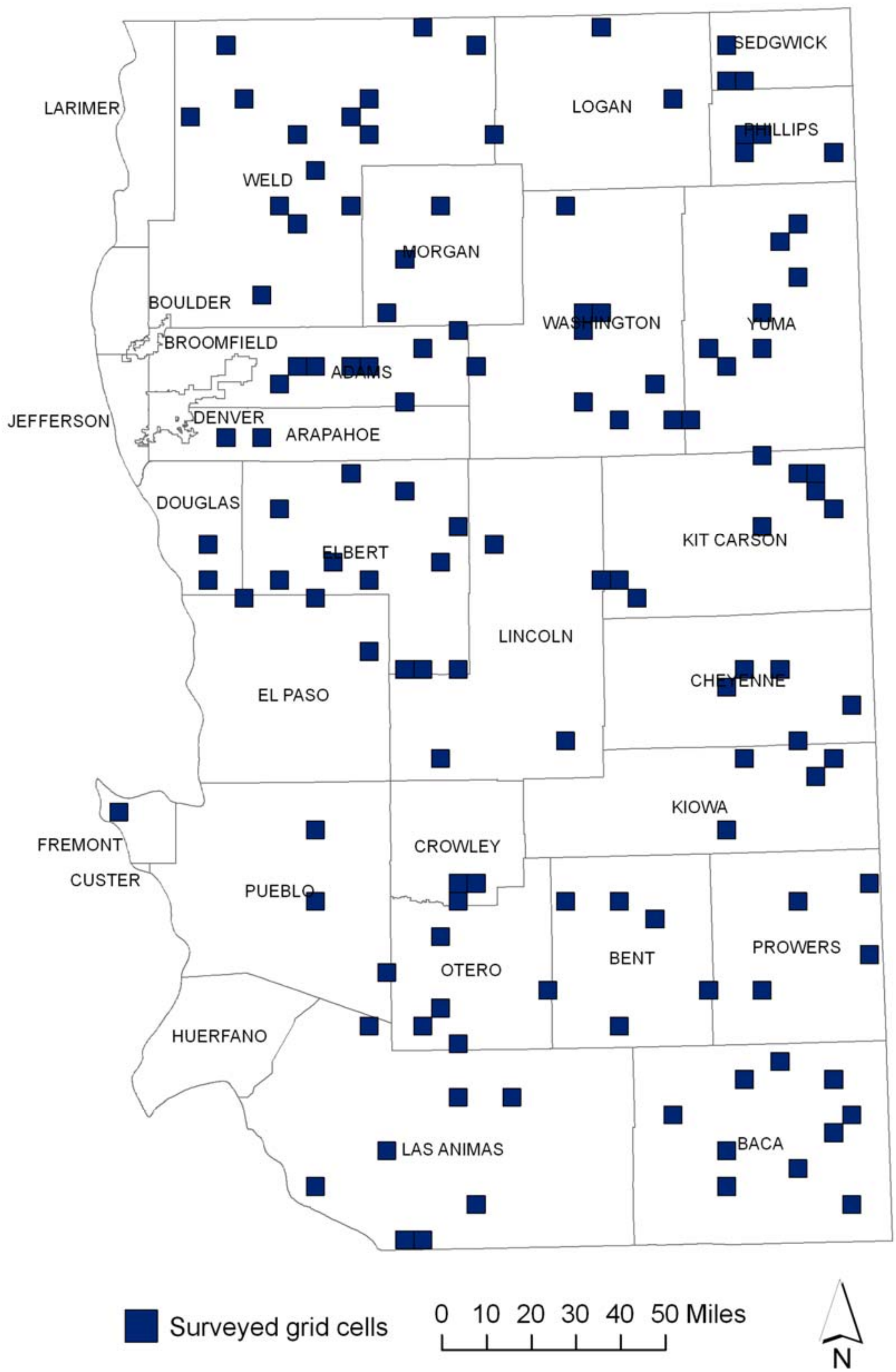


Figure 1. The randomly selected grid cells that were field surveyed and used to estimate playa density and abundance in the BCR18 region of eastern Colorado.

Results

GIS database Verification

With the incorporation of all revisions to the GIS database of playa locations, the dataset now indicates 8,347 potential playa locations (see Figure 2) in 27 counties.

During 2004-2007, we attempted to visit 1,529 potential playa locations predicted by our GIS database. Three hundred locations were not accessible. Of 1,239 locations we visited, we determined that 63% were playas, 14% were not playas (e.g., other water body types or not water bodies), and 23% could not be verified as playas but would need further examination to determine their status (please see Table 2). In addition, we discovered 462 previously unmapped playas during the course of the study, bringing the total of surveyed playas to 1,237.

Table 2. Verification of potential playa locations in the GIS database.

	Final Status				
Field Status	verified	probable	potential	low potential	not a playa
playa	775	1			3
possible playa		61	2	1	
no playa visible		17		198	17
other waterbodies					154
Total	775	79	2	199	174
Proportion of Total	0.63	0.06	0.00	0.16	0.14

The highest ranking model for the effects of data source on confirmation rate was the full model including all of the covariates: data source; county nested within source; landcover type; playa size; and distance from road (see Appendix B, Table B-1). This model fit the data well (X^2_{767} =771.33, *P* = 0.450) and was 3.7 times more probable than the next best model (Appendix B, Table B-1).

While taking into account the other factors, SSURGO soils was the single most effective data source in predicting playa locations, with 77% of the playas confirmed (Table 3). The LANDSAT and NHD data sources performed poorly, with only 55% and 34% of predicted playas confirmed, respectively (Table 3). The confirmation rate of the SSURGO data source was considerably greater than the NHD (X^2_1 = 19.90, *P* < 0.001) and LANDSAT (X^2_1 = 10.67, *P* = 0.001) data sources, with no strong difference between the NHD and LANDSAT data sources (X^2_1 = 3.74, *P* = 0.053). When potential playa locations were predicted by LANDSAT or NHD as well as SSURGO, then confirmation rates were considerably improved to 89% (X^2_1 = 21.16, *P* < 0.001) and 90% (X^2_1 = 16.39, *P* < 0.001), respectively (Table 3; Appendix B, Table B-3).

Playas were also confirmed at different rates among the landcover types, with the greatest rate confirmed in grassland (84%), followed by CRP (74%), which was in turn followed by cropland (66%; Table 3). There was a considerable difference between the confirmation rate of grassland and cropland (X^2_1 = 12.49, *P* < 0.001), with no measurable differences between the other landcover types. In addition, the confirmation rate of the counties varied within each of the data source (Appendix B; Table 4-B).

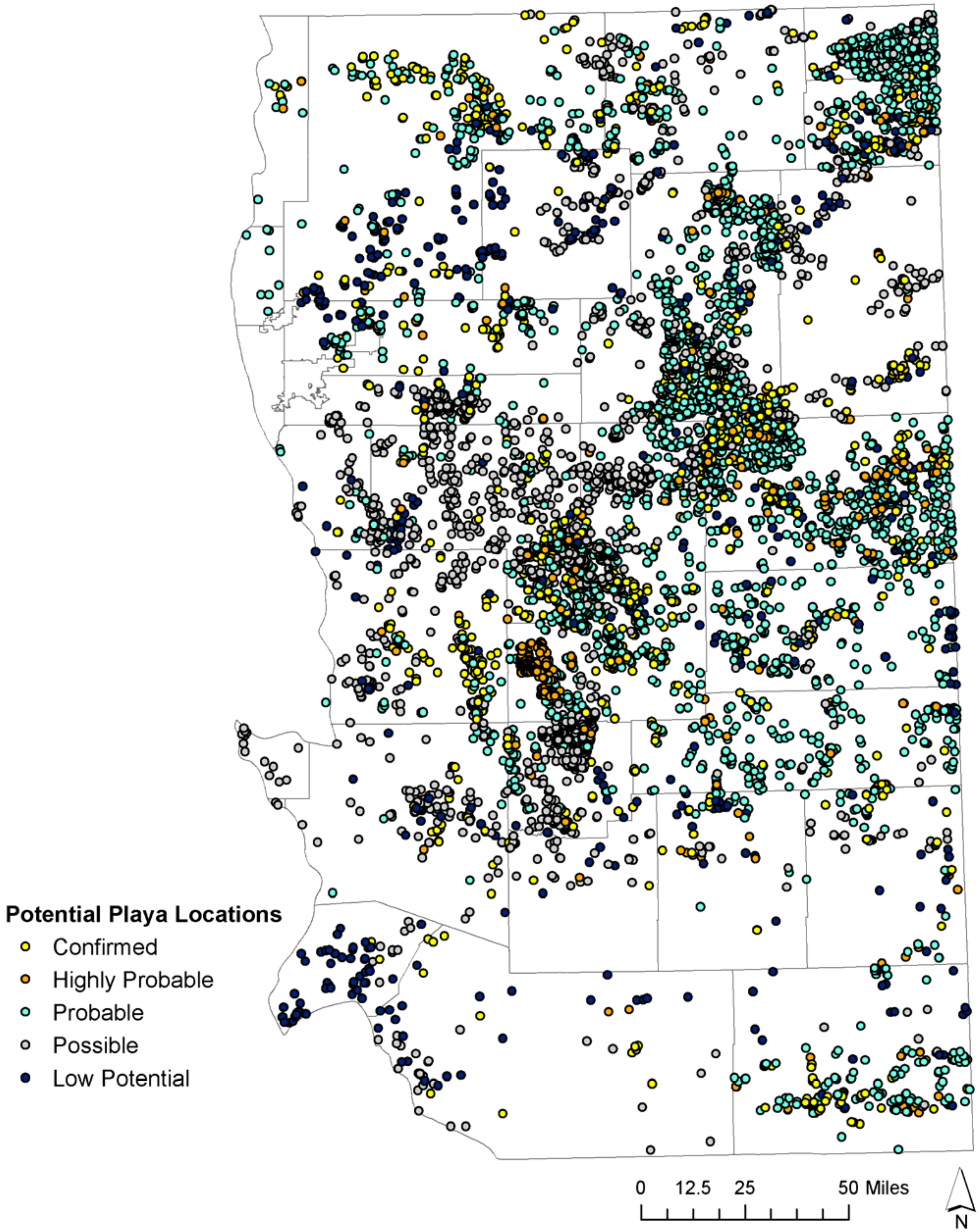


Figure 2. All potential playa locations in RMBO GIS database of BCR 18 in Colorado, December

The confirmation rates of the playas were positively related to the $\log_e$ of playa area (ha; $\beta = 0.264$; SE = 0.121) and negatively related to distance from the road (m; $\beta = -0.002$; SE = 0.001). The relationship between confirmation rate and playa area showed a positive curvilinear relationship where confirmation rate increased sharply up to approximately 5 ha and then reached a plateau in confirmation rate of approx. 65% thereafter (not shown).

Table 3. Estimated playa confirmation rates and standard errors by data source, landcover type, and county.

Parameter	Estimate	Standard Error
Data Source		
LANDSAT	0.549	0.0648
NHD	0.342	0.0870
SOILS	0.766	0.0364
LANDSAT/SOILS	0.891	0.0342
NHD/SOILS	0.905	0.0537
LANDSAT/NHD/SOILS	0.841	0.0763
Landcover		
CRP	0.742	0.0671
Cropland	0.663	0.0420
Grassland	0.837	0.0357
County		
Adams	0.317	0.1256
Arapahoe	0.769	0.0881
Baca	0.545	0.0863
Bent	0.305	0.1553
Crowley	0.681	0.1374
El Paso	0.865	0.0904
Elbert	0.750	0.0712
Kiowa	0.731	0.1413
Kit Carson	0.850	0.0450
Lincoln	0.959	0.0288
Logan	0.605	0.2027
Morgan	0.418	0.1825
Otero	0.235	0.2087
Phillips	0.667	0.1337
Prowers	0.447	0.1107
Pueblo	0.394	0.1058
Washington	0.791	0.0531
Weld	0.498	0.0815
Yuma	0.817	0.0682

Mean playa confirmation rates varied among counties, while accounting for all other factors (Table 3; and see Appendix B, Table B-3 for pair-wise comparisons). For instance, confirmation rates ranged from less than 40% in Bent, Otero, and Pueblo counties to over 80% in El Paso, Kit Carson, Lincoln, and Yuma counties (Table 3). In addition, data sources within some counties differed in their ability to correctly predict playas (Appendix B, Table B-5).

The best model of the SSURGO data types on confirmation rate included the effects of soil type, county nested within soil type, landcover type, and distance to road (see

Appendix B, Table B-1). This model fit the data very well (X^2_{616} = 557.26, *P* = 0.956) and was 2.2 times more probable than the next best model (Appendix B, Table B-1). After accounting for the other factors, the Apishapa soil series exhibited higher confirmation rates than the "playa" (X^2_1 = 7.05, *P* = 0.008) and "intermittent water" (X^2_1 = 8.69, *P* = 0.003) categories (Table 4). The confirmation rates of the other SSURGO data types were not appreciably different. Nevertheless, there were considerable differences between the playa confirmation rates for counties nested within the different soil types (Table 4 and Appendix B, Table B-7). As in the analysis of the primary data sources, the SSURGO data showed differences in the confirmation rate of playas in grassland and cropland (X^2_1 = 23.49, *P* < 0.001) as well as declining confirmation rate with increasing distance from the road (m; β = -0.002; SE = 0.001). In contrast, there was little evidence that playa size affected the confirmation rate of the SSURGO data sources (Appendix B, Table B-6).

Table 4. Modeled confirmation rates of playas predicted by SSURGO, by soil type and county within soil type.

Parameter	*County*	*Estimate*	*SE*
Apishapa family		0.984	0.0161
Intermittent Water		0.725	0.0692
Playa		0.796	0.0376
Pleasant family		0.860	0.0262
Apishapa family	Lincoln	0.984	0.0161
Intermittent Water	Adams	0.580	0.0856
Intermittent Water	Arapahoe	0.836	0.0823
Intermittent Water	Crowley	0.779	0.2090
Intermittent Water	Logan	0.796	0.1383
Intermittent Water	Phillips	0.569	0.0847
Playa	Baca	0.600	0.0825
Playa	El Paso	0.904	0.0672
Playa	Elbert	0.904	0.0345
Playa	Kiowa	0.835	0.0838
Playa	Prowers	0.635	0.1301
Playa	Weld	0.753	0.0818
Pleasant family	Kit Carson	0.934	0.0206
Pleasant family	Washington	0.727	0.0440

Conditional Assessment

The majority of playas surveyed were found in grassland (Figure 3; n = 1,087 with complete data). Forty-five percent were reported as grazed, 30% plowed, and 1% hayed. Thirteen percent of the playas we observed had evidence of deliberate hydrological modification. Pitting was the most common hydrological modification we observed (n = 95; 9%), followed by impoundment or berms (n = 72; 7%). We noted constricted inlets or outlets at fifteen playas and wells for six playas. Four percent of all playas were noted as having two or three hydrological modifications; the others only had one modification each.

Roads impacted 21% of the playas in our final model. If we report the proportion of whole playas impacted by roads (rather than the number after splitting those bisected by roads), 15% of playas were affected by roads. Most were bisected by roads (9%), with five percent affected by roads just clipping their edges.

Combining information regarding land use and other hydrological modifications, we found that 34% of playas were in native grassland without hydrological modifications or road impacts.

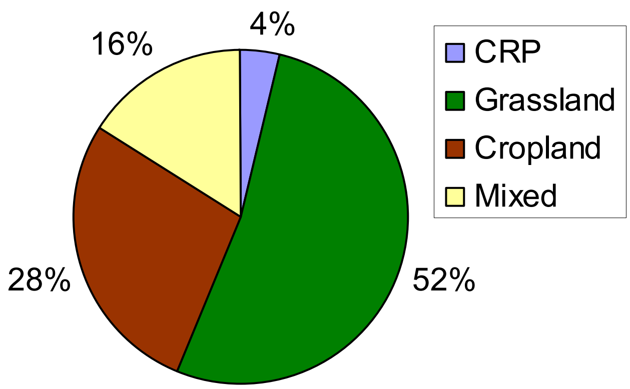


Figure 3. Dominant land uses reported for surveyed playas in eastern Colorado, 2004-2007.

The hydrological conditions we encountered were dry 45% of the time, less than half full of water 23% of the time, and more than half flooded 32% of the time (n = 2,027 surveys reporting surface hydrology). Focusing on the wet playas observed during the fall of 2006, the average hydroperiod was 31.5 days (SE = 3.13; n = 11 that went dry). The average minimum hydroperiod estimated for another 82 playas that stayed wet throughout the season was 40.9 days (± 1.12 SE).

Playa Sizes

The average mapped size of all playas verified in our GIS database was 6.68 +/- 0.32 (2.70 +/- 0.13 ha). The distribution of playa sizes is highly skewed, with smaller playas more common than large ones (see Figure 4). Fifty-seven percent of verified playas are less than five ac in size; 30% are less than 2 ac, 15% less than 1 ac, and 6% are less than 0.5 ac. The maximum size reported for a verified playa was 192 ac (78 ha); only one other playa exceeded 100 ac (166 ac; 67 ha).

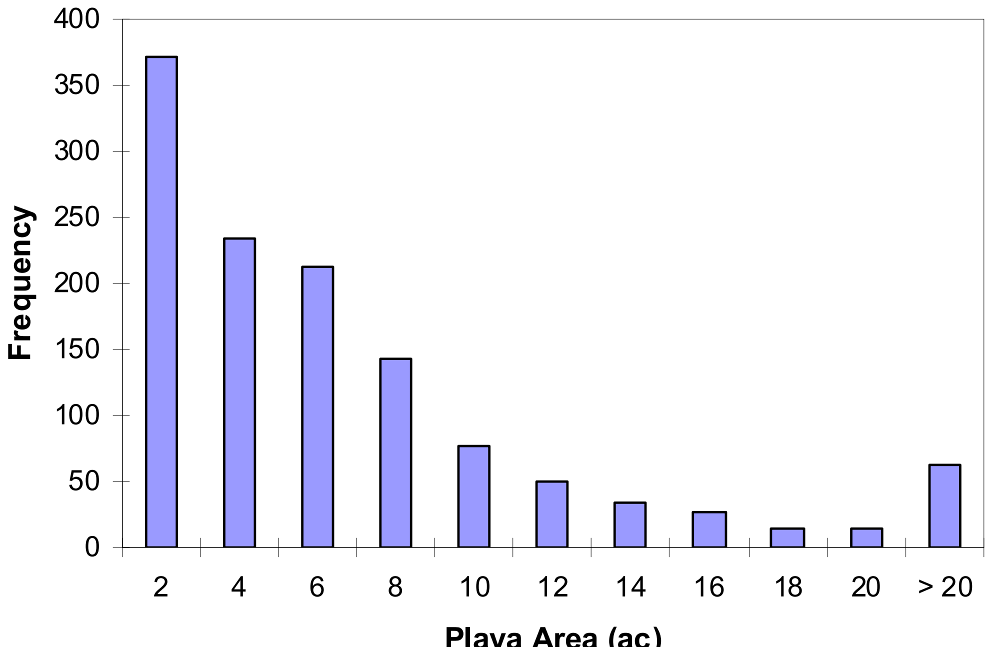


Figure 4. Histogram indicating the frequency of playas in various size classes. The values on the x-axis represent the maximum for the size class (e.g., 2 indicates playas 0-2 ac in size).

Playa Density and Abundance

The highest ranking detection model for the estimation of playa density and abundance was the uniform - simple polynomial model post-stratified by playa size. This model was 2.8 times more probable than the next best model (ΔAICc = 2.04). The detection functions stratified by small (X_4^2 = 2.23, *P* = 0.526), intermediate (X_4^2 = 4.81, *P* = 0.307), and large (X_4^2 = 2.90, *P* = 0.575) playas demonstrated a good fit to the data. The detection probabilities of small (*p* = 0.47, SE = 0.019) and intermediate (*p* = 0.51, SE = 0.026) playas were considerably less than the detection probability of large (*p* = 0.83, SE = 0.086) playas.

The estimated average density of playas mi^{-2} from the best approximating model was 0.46 (SE = 0.052; 95% CI = 0.37, 0.58). Projected across the study area, this yielded an estimate of 18,178 (SE = 2,036) playas in the BCR 18 of Colorado, with a 95% confidence interval of 14,597 – 22,636 playas. The density estimate for playas mi^{-2} greater than 1 acre was 0.28 (SE = 0.042; 95% CI = 0.21, 0.38). Accordingly, the projected abundance of playas >1 acre in eastern Colorado was 11,167 (SE = 1,654; 95% CI = 8,357, 14,922). This result indicates the overall estimate of playa abundance in eastern Colorado included a large number of small playas (approx. 7,000) less than 1 acre in size. As for the estimation of playa density and abundance by county, the highest ranking detection model was the uniform - cosine model. This detection model fit the data (X^2_4 = 4.62, *P* = 0.328). However, because ΔAICc for the half-normal - hermite polynomial and uniform - simple polynomial models were <1.8, we used model averaging to estimate playa density and abundance by county (Appendix B, Table B-8). No playas were detetected in the sampling grids for Otero (*n* = 5) and Prowers (*n* = 4) counties, indicating low playa densities in these counties. For counties where playas were detected, Adams, Baca and Las Animas counties showed mean playa densities mi^{-2} less than 0.2, whereas Crowley, Elbert and Pueblo counties exhibited mean playa densities mi^{-2} greater than 0.9 (Appendix B, Table B-8). Athough the density estimates by county utilized detection data for the entire State, low sample sizes in the counties resulted in relatively uncertain density estimates and poor precision at the county level (Appendix B, Table B-8).

Discussion

Our random sample of playas within the study area provided the first empirical estimate of playa density and abundance within the BCR 18 of Colorado. Because our estimates were based on surveys from roads, these numbers could be biased if playas were non-randomly distributed with regard to roads. The estimates could be biased low if roadways were designed to avoid high playa concentrations. On the other hand, the estimates could be biased high, if playas were counted twice each time a playa was bisected by a road. However, when playas were bisected by the road, we avoided overestimation by treating these playas as intact (non-bisected) in our analysis. The assumption that playas are randomly distributed with respect to roads is likely to be met in highly roaded areas with the systematic placement of roads along section boundaries. Including all sizes of playas, our model estimated a range of approximately 14,000 – 23,000 playas within the study area. These numbers are two to three times the number occurring within the GIS database, and far exceed any previous estimates of playa numbers in this region. To provide estimates consistent with other studies across the region, we estimated the number of playas greater than one acre in size to be between 8,000 and 15,000. Until recently, few playas were thought to exist outside of the Southern Great Plains (centered on the panhandle of Texas), and previous studies included only the most southeast portion of Colorado within their range (Smith 2003). For instance, one study estimated only 198 playas for Colorado (Guthery et al. 1981 in Smith 2003). Estimates of the number of playas in the Southern Great Plains averaged around 25,000 (e.g., Curtis and Beierman 1980, Guthery and Bryant 1982, and Ostercamp and Wood 1987 in Smith 2003). The number of playas north of the Southern Great Plains in Kansas, Colorado, and Nebraska was previously unknown (Smith 2003), although the PLJV now estimates more than 60,000 rangewide (http:\\www.pljv.org). This study therefore contributes much to knowledge of the abundance and distribution of this wetland resource.

This study also improved our understanding of the functioning of playa wetlands in eastern Colorado. Playas in Colorado average smaller than the 6.3 ha (15.6 acres) estimated for the playas of the Southern High Plains (Guthery and Bryant 1982). This may have implications for hydroperiod, as smaller playas typically pond water for shorter durations than larger playas (Smith and Haukos 2002; Howard et al. 2003). Indeed, nearly half of our playa visits were to dry playas, underscoring the ephemeral nature of this wetland type. In a recent study of Texas playas, 58% were found to hold water at least 75% of the year, while an additional 36% held water between 25-50% of the time, based on interpretation of year-round satellite imagery from 1985-2000 (Howard et al. 2003). While we do not have an equivalent dataset regarding Colorado playa hydroperiods, it seems that at least in the years of this study, playas in Colorado are on average drier than their Texas counterparts. This may be due to regional differences in rainfall patterns or greater inputs from irrigation tail water in Texas (Smith 2003). However, we also observed a fall migration season in which many of the playas held water for at least 40 days, after which we stopped monitoring for the winter. Our study has underscored how the episodic nature of rainfall in this region drives the hydrological function of playas. However, a more in-depth analysis of the hydrologic function of playas in Colorado is still warranted. In particular, how often do playas (of particular size and soil type) become inundated, how much rain or how heavy of a rain event is required to fill them, and how long do playas in this area typically pond water at different times of years are outstanding questions. In addition, conservation partners would benefit by knowing what proportion of playas in eastern Colorado should be expected to be wet each spring,

Playa in grassland

summer, or fall, and if those numbers are expected to change in the context of global climate change. In contrast to other regions where playas are mostly in cropland (e.g., 75% for the Southern High Plains; Nelson et al. 1983), the majority of field visited playas in the Colorado database are within native shortgrass prairie. Moreover, only 30% of the playas surveyed in Colorado were being farmed. In contrast, 46% of the playas in the Southern High Plains have more than 25% of the basin disked or cultivated (Guthery and Bryant 1982). Although the opportunistic survey of playa conditions prevented a quantitative comparison of landcover types, the occurrence of playas in different landcover types has several important implications.

First, grassland playas are less susceptible to sedimentation from farming practices, which is believed to be the single greatest threat to the persistence of playa wetlands (Luo et al. 1997; Smith 2003). Indeed, sedimentation had destroyed the entire wetland volume for 18 of 20 playas in cropland in Texas, and cropland playas contained over 8 times as much sediment as grassland playas (Luo et al. 1997). However, rangeland playas were not entirely free of sedimentation effects; sedimentation rates exceeded the natural deepening of these playas, which the authors indicated may have been due to cultivation elsewhere in the watershed (Luo et al 1997). Sedimentation may directly impact the existence of the playa, shorten the hydroperiod, increase evaporation rates, increase infiltration rates, alter plant communities, and negatively impact wildlife utilization (Luo et al. 1997).

Secondly, playas surrounded by native prairie have high conservation values as they best represent the condition of playas prior to the conversion of the landscape to agricultural production. While livestock grazing may or may not create conditions that differ from prehistoric conditions, it is likely that these playas function more similarly to a reference state than playas surrounded by farmland. We also studied a number of playas that were participating in grazing management programs (see Chapter 6), which afford an opportunity to observe the effects of different grazing regimes. We found greater plant species richness in playas in grassland as compared to cropland playas (Chapter 3) and greater use of grassland playas than cropland playas by landbirds (Chapter 5). We are further exploring the relationship of human disturbance to the quality of playas as measured by use by migratory waterbirds and by floristic quality in our sequel project *Floristic Quality and Wildlife Assessment of Playas in Eastern Colorado*, which will be completed in 2009.

We also found lower rates of deliberate hydrological manipulations on the playas of Colorado in comparison to playas elsewhere. In Colorado, pits were the most prevalent manipulation, affecting 9% of playas surveyed; these pits were mostly designed to impound water in grazing lands. This is much lower than the estimated 69% of playas

Pitted playa

greater than 4 ha that had been modified by pits within the Southern High Plains, where pits are usually employed to collect irrigation tail water (Guthery and Bryant 1982). However, our records of hydrologic modifications should be considered minimal estimates because they are based on opportunistic, roadside surveys. Nevertheless, pits can have detrimental impacts on habitat conditions for wildlife primarily by shortening hydroperiods and deepening water. In a study comparing excavated playas to unmodified playas in Texas, waterfowl use and insect abundance and diversity were reduced in the excavated playas (Rhodes and Garcia 1981). In addition, models of shorebird use of playas in southwestern Nebraska indicate higher shorebird use of playas without pits (RMBO, unpublished data).

Prior to this study, we had little information regarding the time a playa remains inundated following a major rain event. In September 2006, after a prolonged dry period, playas filled by rainfall held water for over 40 days. Some playas were still holding water in 50 days after inundation. Our work over three years suggests that rainfall patterns are highly variable in this region, but that a large enough rainfall event can provide substantial quantities of wetland habitat even following drought. It should be noted that although we sampled nearly equal ratios of wet to dry playas, dry playas were much more common. Indeed, we tracked daily rainfall and designed a specific sampling approach in order to obtain samples from wet playas.

This study has substantially improved the GIS database of potential playa locations currently available for eastern Colorado, including 1,237 field-verified playas and an additional 6,809 for investigation. In addition, our analyses of playa confirmation rates by various data sources further guides conservation partners into understanding the relative accuracy of the various data sources. Playas predicted by SSURGO soils data were most likely to be confirmed, and this was by far the most reliable data source. The confirmation rate of the SSURGO data was not influenced by playa size, suggesting that playa detection was less problematic for this data source. In addition, we found strong regional variation in confirmation rates among counties. We expected confirmation rates to vary among counties within the SSURGO dataset because counties assembled their soils maps independently, but we also found variation among counties within other data sources. Indeed, we confirmed over 90% of playas in several counties, while fewer than 30% were confirmed in several other counties. Confirmation rates were affected by playa sizes, distances from the road, and the landcover in which the playas were found. Greater confirmation rates were found for playas within grassland than for playas within cropland. This could represent a difference in the ability to detect playas among land cover types, or an underlying difference of the playa confirmation rate within each landcover type. However, after accounting for the low confirmation of small playas, the effect of landcover on confirmation rate was still apparent. The low confirmation rate in cropland in comparison with grassland may reflect the loss of playa functioning within agricultural landscapes, but this requires further research. Nevertheless when modeling confirmation rates with playa size and land cover as covariates, we still found substantial differences in confirmation among data sources and counties. Our findings can provide a baseline for further investigation into what factors differ among these counties, and for distinguishing among low detection rates versus losses of playas from those counties. This is important because if losses are high in some counties, then conservation programs could be directed at those areas and resource concerns.

The differences in numbers from the 8,347 contained in our GIS database and the estimated 14,597 – 22,636 predicted by our playa abundance analysis suggest that additional work in locating unmapped playas in eastern Colorado would be quite profitable. Due to the relative effectiveness of SSURGO data in predicting playas, further mapping of potential playa locations should be considered by soils analyses. In addition, implementation of digital National Wetlands Inventory data would likely greatly improve the model of potential playa locations, as this data source performed well in predicting playas in southwestern Nebraska (RMBO, unpublished data).

CHAPTER 3. VEGETATION OF PLAYAS

Sampling vegetation at a Colorado playa

Floristic information is a primary component in the ecological understanding of playa wetlands. Well-described in the Southern High Plains region (e.g., Haukos and Smith 1997), the flora of Colorado playas were less well studied. To describe the vegetative characteristics of Colorado playas, we sampled plants at a subset of playas within Colorado. Initially we pursued a random selection of locations generated by our GIS database. As playas became recognized within the conservation community, we then incorporated all restored playas into the project. We collected vegetation data for all playas enrolled in conservation programs, as well as for nearby comparison playas not receiving the conservation measures. This chapter summarizes the vegetation data from all playas surveyed from 2004-2007. Further floristic information will be made available in the Final Report on the *Floristic Quality Assessment* project in the summer of 2009.

Methods

Site Selection

The playas represented by vegetation information were selected in several ways, resulting in an opportunistic sample dispersed across the study area (n = 116 playas; Figure 5). In 2004 we generated a list of randomly selected playas to receive vegetation monitoring, stratified in GIS by landuse and size. We sampled 16 playas as we attempted to achieve an even-sized sample number for playas of each size and land use category. Due to the difficulty in acquiring permission to private land and in order to increase our sample sizes, we sampled an additional five playas that were non-randomly selected. In 2005, we revisited the 16 randomly selected playas from the previous year and selected five more through the stratified random selection process. In 2006, we added an additional 24 randomly selected playas as well as playas enrolling in conservation programs for a total of 59 sampled. In 2007, we collected vegetation data for playas that had been restored or were planned for restoration, playas designated as their controls (nearby, same landcover, with the same disturbances pre-restoration), and playas selected for part of the *Floristic Quality Assessment* (FQA) study (total n = 75). Here we summarize findings based on all playas surveyed from 2004-2007. Comparisons of vegetation in restored versus control playas are presented in Chapter 6. We surveyed each playa once per year except for 24 playas that were part of the FQA study, which were sampled twice each in 2007; for these we present the averages derived from the two 2007 surveys in this report. All playas were surveyed when dry.

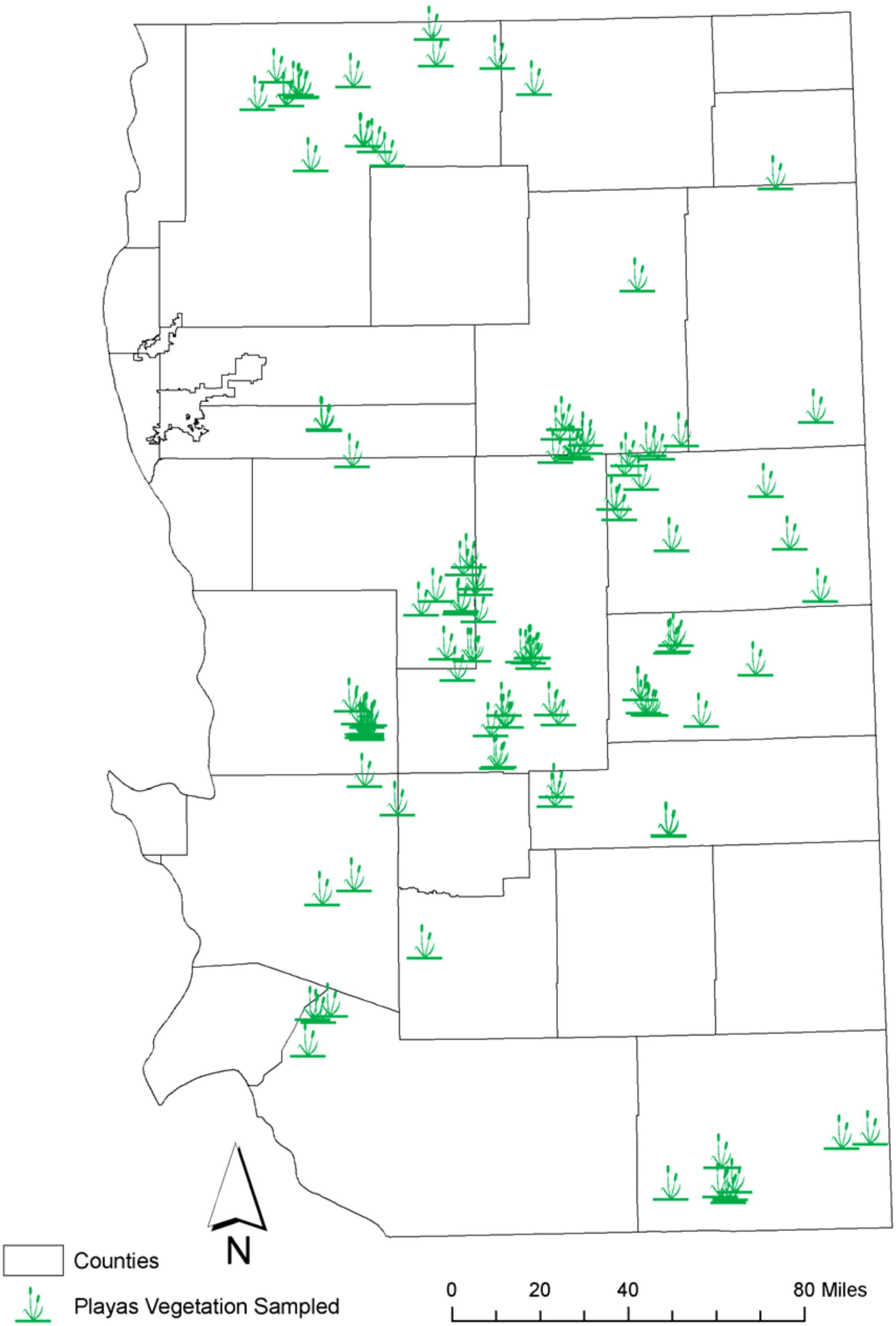
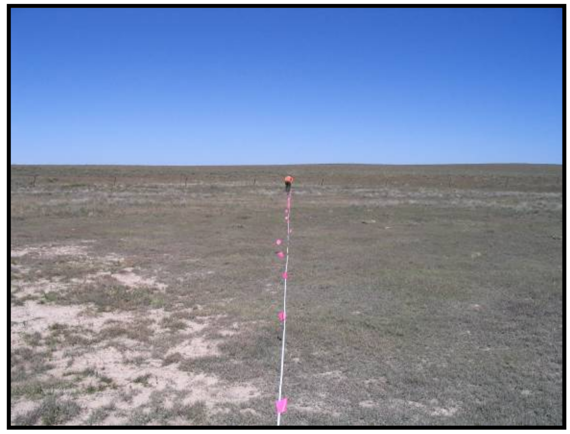


Figure 5. Playas in eastern Colorado where we sampled vegetation 2004-2007.

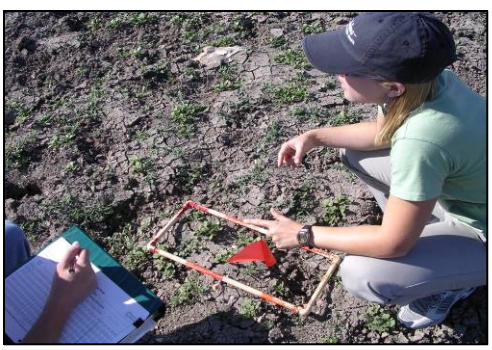
Field Sampling

We marked the playa center and established two transects originating from that point, the first extending along the longest axis of the playa and the second perpendicular to the first. For each transect, we measured the distance from the playa's center to the observable upland interface (Flowers 1996, Rivers 2003). This distance was divided by 20 to determine the spacing distance between 20 transect sample points. This method standardized the sampling effort among playas of different sizes. Another five sample points for each transect line were in upland vegetation.



Transect for sampling vegetation

To characterize vegetation, we used a 25 x 50 cm plot or Daubenmire frame (Daubenmire 1959). This frame was positioned at each of the 20 sample points, with the longer side parallel to the transect line. Plots were placed on alternating sides of the transect line to improve the probability of adequately sampling. Within each quadrat we estimated cover by plant species as well as five other cover types: bare ground, water, litter or duff. Percent canopy cover was recorded as one of six cover classes: 1=0–5%, 2=5–25%, 3=25–50%, 4=50–75%, 5=75–95%, 6=95–100% (Daubenmire 1959). Plant height was recorded using a meter stick. The plant that had the greatest height within each quadrant was measured to the nearest 0.5 cm. After completing 20 plot measurements, we surveyed the entire playa area in search of plant species that could have been missed within the quadrats. This additional survey allowed for a more complete plant list for each playa.



Daubenmire frame for vegetation sampling

Identification of Field Specimens

If a plant species was not definitively identified in the field, a specimen was collected for subsequent identification. In 2007, a specimen of every plant on every playa was collected. All plant specimens from 2007 were identified by personnel from the Denver Botanic Gardens (Donald Hazlett) and voucher specimens for the quality specimens are archived at the Kathern Kalmbach herbarium in Denver. The plant nomenclature used for plant species is follows the online University of Colorado (Boulder) checklist.

Analyses

Using the USDA PLANTS database (http://plants.usda.gov/) we categorized each plant species according to wetland indicator status (obligate wetland, facultative wetland, facultative, facultative upland, 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). Here we highlight obligate wetland plants (99% probability of occurring in wetlands), facultative wetland plants (67-99% likely to occur in wetlands), and facultative plants (34-66% likely to occur in wetlands). First we included all plants with these statuses on either the national or Region 5 list, then we removed those that were classified as FACU on the Region 5 list. If available, we used the USDA Region 5 indicator status rather than the national status. We also used the USDA PLANTS Database to assign each plant to a lifeform (e.g. annual or perennial) and to determine origin as native or introduced. In addition, we related plants to the Colorado Department of Agriculture Noxious Weed List (www.colorado.gov/ag/csd). Only plants identified to species were categorized.

We also compared our plant species to the 326 species identified in the *Common Flora of the Playa Lakes* (Haukos and Smith 1997), which sought to provide a comprehensive list of the plants of the playa lakes by compiling data from several previous studies. This book included data from Hoagland (1991) who documented 38 species of plants from surveys in Colorado, as well as the sampling of the authors which included four playas sampled in Las Animas County and five playas in Baca County. The authors did not distinguish their findings by state.

Water smartweed (*Persicaria amphibian*): a native, obligate wetland species in a playa basin

We calculated mean percent cover for each species within each playa using cover class midpoints. Data summaries were calculated using MS Access, MS Excel, and JMP® statistical software for Windows. We used an Analysis of Variance to test for differences in mean cover among different land cover types and between the playa basins and uplands (averaged across years). Interaction terms were tested for and not found to be significant in all models. All results are significant at the $\alpha < 0.05$ level unless otherwise reported.

To compare plant species richness between playas and uplands, we randomly sampled the plots within playa basins to arrive at an equal number of playa and upland plots per playa (usually n = 10). We estimated specicies richness by counting number of species occurring over equal numbers plots in the playa basin and upland.

Results

Species Composition

In total we completed 176 intensive vegetation surveys on 116 playas located within 17 counties in eastern Colorado. Two playas were visited in four years, thirteen in three years, 28 were visited in two years, and 73 were visited in one year. Sixteen of the playas were surrounded by cropland, 88 by grassland, and 12 were surrounded by a combination of cropland, grassland, and/or CRP.

We identified 245 non-crop plant species in the vegetation of sampled playas. One hundred thirty seven of these species (55%) were found within playas but not in surrounding uplands. Twelve plant species (5%) were identified within the uplands but never within the playa basins. A list of all plant species and genera documented during surveys is presented in Appendix C.

The most common plant species were buffalograss, Russian thistle, and western wheatgrass (Table 5).

Table 5. Plant species found in at least one third of playas sampled in eastern Colorado.

Scientific Name	**Common Name**	**Nativity**	**% Playas Occupied**
Buchloe dactyloides	buffalograss	Native	77
Salsola australis	Russian thistle	Exotic	74
Pascopyrum smithii	western wheatgrass	Native	72
Bassia sieversiana	kochia	Exotic	66
Verbena bracteata	prostrate vervain	Exotic	55
Oenothera canescens	spotted evening primrose	Native	50
Ratibida tagetes	short-ray prairie coneflower	Native	49
Eleocharis palustris	common spikerush	Native	47
Conyza canadensis	marestail, horseweed	Exotic	45
Plantago patagonica	wooly plantain	Native	43
Phyla cuneifolia	frogfruit	Native	42
Portulaca oleracea	common purslane	Exotic	41
Eleocharis acicularis	needle spikerush	Native	40
Polygonum ramosissimum	bushy knotweed	Native	37
Grindelia squarrosa	curlycup gumweed	Native	37
Ambrosia tomentosa	skeletonleaf bursage/bur ragweed	Native	35
Chondrosum gracile	blue grama	Native	35

We identified 85 plants with wetland indicator statuses of facultative, facultative wet, or wetland obligate according to either the Region 5 or national list. Fifty-six of these species were facultative wet or wetland obligate; 28 species were obligates. The most commonly encountered wetland species are listed in Table 6. We detected a number of rarer wetland species as well, including *Ammannia robusta* (grand redstem), *Bacopa rotundifolia* (disk waterhyssop), *Bergia texana* (Texas bergia), *Portulaca halimoides* (silkcotton purslane), *Heteranthera limosa* (blue mud plantain), *Cyperus acuminatus* (tapertip flatsedge), *Marsilea mucronata* (western water clover, pepperwort), and *Myosurus minimus* (bristly mousetail).

Table 6. Wetland plants occuring in greater than 25% of playas surveyed

Scientific Name	Common Name	% Playas Occurence	National WIS[1]	Region 5 WIS
Oenothera canescens	spotted evening primrose	50	FAC,FACW-	FACW-
Eleocharis palustris	common spikerush	47	OBL	OBL
Conyza canadensis	marestail, horseweed	45	UPL,FAC	FACW
Phyla cuneifolia	frogfruit	42	FAC,FACW	FAC
Eleocharis acicularis	needle spikerush	40	OBL	OBL
Polygonum ramosissimum	bushy knotweed	37	FACU-,FACW	FAC
Marsilea mucronata	western water clover	30	OBL	OBL
Rorippa sinuata	spreading yellowcress	28	FAC+,FACW	FACW
Iva axillaris	poverty sumpweed	28	FACU,FACW	FAC
Echinochloa crus-galli	barnyard grass	27	FACU,FACW	FACW
Polygonum aviculare	prostrate knotweed	26	UPL,FACW	

1. Wetland Indicator Status, (http://plants.usda.gov/).

We found 114 plant species that were not reported in the Haukos and Smith flora (1997). Our observations included five families (*Capparaceae*, *Caryophyllaceae*, *Grossulariaceae*, *Papaveraceae*, and *Polemoniaceae*) not reported in their work. We also found 132 species of plants from 31 families that were among those listed by Haukos and Smith. Haukos and Smith listed 199 species that we never observed in playas, including 30 families that we never observed. Of the species detected by Haukos and Smith and not by our study, seven were known to have been observed within Colorado (from Hoagland 1991): *Erigeron flagellaris* (fleabane), *Packera plattensis* (prairie ragwort), *Lithospermum incisum* (narrowleaf groomwell), *Eustoma grandiflorum* (prairie gentian), *Rumex maritimus* (golden dock), *Castilleja integra* (Indian paintbrush), and *Tamarix chinesis* (Chinese tamarix).

Focusing on wetland plants, we found 21 species not reported in Haukos and Smith 1997 (see Table 7). Fourteen of these were native plants and seven were exotics. We found most of these plants in 5% or fewer of the playas we surveyed. However, one native wetland obligate species, *Ammannia robusta* (Grand Redstem) was documented in 61% of the playas we surveyed. Haukos and Smith reported 74 wetland species that we did not detect.

Table 7. Wetland plant species we detected that were not reported in Haukos and Smith (1997).

Scientific Name	Common Name	National WIS[1]	Region 5 WIS
Amaranthus blitoides	mat amaranth	FACU,FACW	FACW
Ammannia robusta	grand redstem	FACW+,OBL	OBL
Atriplex argentea	silverscale saltbrush	FACU,FAC	FAC
Cardaria latifolia	tall whitetop	FACU,FACW	FACW
Carex aquatilis	water sedge	OBL	OBL
Critesion brachyantherum	meadow barley	FAC,FACW	
Cyperus aristatus	bearded flatsedge	FACW+,OBL	OBL
Eleocharis palustris	common spikerush	OBL	OBL
Gnaphalium palustre	western marsh cudweed	FAC+,OBL	OBL

Scientific Name	Common Name	National WIS[1]	Region 5 WIS
Muhlenbergia asperifolia	scratchgrass muhly	FACW,FACW+	FACW
Portulaca halimoides	silkcotton purslane	FACW	NI
Ribes aureum	golden currant	FAC-,FACW	NI
Rumex stenophyllus	narrowleaf dock	FACW-,FACW+	FACW+
Rumex triangulivalvis	Mexican dock	FACU,FACW	FAC
Sanguisorba minor	small burnet	UPL,FAC	NI
Schoenoplectus pungens	common threesquare	FACW+,OBL	OBL
Setaria glauca	yellow foxtail	FACU,FAC	
Sorghum vulgare	grain sorghum	UPL,FAC	
Suaeda calceoliformis	Pursh seepweed	FACW-,FACW+	FACW
Tamarix ramosissima	saltcedar, tamarisk	FAC,FACW	FACW
Ximenesia encelioides	golden crownbeard/goldweed	FACU-,FAC	FAC

1. Wetland Indicator Status, (http://plants.usda.gov/).

Seventy-four percent of the plants we identified in playas were native to Colorado. Some of the exotic species were encountered frequently (Table 8; see also Appendix C). We documented ten species on the Colorado noxious weed list, with field bindweed (*Convolvulus arvensis*) the most common found at 11% of playas surveyed (see Table 8).

Table 8: Noxious weeds found in playas in eastern Colorado

Scientific Name	Common Name	Level of Concern	% Playas Occupied
Convolvulus arvensis	field bindweed	C	11
Anisantha tectorum	cheatgrass	C	9
Tribulus terrestris	puncturevine	C	8
Breea arvensis	canada thistle	B	3
Panicum miliaceum	wild proso millet	C	3
Tamarix ramosissima	saltcedar, tamarisk	B	2
Cardaria latifolia	tall whitetop	B	1
Cirsium vulgare	bull thistle	B	1
Erodium cicutarium	redstem stork's bill	B	1
Verbascum thapsus	common mullein	C	1

Plant Cover

Within the playa basins, the most prevalent cover type was bare ground, averaging 50.2% cover (SE = 1.89). Cover values of bare ground, forbs, and annuals were greater within playa basins than in adjacent uplands; grass cover was greater within surrounding uplands (Figure 6; see Appendix B, Table B-7 for statistics). Species richness and the number of exotic plants per playa did not differ between playas and surrounding uplands (effect tests $F_1 = 2.07$, $P = 0.151$, $F_1 = 0.099$, $P = 0.753$, respectively).

Playas in grassland (n = 88) had more cover by grass and less cover by bare ground and annuals than did playas in cropland (n = 16; Figure 7; see Appendix B, Table B-8 for statistics). Cover by forbs did not differ between land uses. Plant species richness was greater for playas in grassland than in playas in cropland. There was a trend for the number of exotic plants per playa to be greater in cropland playas than in grassland playas, but the result was not significant at $\alpha < 0.05$.

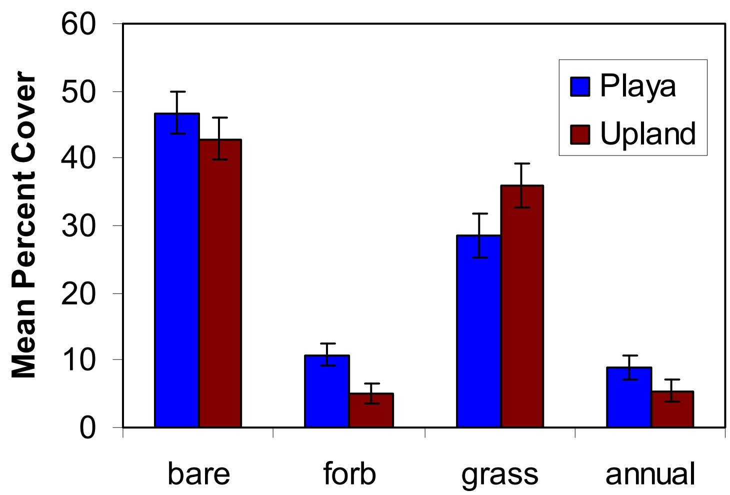


Figure 6. Comparison of mean cover values for playa basins to surrounding uplands (least squared means adjusted for year).

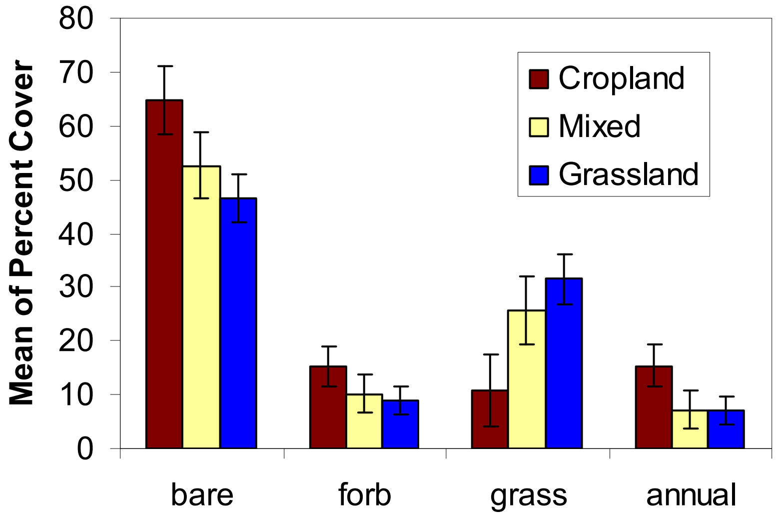


Figure 7. Comparison of mean cover values for playa basins within different surrounding land uses (least squared means adjusted for year).

Across years, we observed continuity in dominant species, although shifts in percent cover by category (e.g., bare ground, forbs) were apparent. Please see Appendix C, Table C-2 for a year by year summary of the dominant three cover types for each of fifteen playas sampled in at least three years.

Plant Heights

Plant heights averaged 26.5 cm (SE = 1.53) in playas and did not differ from plant heights in adjacent uplands (27.86 cm, SE = 1.49). Vegetation heights also did not differ among landcover types.

Discussion

This study has increased our knowledge of playa flora by sampling in fifteen counties north of the area previously sampled by Haukos and Smith in 1997. We documented the occurrence of 114 species not listed in their compilation work, including 21 wetland species. Many of these discoveries are likely due to differences in the ranges of these plants, and it is also possible that these species have been encountered in subsequent surveys. However, these findings could also be attributed to greater survey effort. We completed 176 surveys to 116 playas in seventeen counties, building on the sample of nine playas in two counties incorporated in Haukos and Smith (1997). Our work resulted in the archiving of 231 specimens representing 116 species to the Kathern Kalmbach herbarium in Denver.

Devil's claw (*Proboscidea louisianica*)

Playas likely provide key habitat for many of the 85 wetland plant species documented in our study, including several that are rarely known for Colorado. We hope this stimulates further interest on the part of botanists to further explore the playa flora of Colorado. Furthermore, we worked largely throughout a drought period, and re-sampling during a wet cycle would likely yield additional species detections.

We found that playa vegetation composition differed from the surrounding upland (e.g. Reed 1930). We found that forbs and annuals were more abundant, while grasses were less abundant in playas than in the surrounding uplands. Furthermore, a high proportion of playa plants were not found in adjacent uplands (55%), while only 12% of the upland plants were not found in playas. This supports the assertion that playas do indeed increase the local and regional biodiversity value of the shortgrass prairie (Hoagland and Collins 1997).

The surrounding landscape for a playa influences its floral composition (Smith and Haukos 2002). We found that grasses were more abundant and, like Smith and Haukos (2002), that annuals were less abundant on grassland playas than in cropland playas. We also found that playas in grassland supported a greater species richness of plants than playas in cropland, contrary to their findings, although Smith and Haukos did find greater species diversity in grassland playas. Another difference is that they found a greater frequency of exotic plants in cropland playas than in grassland playas, while we only observed a trend for that effect. This might be due to their higher sample sizes (n = 224), nearly twice the number of playas we sampled. While not unexpected, these data underscore the value of conserving playas within native grasslands.

Like rangeland playas in other regions that receive minimal runoff from irrigation, in general the playas we surveyed were dominated by perennial grasses, such as western wheatgrass (*Pascopyrum smithii*) and buffalograss (*Buchloe dactyloides*) (Hoagland and Collins 1997). Similarly, in a study of Kansas playas, western wheatgrass was the second-most dominant plant after spikerush in playas surrounded by grassland (Wilson 1999). This contrasts to the findings of Haukos and Smith (2002), who in their survey of the Southern High Plains playa lakes region, found that annual plants were dominant in playas, whether the playas were surrounded by predominantly by cropland or by grassland. However, we did find that annuals were more abundant on cropland playas than grassland playas, which also concurs with their findings (Haukos and Smith 2002).

Twenty six percent of the plants we found in eastern Colorado playas were exotics, and ten species were on the state noxious weed list. This concurs with the assertion of Haukos and Smith (2004) that native playa plant communities in the Southern High Plains have been degraded or eliminated due to intensive grazing or cultivation.

Colorado playa with wetland vegetation interspersed with open ground.

Playa basins supported more bare ground and greater cover by forbs and annuals than surrounding uplands. This suggests that when inundated, open water and nutritious seeds from annual plants become available, providing excellent habitat for foraging waterfowl and shorebirds. Colorado playas provide important avian habitat. The playas we sampled generally lacked dense vegetation, with bare ground accounting for nearly 50%. This open habitat is favored by migrating shorebirds, which prefer habitats with vegetative cover less than 25% (Helmers 1993). The productivity of playas in producing seeds and invertebrates is well recognized as being important for supporting migrating waterbirds (Anderson and Smith 1999). Based on their analysis of Northern Pintail crop contents, Sheeley and Smith (1989) found that barnyard grass, curly dock, spikerush, and smartweed were important food resources for migratory birds. Although in low numbers, we observed all of these plants during surveys. In addition, while it is well-documented that migrating shorebirds forage on invertebrates as a protein source, seeds may also be an important part of their diet; for example, seeds comprised approximately 20% of the dietary mass for five species of migrating shorebirds on a Texas playa (Baldassarre and Fisher 1984).

CHAPTER 4. SOIL CHARACTERISTICS OF PLAYAS

Playas in the southern part of their range are distinguished by heavy clay soils, typically in the Randall group (Smith 2003). Many aspects of the hydrological function of playas, including recharge and water retention rates, are affected by the chacteristics of these clay soils. Because no data were available regarding the soils of playas in Colorado, we sampled soils in the random sample of playas locations that we surveyed in our initial year of fieldwork.

Methods

In the playa was dry at the time of the site visit, we dug a single pit within the playa's center to describe soil characteristics. Initial consultation with soil scientists indicated that a single pit would provide sufficient information to characterize the playa soils. We excavated each pit to a depth of about 20 inches. For each soil layer we recorded the depth, texture (e.g., percent sand, silt, clay, and organic matter), Munsell color in the standard sequence of hue, value, and chroma (e.g. 10YR5/2), and presence or absence of hydric features such as oxidized pore linings or redoximorphic features.

Results

In 2004 we sampled soil characteristics for 24 playas in nine counties (Table 9). Every playa that was analyzed for texture contained a clay component. Soils were generally dark with value/chroma reading at or below 3/2 and six playas had obvious hydric features. Three playas were recently tilled but one still had two distinct layers. The depth of the A layer ranged between 2 in and 20 in, often without an obvious organic layer. Because of low variability among playas, the presence of a clay component in all playas surveyed, and the amount of field time required to conduct soil characterizations, we did not continue soils investigations in subsequent years.

Table 9. Soil characteristics of 24 dry playas.

County	Upland Landuse	Depth (in)	Horizon	Munsell Color (wet)	Texture	Structure	Hydric Features
Baca	Prairie	0-20	A	10YR 3/2	ND	Blocky	No
Baca	Prairie	0-3.5	A	10YR 3/2	Silty Clay Loam	Blocky	No
		3.5-7.5	B	10YR 3/2	Sandy Clay Loam	Blocky	No
		7.5-18	C	7.5Y 2.5/1	Silty Clay	Blocky	No
Baca	Prairie	0-3	A	10YR 3/2	Sandy Clay	ND	No
		3-14+	B	10YR 3/2	Silty Clay	ND	No
Baca	Dryland, Irrigated Agriculture	0-12.5	A	10YR 3/2	Sandy Loam	ND	No
		12.5-21	B	10YR 2/1	Silty Clay	ND	No
Baca	Irrigated Agriculture	0-4	A	10YR 2/2	Sandy Clay	ND	No
		4-16	B	10YR 3/1	Sandy Clay	ND	No
Cheyenne	Prairie	0-3	O	ND	ND	ND	No
		3-18	A	2.5Y 3/1	Silty Clay	Blocky	No
Cheyenne	Prairie	0-3	O	ND	ND	ND	No
		3-20	A	10YR 3/1	Silty Clay	ND	Yes
Elbert	Prairie	0-18	A	2.5Y 3/1	Clay	Prismatic	No
Elbert*	Dryland	0-14	A	2.5Y 3/1	Silty Clay Loam	ND	Yes

Table 9. Soil characteristics of 24 dry playas.

County	Upland Landuse	Depth (in)	Horizon	Munsell Color (wet)	Texture	Structure	Hydric Features
	Agriculture	14-19	B	2.5Y 3/1	Clay	ND	No
El Paso	Prairie	0-3.5	A	10YR 3/1	Clay Loam	Blocky	No
		3.5-15	B	2.5Y 3/1	Sandy Clay	Granular	No
El Paso	Prairie	0-1	O	ND	ND	ND	No
		2-6	A	10YR 3/2	Sandy Clay Loam	ND	No
		6-11	B	7.5YR 3/1	Clay Loam	Blocky	No
		11-19	C	10YR 3/1	Clay	Prismatic / Blocky	No
Kit Carson*	Prairie, Irrigated Agriculture	0-20	A	2.5Y 2.5/1	Silty Clay	None	No
Pueblo	Prairie, CRP	0-15	A	2.5Y 5/2	Clay	Prismatic / Blocky	Yes
Washington	Prairie	0-2	O	ND	ND	ND	No
		2-18	A	2.5Y 3/1	Clay	Blocky	No
Washington	Prairie	0-4	A	10YR 4/1	Silty Clay	ND	No
		4-20	B	2.5Y 2.5/1	Silty Clay	Prismatic / Blocky	Yes
Washington*	Dryland Agriculture	0-20	A	10YR 3/1	Silty Clay	Massive	No
Weld	Prairie	0-8	A	10YR 3/2	Clay Loam	Blocky	Yes
		8-21	B	10YR 3/3	Sandy Loam	Massive	Yes
Weld	Prairie	0-13.5	A	2.5Y 4/1	Clay	ND	No
Weld	Prairie	0-3	A	2.5Y 3/1	Silty Clay	ND	No
		3-14+	B	2.5Y 4/1	Clay	ND	No
Weld	Prairie	0-3	A	10YR 4/2	Silty Clay	ND	Yes
		3-6	B	10YR 3/2	Silty Clay	Blocky	Yes
		6-11	C	10YR 3/2	Silty Clay	Blocky	Yes
Weld	Prairie	0-6	A	10YR 3/2	Clay	ND	No
		6-20	B	2.5Y 5/3	Sand	Massive	No
Weld	Prairie	0-3	O	ND	ND	ND	No
		3-20	A	2.5Y 2.5/1	Clay	Prismatic / Blocky	No
Weld	Prairie	0-9	A	10YR 3/1	Silty Clay	Blocky	No
		9-21	B	10YR 4/1	Silty Clay	Blocky	No
Yuma	Prairie, Dryland and Irrigated Agriculture	0-2	O	ND	ND	ND	No
		2-20	A	10YR 3/1	Clay	Blocky	No

ND = No Data.
*=Playa recently plowed

Discussion

Like playas in other areas, we confirmed that most playas in Colorado have characteristic clay soils. Clay soils contribute to playa hydrologic function by impounding water and are vital to many functions of playas, such as recharging ground water and providing habitat for migratory birds and other wildlife (Smith 2003). Playa Lakes Joint Venture has compiled excellent information regarding how recharge takes place; research indicates that water initially percolates into the aquifer through macropores (cracks) in the soils and around the periphery of the playa basins (www.pljv.org). After this initial recharge period, many playas then hold water for extended periods of time.

Many of the playa soils we observed were lacking in hydrological indicators, which makes wetland identification more difficult. However, we were only completing minimal sampling to 20 inches. NRCS protocol recommends sampling to 80 in (7 ft) to look for clay texture (e.g., clay, silty clay, sandy clay) throughout the soil profile to a depth of 5-7' (Andy Steinert, USDA NRCS, personal communication). In addition, playa soils typically exhibit dark colors (3/3 or below in the Munsell color chart) for a minimum thickness of 20" from the soil surface.

We found high confirmation rates for playas predicted to occur on soils in the Apishapa (98%) and Pleasant (86%) soil families (Chapter 2). Pleasant soils were also indicative of playas in the Southern High Plains, but the Apishapa group was not mentioned in an overview of playa soils (Smith 2003). The high confirmation rate we observed suggests that soils are effective for predicting playa locations in eastern Colorado. Although there are not currently other mapped soils that appear promising for predicting playas, future re-mapping efforts may yield additional information and consistency to assist in locating playas (Andy Steinert, USDA NRCS, personal communication).

A playa basin exhibiting macropores

CHAPTER 5. AVIAN USE OF PLAYAS

Playa wetlands provide important habitat for migrating shorebirds and waterfowl in the Great Plains (Smith 2003). The extent that playas are utilized by wildlife is an important consideration for the conservation playa wetlands in eastern Colorado. Count models for estimating variation in abundance are useful for evaluating the influence of environmental factors on the distribution organisms, including habitat degradation from human land use (Guisan and Zimmermann 2000). The predictions from the models can be used to support conservation planning and reserve design (Guisan and Thuiller 2005). We used counts of shorebirds and waterfowl to evaluate the importance of playa attributes for the distribution of these birds during migration. We also analyzed counts of landbirds observed on playas to determine the extent that playa attribututes were important for the distribution of terrestrial birds. In addition, we report the numbers and species composition of bird use of wet and dry playas in Colorado, which had not previously been documented. After two years of drought conditions, we sought wet playas to sample by monitoring daily rainfall data within our study area. This resulted in a series of visits to wet playas in the falls of 2005 and 2006.

Methods

Field Surveys

For all visits to playas throughout the duration of the study, whether road-based rapid assessments or on-site visits to collect vegetation data, we compiled data for all birds observed (see Figure 8 for playas surveyed). Most surveys were from the road with the following protocol. Surveyors used a spotting scope placed along the roadside to visually identify and count all birds using the playa and the upland within 100 m of the playa edge; any aural detections also were recorded. We recorded the date, time of day, duration of survey, estimated temperature, estimated wind speed, and general weather categories. Bird data collected included species, habitat, activity, and when known, sex and age class. In addition, we employed our roadside survey protocol (Chapter 2) to gather data on playa conditions and surrounding landuse. We recorded birds using playa basins and surrounding uplands within ¼ section (¼ mi x ¼ mi).

A field technician surveying birds from the roadside

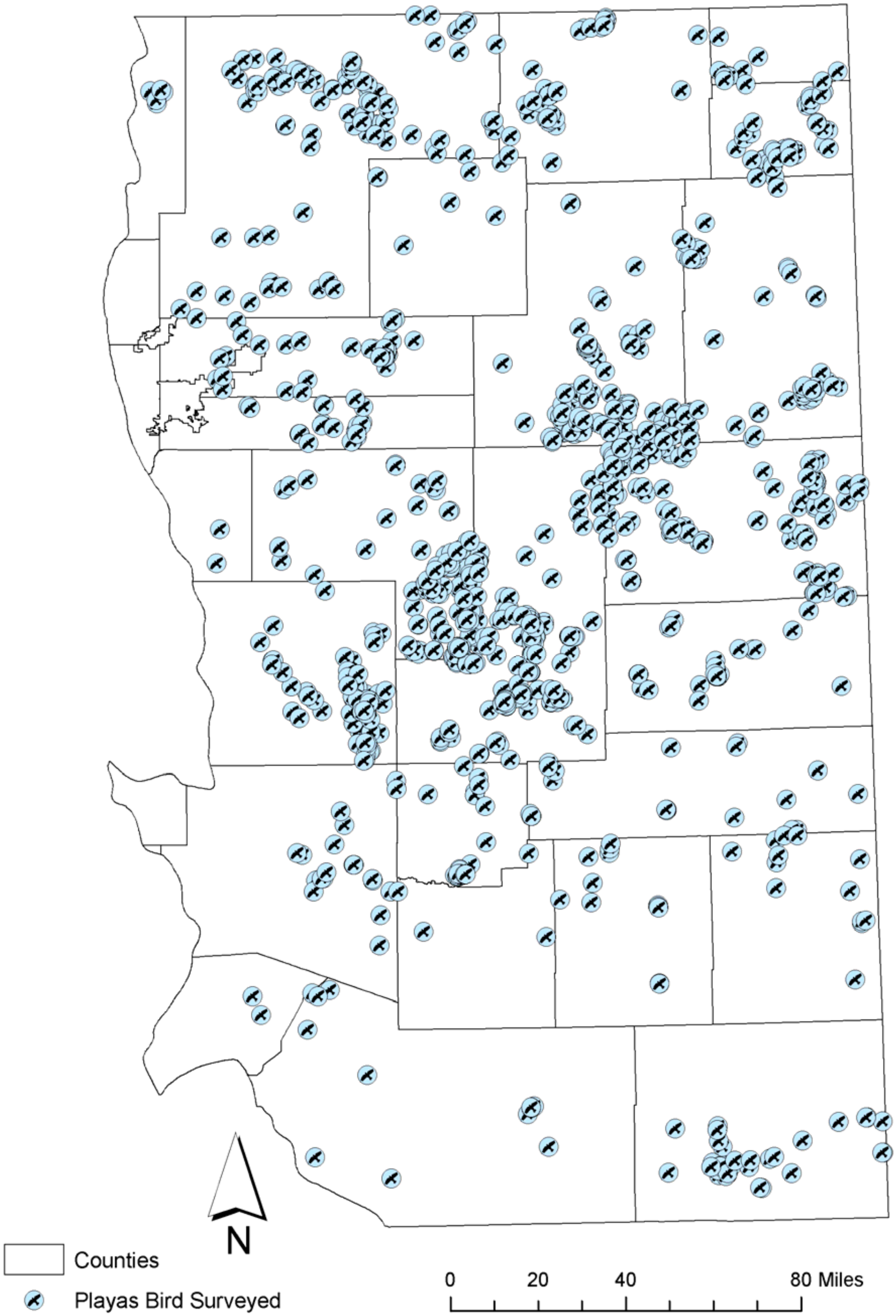


Figure 8. Playas in eastern Colorado where we surveyed for birds 2004-2007.

To better understand habitat availability we also estimated the percent of the playa basin covered by the following categories: dry mud, dry mud vegetated, wet mud (saturated), wet mud vegetated, standing water (inundated), and water with emergent vegetation. Observers were trained to estimate the vegetated area when the playa contained at least 25% vegetation cover.

To improve our sample size of wet playas, we monitored daily rainfall (http://water.weather.gov/download.php) for the fall seasons of 2005 and 2006. We used the rainfall data to focus our monitoring efforts on areas that had recently received heavy rainfall and where we therefore expected to find playas containing standing water. We defined heavy rainfall as at least 2 in of rainfall within 24 hours or 4 in within a week. These thresholds were estimated to be sufficient to pond water for several weeks in most playas, as determined using best professional judgment in consultation with other scientists familiar with playas.

We then mapped possible playas in the high rainfall areas and surveyed all wet playas within a distance of the road from which waterfowl and shorebirds could be distinguished. Surveys were repeated every 7 to 10 days for as long as playas contained standing water or moist soil within the migratory season (surveys finished October 30 2005 and November 17, 2006).

Analyses

Our primary research objective was to discover what playa attributes were important to landbirds and migratory waterbirds. We analysed count models for the abundance of all birds separately for wet and dry playas because the species composition of wet and dry playas were considerably different. Count models for the abundance of shorebirds and waterfowl were considered for wet playas only. We modeled the abundance of landbirds for wet and dry playas on the basis that the species composition of wet and dry playas was similar.

The counts of individual birds within the landbird, shorebird and waterfowl groups were modeled as a function of covariates (Table 10) using a generalized linear mixed model (McCulloch 2003). This model assumed a normal distribution for the random effects of playa ID and included a block covariance structure for the categories of playa ID (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 / 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 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 migratory chronology (Group A), then established the dimensions of the ecological model (Group B) and then determined the inclusion of proximity to wetland covariates (Group C; Table 10). The time chronology part of the model was built using all subsets of the Season, Year, Date, Season*Date, and Year*Date covariates (Table 10). In addition, we evaluated the threshold ($\log_e$*Date) and quadratic (Date + Date^2) functional forms of the Date covariate. The migration chronology covariates were forced into the full model containing all seven covariates in Table 10. After arriving at the migration chronology part of the model, the ecological model was constructed using all subsets of the Group B covariates in Table 10. 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 determining the best model composed of ecological covariates, we evaluated the best subsets of the Area and Wetland covariates. Finally, we used information-theoretic model selection to evaluate the likelihood of the models given the parameters and to estimate the amount of 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 and evidence ratios were used as strength of evidence for the competing models (Burnham and Anderson 2002). The estimates for the mean and standard errors of the response variables were estimated using the exponential transformation of the least squares means (SAS Institute 2008) and the delta method (Powell 2007), respectively.

Table 10. Covariates tested in the full models testing factors influencing confirmation rates of potential playa locations.

Group	Variable	Description	Range and Levels
A	Date	Ordinal date of the survey from 1 Jan. – 1 July or from 1 July – 31 Dec.	1 - 182
A	Year	Year of the survey	2004 - 2007
A	Season	Season of the survey, divided at July 1	Spring, Fall
B	Size	Playa area (ha) from the GIS database	0.13 - 26.02 ha
B	Wetness	Hydrologic condition of the playa during survey;(≥ 1% mud or standing water=wet)	Dry, Wet
B	Landcover	Dominant landcover type of playa from field surveys	Grass, Agriculture
B	Hydro	Hydrologic modification of playa	Altered, Not Altered
B	Road	Distance (km) from playa center to nearest road	0.01 - 5.05 km
C	Area	Area (%) within 2 km from playa edge comprised by other playas	0.0 - 6.3 %
C	Wetland	Distance (km) from playa center to nearest wetland (not playa) indicated in NHD	0.30 – 23.19 km

Results

Playa Surveys

We conducted 1142 surveys of 576 playas, from April through mid-November 2004-2007. We surveyed each playa between 1 and 12 times over the course of our study. Most playas were surveyed only once (66%), 92% of playas were surveyed five or fewer times, and 46 playas were surveyed six or more times. Most of the repeat surveys were to wet playas during fall migration seasons 2005 and 2006. Approximately half of our surveys were to dry playas and half to wet playas (603 were wet; 53%). Twenty-seven percent of all bird surveys yielded no bird detections. Of the surveys with no birds, 71% were of dry playas.

We estimated cover types for 766 surveys to 216 wet playas in 2005 and 2006; most values were from the fall. Across all degrees of wetness, we found on average 46% of playas were estimated to be unvegetated (SE = 2.49). On average we found 24% of the playa basins were covered in mud, while 50% was covered by standing water (Figure 9).

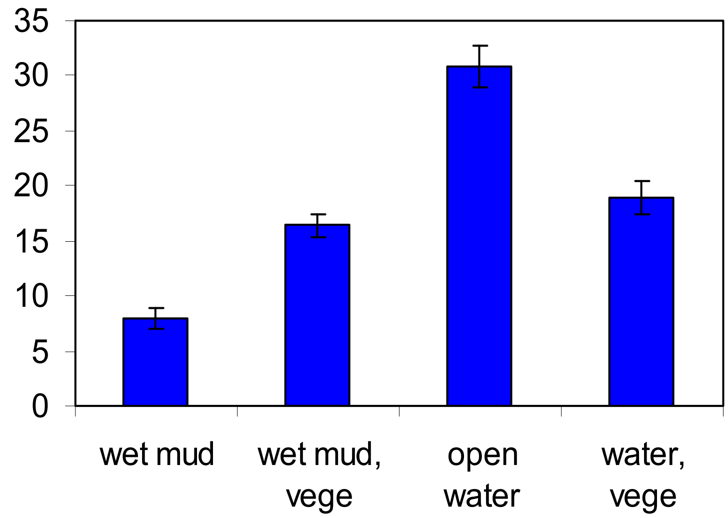


Figure 9. Average conditions of wet playas surveyed during 2005-2006.

Avian Use

We documented use of playas by 48,830 birds of 148 species during the course of the study (Table 11 and see Appendix D for a complete list). This included 22 species of waterfowl, 27 species of shorebird, 12 species of other waterbirds (e.g., cranes, gulls, herons), 6 other species of wetland dependent birds (e.g., Yellow-headed Blackbird, Marsh Wren) and 81 species of landbird.

Landbirds as a group were found with the greatest frequency, while waterfowl were the most numerous (Tables 11 and 12). Other waterbirds were least frequently detected but sometimes detected in large groups (e.g., flocks of at least 1,000 Sandhill Cranes on multiple occasions).

Table 11: Frequency and abundance of birds detected by guild

Guild	Number Occupied Playas	Percent Occupied Playas	Total Number of Individuals Observed	Average flock size
Waterfowl	103	18	26,948	262
Shorebirds	146	25	3,517	24
Other Waterbirds	67	12	6,209	93
Landbirds	382	66	12,156	32
All Birds	**414**	**72**	**48,830**	**118**

Flock sizes, as represented by the average number of birds in that guild from among surveys where birds of that guild were present are presented in Table 10. These averages incorporate many small numbers and fewer high counts. For instance, for waterfowl we observed large flocks (7 surveys had 1,000 or more waterfowl; another 7 surveys found 500-1,000 waterfowl), but we also had 91 surveys in which waterfowl were observed in numbers fewer than 10. The species recorded in greatest numbers are listed below (Table 12).

Table 12: The most abundant bird species found using playas; all species with at least 1,500 individuals detected.

Scientific Name	**Common Name**	**Total # observed**
Eremophila alpestris	Horned Lark	11,473
Anas crecca	Green-winged Teal	7,374
Grus canadensis	Sandhill Crane	6,791
Anas platyrhynchos	Mallard	4,530
Chen spp.	Light Goose (undifferentiated Ross's and Snow Goose)	3,049
Charadrius vociferus	Killdeer	2,453
Anas acuta	Northern Pintail	2,353
Calcarius ornatus	Chestnut-collared Longspur	2,098
Calcarius mccownii	McCown's Longspur	2,028
Anas clypeata	Northern Shoveler	1,949
Branta canadensis	Canada Goose	1,686

Species of Conservation Concern

We detected twenty-seven species of Greatest Conservation Need (SGCN; Colorado Division of Wildlife 2006), including five Species of Special Concern and two state Threatened species. The five Species of Special Concern were Ferruginous Hawk (*Buteo regalis*), Mountain Plover (*Charadrius montanus*), Peregrine Falcon (*Falco peregrinus*), Sandhill Crane (*Grus canadensis*) and Long-billed Curlew (*Numenius americanus*). The two state threatened species we found were Burrowing Owl (*Athene cunicularia*) and Bald Eagle (*Haliaeetus leucocephalus*). Seventeen of the SGCN species were Tier 1 species; 10 were Tier 2 species. The four most common SGCN species (occurred in greater than 5% of the playas surveyed) were Lark Bunting (*Calamospiza melanocorys*), Chestnut-collard Longspur (*Calcarius ornatus*), McCown's Longspur (*Calcarius mccownii*) and Northern Harrier (*Circus cyaneus*).

Avian Use Models

For all bird species using dry playas, the mean number of birds observed on each playa per survey was 4.34 (SE = 0.543). The best negative binomial count model for the abundance of all birds included playa size, surrounding landcover type, hydrologic alterations, distance to road, and distance to nearest wetland (see Appendix B, Table B-9). This model was 6.1 times more probable than the next best competing model (Appendix B, Table B-9). Bird use was greater for playas in grassland, playas with hydrological alterations, and during the fall season (Appendix B, Tables B-10 and B-11). Avian abundance also increased with increasing playa size and distance from the road, and declined with increasing distance from other wetlands (Appendix B, Tables B-10 and B-11).

The average number of all birds detected on each wet playa per survey was 25.52 (SE = 3.729). The highest ranking negative binomial model included playa size, proximity to other playas, and hydrologic modifications, and was was 3.9 time more probable than the next best competing model (see Appendix B, Table B-12). Overall bird abundance on wet playas showed differences between years and was greater during the spring (Appendix B, Tables B-13 and B-14). Bird use was positively related to playa size and the percentage of playa cover in the landscape, and abundance was higher in hydrologically modified playas (Appendix B, Tables B-13 and B-14).

The mean number of landbirds observed on dry playas per survey was 3.57 (SE = 0.402), while the mean number on wet playas was 7.97 (SE = 1.034). The best negative binomial count model contained playa size, surrounding landuse, hydrological modification, distance to road, and distance to nearest wetland (see Appendix B, Table B-15). This model was 3.6 times more probable than the next best competing model (Appendix B, Table B-15). Landbird use was greater on grassland playas and hydrologically altered playas (Appendix B, Tables B-16 and B-17). Landbird use was also positively related to playa size and distance from the road, and negatively related to distance from the nearest wetland.

The mean number of shorebirds detected on wet playas per survey was 4.10 (SE = 0.707). The best negative binomial count model included the effects of playa size, hydrological modification and area of playa cover in the surrounding landscape, and was 9.8 times more probable than the next best competing model (Appendix B, Table B-18). Shorebird numbers were greater in playas without hydrological modifications and during the spring, and were also positively related to the $\log_e$*area of playas and the percent of playa cover in the surrounding landscape (Appendix B, Tables B-19 and B-20). Although the 95% confidence interval for the effect of hydrological modification included zero (Appendix B, Tables B-19), this covariate had a high probability of occurring in the top model (cumulative AIC weight = 0.63) and was present in the four of the five highest ranking models prior to fitting the proximity to wetland covariates. The relationship between shorebird numbers and playa size increased non-linearly such that shorebird numbers increased sharply with playa area up to approximately 5 ha (12.4 ac) after which the relationship between shorebird numbers and playa area was less pronounced (not shown).

The mean number of waterfowl observed on each wet playa per survey was 4.43 (SE = 1.720). The highest ranking negative binomial count model included the effects of playa size the percet of playa cover in the landscapes, and was 13.1 times more probable than the next best competing model (Appendix B, Table B-21). Waterfowl abundance was greater during the spring, and increased with increasing playa size and percent of playa cover in the surrounding landscape (Appendix B, Tables B-22 and B-23).

Blue-winged teal entering an open-water wetland.

Discussion

The importance of playas in the Rainwater Basin and in the High Plains of Texas has been well-documented (summarized in Smith 2003). However, until this study, migratory bird use of mid-latitude (approximately 40º) playas in the western portion of the Central Plains was relatively unstudied. Playas in Colorado supported 148 avian species, including 67 wetland-dependent species and 27 of the state's avian Species of Greatest Conservation Need.

Long-billed Curlew, a Tier 1 Species of Greatest Conservation Need found on Colorado playas.

Playas are invaluable resources for migratory birds in the Great Plains, where transcontinental shorebirds disperse and use available wetlands opportunistically during migration (Skagen and Knopf 1993). Migratory stopover habitats provide critical staging areas for avian migrants requiring rest and replacement of depleted energy reserves when traveling long distances between breeding and wintering grounds (Skagen and Knopf 1993, Skagen and Knopf 1994). Because Colorado playas typically are about half bare ground, when flooded they become ideal shorebird habitat. Migrating shorebirds have been shown to select shallow, sparsely vegetated wetlands with substantial mudflats (Colwell and Oring 1998) with vegetative cover less than 25% (Helmers 1993). Although we documented use by many species of shorebirds, we did not observe particularly high numbers of shorebirds on our sites. This is most likely attributed to our lack of surveys in April-August during peak shorebird migration season because playas were dry. Indeed, Andres (2007) found that shorebird numbers on reservoirs along the South Platte River within our study area peaked in late August-early September. Instead, most of our repeat surveys of wet playas took place in September and October during peak waterfowl migration season. We found use of playas by shorebirds and waterfowl within days of their initial inundation, as documented for Great Plains migrant shorebirds by Skagen and Knopf (1994).

We found local ecological factors as well as landscape composition factors related to bird use. Like many other wetland birds studies, we found that playa size was an important determinant in bird use for all groups of birds examined (e.g., LaGrange and Dinsmore 1989, Brennan 2004, Neimuth et al. 2006). The abundance of landbirds and waterfowl increased with playa size in a linear fashion. In contrast, shorebird abundance increased rapidly with playa size up to approximately 12 acres in size, after which the area affect was less pronounced. Proximity to other playas also was important in increasing use of wet playas by shorebirds and waterfowl, as found in a similar study of spring-migrant shorebirds using wetlands within agricultural fields in the drift prairie of North Dakota (Neimuth et al. 2006). This suggests that playas in complexes may be more attractive than isolated playas for birds, perhaps offering increased foraging opportunities with relatively low search costs (Farmer and Parent 1997). In the North Dakota study proximity to semi-permanent and permanent wetlands was the variable investigated, while in our study the area of playa wetland within 2 km was a stronger correlate to shorebird and waterfowl numbers than distance to nearest mapped non-playa wetland.

A playa in grassland exhibiting shallow water habitat

Landcover was another important factor for landbirds on dry playas, with greater bird use of playas in native prairie grassland. Birds also responded to whether or not playas had been hydrologically modified. We found higher numbers of landbirds on both wet and dry playas with hydrological alterations, which may have resulted from the greater number of habitats typically found in modified playas. Playas with pit excavations often exhibit longer hydroperiods (Smith 2003), which may increase water availability for landbirds. However, shorebirds were less abundant on hydrologically modified playas, also found by Neimuth et al. (2006). It is likely that shorebirds prefer unmodified playas because the natural slope in unmodified playas creates superior shallow foraging habitat conditions. The longer hydroperiods of pitted playas also results in lower invertebrate abundance (Smith 2003), which may reduce invertebrate food resources available to migrating shorebirds.

CHAPTER 6. PLAYA CONSERVATION PROGRAMS

At the inception of this project in 2004, there were virtually no conservation projects on playas within eastern Colorado. Through the course of this project, playas became recognized as a resource of concern by a variety of conservation partners, including the Colorado Division of Wildlife, USFWS Partners for Wildlife, the USDA Natural Resources Conservation Service, and Rocky Mountain Bird Observatory's (RMBO) Stewardship Division. These entities and others began delivering playa conservation projects including retirement from farming, buffer strip plantings, filling pits, and managed grazing. In this section we describe the projects implemented directly by RMBO, as well as a summary of the volume of projects delivered by the greater conservation partnership. We also provide a discussion of the effectiveness of restoration practices in relation to various measures of playa quality or function. In Chapter 4 we describe variation in vegetative characteristics of restored playas in comparison to control playas. Chapter 6 provides further information about conservation projects by compiling spatial data for conservation and bringing together conservation recommendations of the project.

Methods

Project Delivery

Private landowner and NRCS biologist discussing conservation practices for a farmed playa

RMBO rangeland playa restoration projects have entailed pit filling, alternate water development, fence reconfiguration, and fencing for grazing management. Pit filling is a practice utilized to restore the natural hydrology of a playa basin. In the past, many livestock producers have used heavy equipment to deepen playas or parts of playas so that they hold water for their livestock to use over a longer period of time. Re-filling the excavated pit to restore the natural soil gradient is a restoration practice that restores hydrologic function, re-distributing shallower water over a larger area for a shorter period of time. This provides shallow foraging habitat for shorebirds and waterfowl, as well as more appropriate conditions for many wetland-dependent plants, especially annuals that provide important seed resources for migratory waterbirds. In return for diminishing their opportunity to water their livestock within the playa basin, most of the restoration projects also provide a clean, reliable water source for the producer. This

Bulldozer filling-in a pit in a playa to restore natural hydrology

alleviates the need to water the cattle in the playa and also adds flexibility to the livestock producer's grazing operation as they can now graze the pasture when they want without having to be dependent on the unreliable and erratic availability of water in the playa. Alternate water sources have been provided by the extension of existing water pipelines, the addition of water storage tanks, or new wells in some instances.

Another restoration practice often utilized for rangeland playa conservation is fencing development to facilitate grazing management, with the objective of increasing the accumulation of wetland and residual vegetation. Wetland plants often provide great seed resources for migratory waterfowl, and residual vegetation is important in providing a substrate for invertebrates in flooded playas, another important foraging resources for migratory waterbirds. These projects always entail a management agreement which recommends a grazing management plan. A frequent recommendation has been to graze playa basins every third year. Finally, fence reconfiguration has also been used on several occasions to remove fencing that bisects playa basins to reduce potential fragmentation and collision effects.

On farmed playas, RMBO has worked with agricultural producers to retire their playas from farming and to reseed a buffer with native vegetation surrounding the basin. This vegetative buffer is put in place to reduce sedimentation from the surrounding cultivated land which can eventually lead to the filling of the playa basin. Filling of playas by sedimentation is thought to be the leading cause of playa loss, so these projects are instrumental in abating that threat.

Monitoring

RMBO collected vegetation cover data for restored playas or playas planned for restoration during 2006 and 2007, including playas designated as their controls (nearby, same landcover, with the same disturbances pre-restoration) in 2007 (see Figure 10 for their locations. Some of these playas were also sampled in 2004 and 2005. Please see the *Field Sampling* section of Methods in Chapter 3 for vegetation sampling methodology. To compare restored to control playas, we compared cover types in a paired T-test (grouping by restoration practice and proximity) after averaging across years for those sampled in multiple years. All results are significant at $\alpha < 0.05$ level unless otherwise reported.

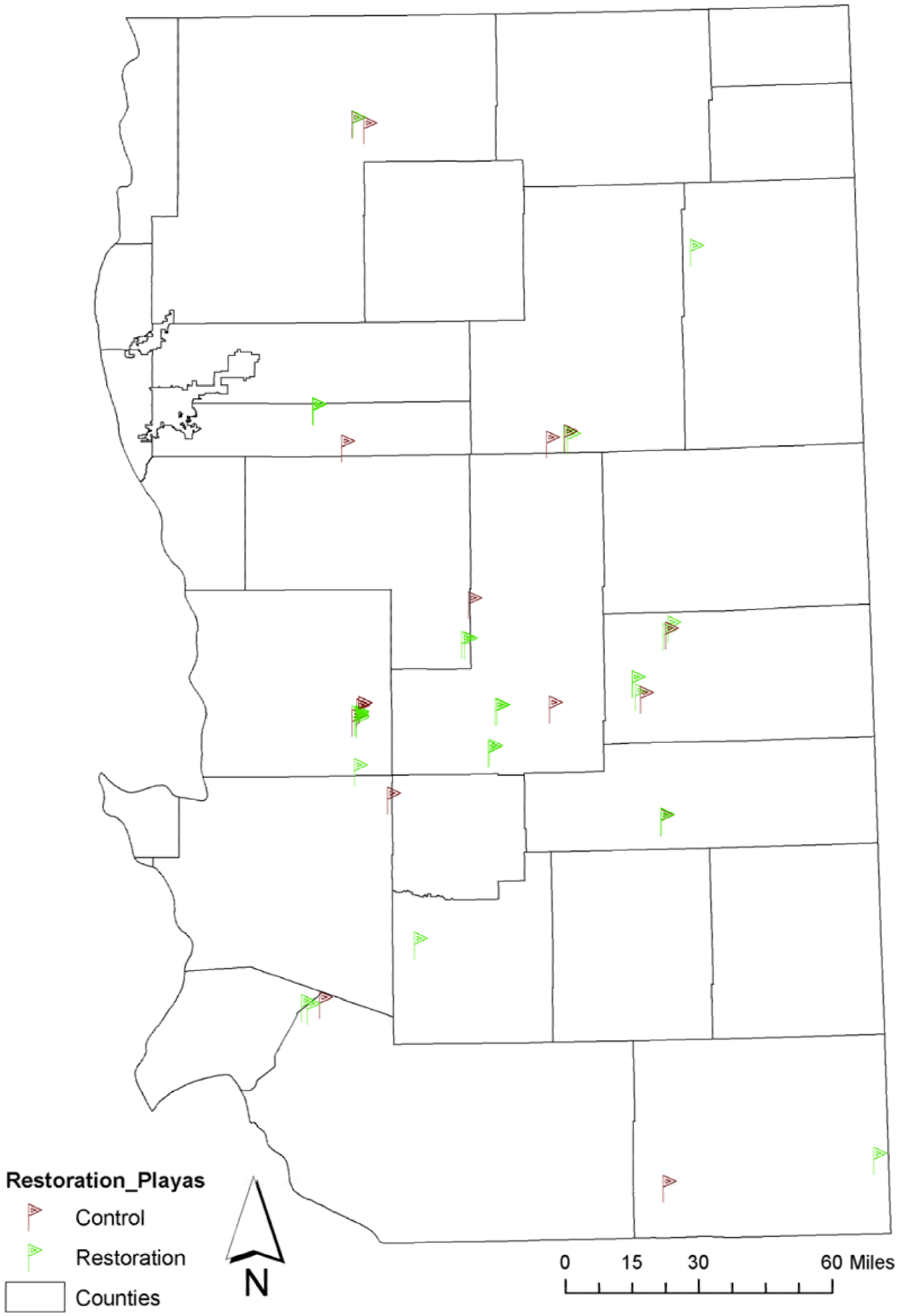


Figure 10. The locations of playas in restoration programs where we sampled vegetation, as well as their comparison (control) playas.

Results

Project Delivery

Since 2004, Rocky Mountain Bird Observatory has worked with eleven agricultural producers in eight Colorado counties to restore and enhance wildlife habitat on 19 playas in shortgrass prairie and four playas in cropland. Cumulatively, these projects have enhanced 1,029 playa acres. All projects are secured with management agreements, most of which are for ten years.

RMBO has delivered these projects within its Stewardship Division, in partnership with a variety of other conservation organizations including USFWS Partners for Fish & Wildlife Program, Colorado Division of Wildlife, and the Natural Resources Conservation Service. Funding for projects has been applied from a number of sources, including the USFWS *Private Stewardship Grant Program*, National Fish and Wildlife Foundation *Conoco-Phillips SPIRIT of Migratory Bird Conservation Grant*, USFWS *North American Wetlands Conservation Act – Small Grant*, and the Playa Lakes Joint Venture *Conoco-Phillips Habitat Grant*.

Monitoring

In total, we assessed vegetation for 33 playas within restoration programs, in addition to 17 playas selected as controls. We collected baseline data for many playas which had conservation practices applied late in 2006 or in 2007. We restrict our comparisons here to playas that had at least one growing season since restoration. This results in 22 playas that fall into seven groups (most groups contain two restored playas and one control). Of these, four groups entailed fencing and grazing management and three groups included fencing as well as pit removal. All playas examined here were within grassland.

Restored playas showed greater cover by forbs than did control playas (t_5 =2.72, p = 0.04; Figure 11). The percent cover by bare ground, annuals, or grasses did not differ (t_5 = -1.88, 2.08, -1.96, respectively; Figure 11). The species richness of plants between restored and control playas also did not differ (t_5 = -0.96, p = 0.38).

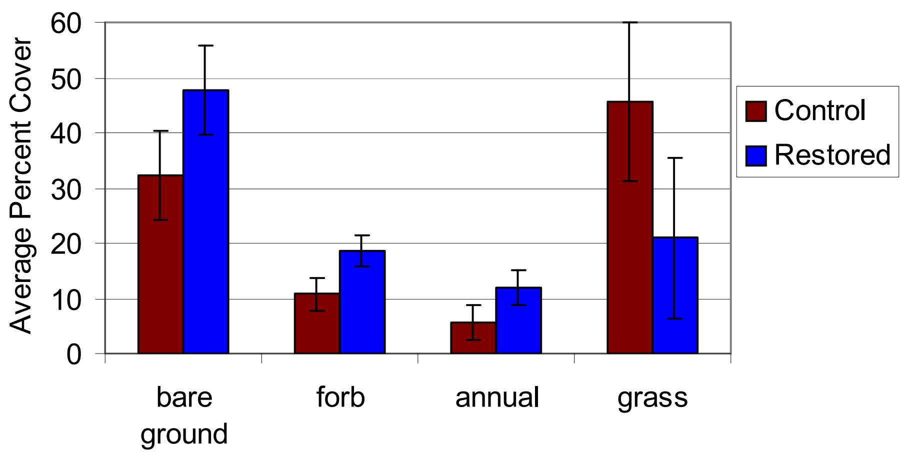


Figure 11. Differences in mean cover in restored and control playas.

Discussion

Our vegetation monitoring indicated that playas receiving fencing, grazing management, and, in some cases pit removal, provide greater cover by forbs than do paired comparison playas with similar land use and human modifications. This finding is of interest because across the landscape in general playas provide greater forb cover than do surrounding uplands; this effect is then magnified with the application of conservation practices.

Because conservation projects were only implemented starting in 2005, we had a very limited sample size of projects (n = 7 groups) that had been in place for at least one full growing season to study. Our power was therefore quite limited for measuring differences among restored playas and unrestored comparison playas. However, we do have baseline data for many other playa projects, which should provide an excellent resource for managers who would like to learn more about the effects of conservation practices.

Stock tank provided as alternate watering source for a livestock producer who filled-in a pit in a playa

Although our original objectives of relating restoration practices to hydrology, runoff, sedimentation, wetland quality, and wildlife use were difficult to attain during the limited scope and timeframe of this project, we can provide a discussion of expected outcomes of the types of conservation projects we studied. Pit removal is expected to shorten the hydroperiod length, but re-create a more natural gradient providing greater area of shallow water and water edge habitat. This provides important habitat for invertebrates and foraging habitat for shorebirds. In playas that are previously farmed, buffers are expected to decrease sedimentation but may have the unintended effect of limiting runoff to those playas (Melcher and Skagen 2005). We observed such effects on playas in planted grasses in Nebraska (RMBO, unpublished data). Additional research is needed to determine how buffer size and species composition relate to sedimentation rates as well as inundation frequency. We are further exploring the relationship of human disturbance to the quality of playas as measured by use by migratory waterbirds and by floristic quality in our sequel project *Floristic Quality and Wildlife Assessment of Playas in Eastern Colorado*, which will be completed in 2009. We hypothesize that wetland quality is improved by well-managed grazing and will test that further by applying *the Floristic Quality Assessment* to these playas. Finally, we do not have sufficient information at this time to determine how wildlife use relates to restoration practices, but this should be a promising area of future research.

We see a good deal of potential for further restoration efforts of playas in eastern Colorado. First, we know of the locations of many playas based upon our GIS database, including more than 300 currently farmed and more than 100 with documented hydrological modifications. Each of these represents a conservation opportunity. RMBO is well suited to pursue future conservation opportunities based on the strong connections it has formed with the agricultural community of eastern Colorado. We have conducted on-the-ground visits to over 200 ranches and farms. By participating in numerous outreach and public events each year, we have reached an estimated 3,500 private producers about wildlife conservation opportunities. We run the Prairie and Wetlands Focus Area Committee which provides a forum for private landowners, governmental agency representatives, and members of non-governmental organizations to interact, strategize, and deliver conservation for playas.

We recognize several opportunities for the USDA Farm Bill to assist in conserving playas. First, farmed playas can be retired and buffered from sedimentation through programs such as the Conservation Reserve Program (CRP). Secondly, pit removal, fencing, and alternate water development may be accomplished under programs such as Wildlife Habitat Incentives Program (WHIP) and Environmental Quality Incentives Program (EQIP). Another opportunity lies in the large number of acres that are expiring from CRP contracts over the next several years in eastern Colorado. Conversion of expiring CRP acres into grazing land provides grassland buffers to playas that would otherwise be at risk for sedimentation if the ground was instead reinstated into crop production. Incentive payments and cost-share for fencing and water development are available under EQIP for such projects, and we are able to provide additional incentives based on non-federal sources of funds.

Finally, RMBO has just employed four Farm Bill Biologists, two of which are dedicated to eastern Colorado. Their positions reflect a partnership between the Colorado Division of Wildlife, the USDA Natural Resources Conservation Service, and RMBO and a dedication to accomplish wildlife conservation together. These biologists are uniquely suited to carry forth the important playa restoration work that has been initiated in the past several years.

Chapter 7. THE CONSERVATION MODEL

A fundamental goal of this project was to provide conservation practitioners with information that may be important to playa conservation in eastern Colorado. In this section, we synthesized the findings of this project into a set of conservation recommendations. We conducted additional analyses that translated playa attributes of conservation importance into spatially explicit maps. These data layers may be used by partners to guide conservation efforts and identify particular regions of the study area best suited for accomplishing specific conservation goals.

Our avian habitat use models indicated that bird use increases with playa size and with the acreage of playas in the surrounding landscape. Therefore we investigated whether there was spatial variation in the distribution of playas and distribution of playa sizes within the study area. In addition, to assist conservation practitioners identify areas where playas could be restored, we examined our field data for spatial patterns in the prevalence of hydrological modifications to playas or in the distribution of playas currently in rowcrop agriculture.

Grassland playa in eastern Colorado

Methods

We investigated the extent that playa size, playa density, the proportion hydrologically modified, and the proportion of playas in grassland were spatially autocorrelated. The observed pattern of autocorrelation for these variables was then used to generate predictive maps illustrating the pattern of aggregation on the landscape.

The study area encompassed 113,400 km2 of eastern Colorado. The entire study area was overlaid with a 6.44 x 6.44 km (41.4 km2, 16 mi2) sampling grid using ArcGIS ESRI 2005). The sampling grid was intersected with the boundaries of metropolitan areas along the Front Range. Of the 2595 grid cells, 133 intersected the major metropolitan areas and were removed, resulting in a sampling frame of 2462 grid cells. The grid cell polygons were converted into a point feature class referenced by the coordinates of the center of the grid cells using the Feature to Point Tool in ArcGIS (ESRI 2005). The spatial analyses were based on a total of 416 grid cells containing the 1085 playas that were confirmed in the field (Figure 12).

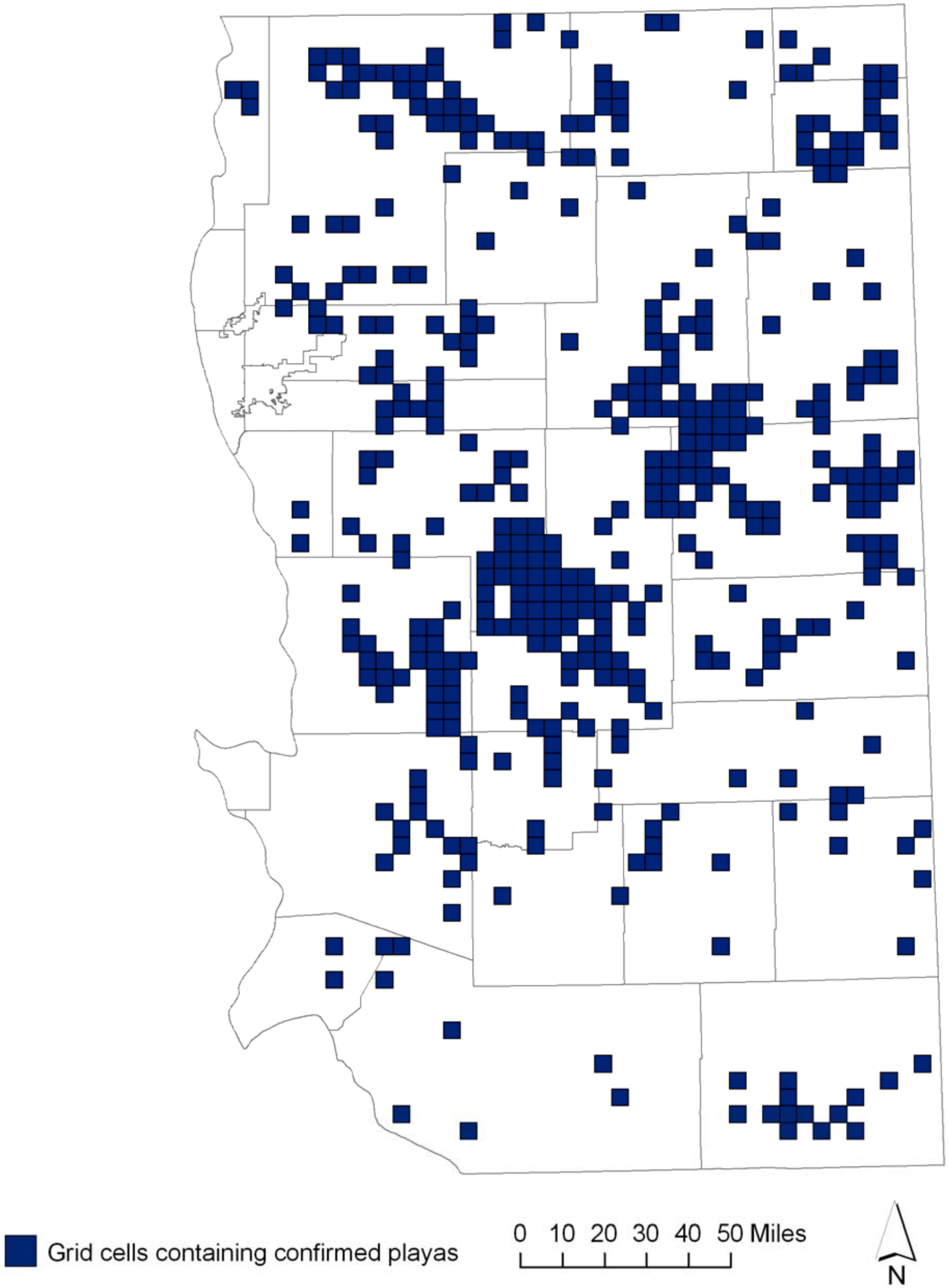


Figure 12. A map depicting the grid cells containing confirmed playas, used to generate spatial models of playa characteristics in eastern Colorado.

The mean size of confirmed playas (ha) was calculated for each grid cell containing confirmed playas (*n* = 416). The density of confirmed playas in the GIS database (km^{-2}) was calculated for all available grid cells (2462). The proportion of confirmed playas with hydrological modifications (excavations, berms, or pits) was summarized for each grid cell containing confirmed playas (*n* = 416). Likewise, the proportion of confirmed playas occurring in native grassland was calculated for each cell containing confirmed playas (*n* = 416).

We quantified the aggregation of playa attributes departures from spatially uniform distributions using Moran's (1950) Index (PROC VARIOGRAM, SAS Institute 2008). The spatial analysis was weighted by the inverse of the distance between sample points and used randomization to account for non-normal distributions (SAS Institute 2008). We also used PROC VARIOGRAM (SAS Institute 2008) to estimate the lag distance and bin number parameters for each playa attribute to be used in the predictive semivariogram models.

The Geostatistical Analyst extension in ArcGIS (ESRI 2005) was used to analyze and map spatial patterns of the playa attributes. The playa size data were $\log_e$ transformed prior to analysis. Global trends along the x,y axes were de-trended prior to fitting the 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. The cross validation function in the Geostatistical Analyst extension was used to evaluate the fit of the models (ESRI 2005). The semivariogram model exhibiting the value of the root-mean-squared standardized error (RSE) closest to one was selected for generating the prediction maps. The Ordinary Kriging model (Cressie 1988) was used to interpolate the data and to generate the final prediction maps for the playa attributes.

Results

We observed considerable spatial autocorrelation in all playa attributes investigated. The proportion of playas in grassland exhibited the greatest level of spatial clustering (Moran's I = 0.098, SD = 0.0044, Z = 23.0, P < 0.001) followed by playas with hydrological modifications (Moran's I = 0.046, SD = 0.0044, Z = 11.14, P < 0.001), playa abundance (Moran's I = 0.027, SD = 0.0044, Z = 40.50, P < 0.001), and playa size (Moran's I = 0.012, SD = 0.0007, Z = 3.21, P = 0.001). However, the coefficient of variation (CV) for the effect of spatial autocorrelation on the playa attributes was much smaller for playa abundance (CV = 2.5%) followed by the proportion of playas in grassland (CV = 4.5%), proportion of playas with hydrological modifications (CV = 9.5%), and playa size (CV = 38.5%).

The playa size data exhibited a second-order polynomial trend with smaller playas tending to occur in the center of the study area (Figure 13). This trend was removed from the data prior to fitting the semivariogram models and then added back to the final mapped surface. The spherical semivariogram model exhibited the best fit to the playa size data (RSE = 1.030) and this model was used to generate the predictive map (Figure 13).

The abundance of playas in the GIS database also exhibited a second-order polynomial trend with higher numbers occurring in the center of the study area (Figure 14). As above, this trend was removed from the data prior to fitting the semivariogram models and then added back to the final mapped surface. The Gaussian semivariogram model exhibited the best fit to the density data (RSE = 0.968) and was used to generate the final map (Figure 14).

The data for the proportion of playas with hydrological modifications exhibited a linear trend with hydrological modifications declining from southwest to northeast (Figure 15). This trend was removed from the data prior to fitting the semivariogram models, after which the trend was incorporated back to the final mapped surface. The Gaussian semivariogram model exhibited the best fit to the data (RSE = 1.040) and this model was used to generate the predictive surface (Figure 15).

The data for the proportion of playas occurring in grassland exhibited a second-order polynomial trend with lower proportion of playas in grasslands occurring in the east-central portion of the study area (Figure 16). This trend was removed from the data prior to fitting the semivariogram models and then added back to the final mapped surface. The exponential semivariogram model exhibited the best fit to the playa size data (RSE = 1.001) and this model was used to generate the final prediction map in Figure 16.

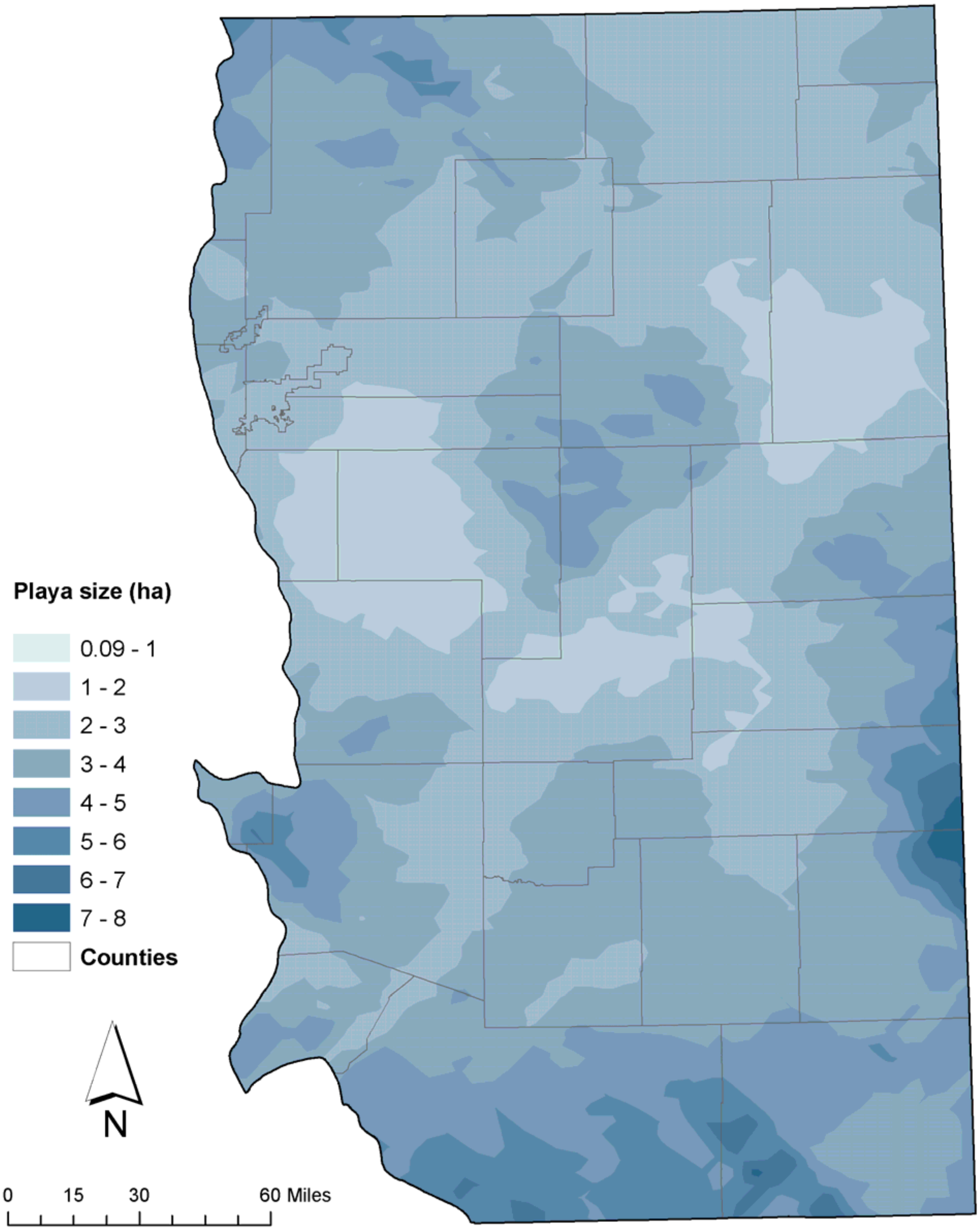


Figure 13. A spatial depiction of average playa size in eastern Colorado (e.g., where playas tend to be smaller or larger), based on field-verified playas within our GIS database.

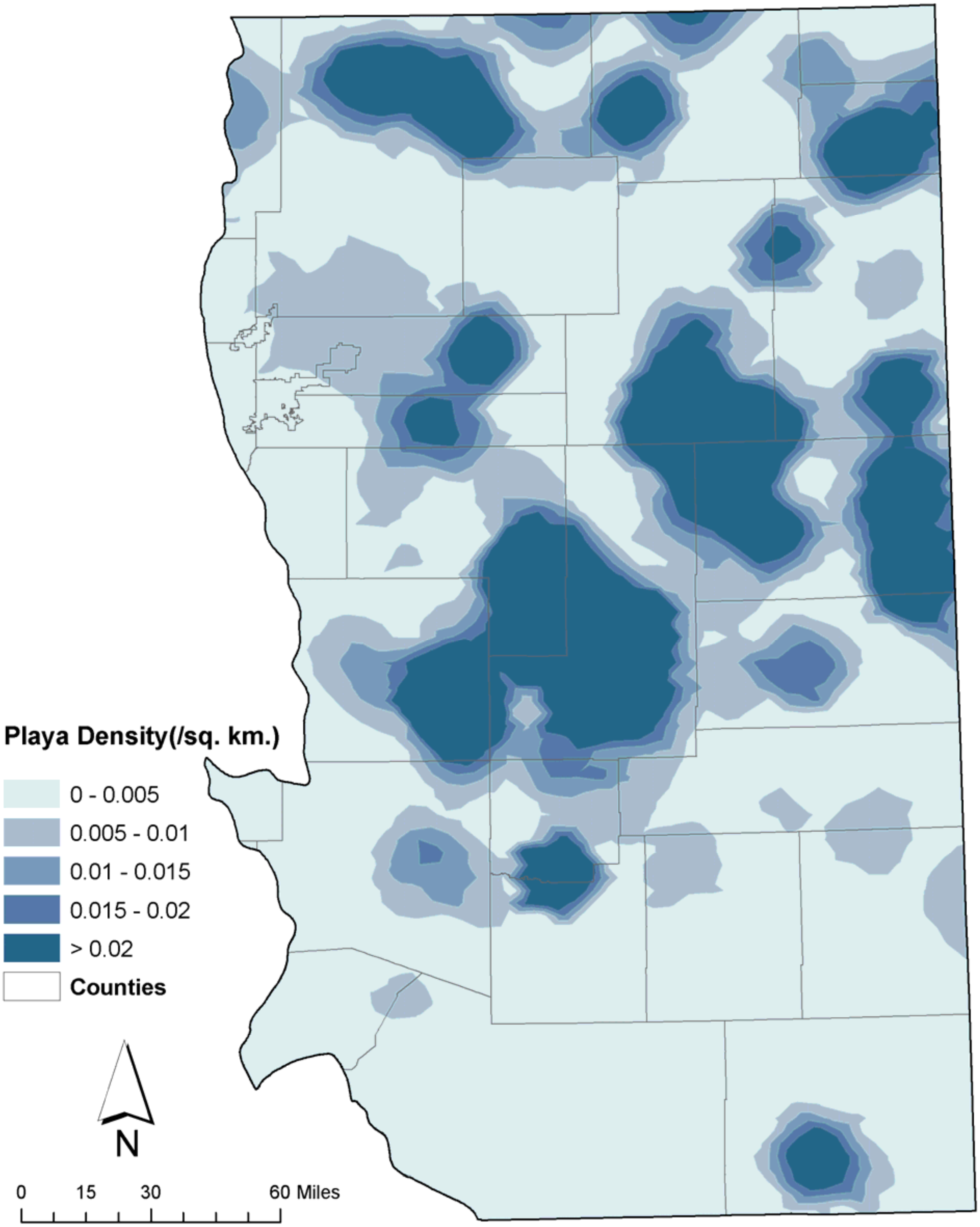


Figure 14. A spatial representation of concentrations of verified playas within our GIS database. (The estimates of playa density presented in Chapter 2 indicate some regions may have higher densities of playas than are depicted in the GIS database.)

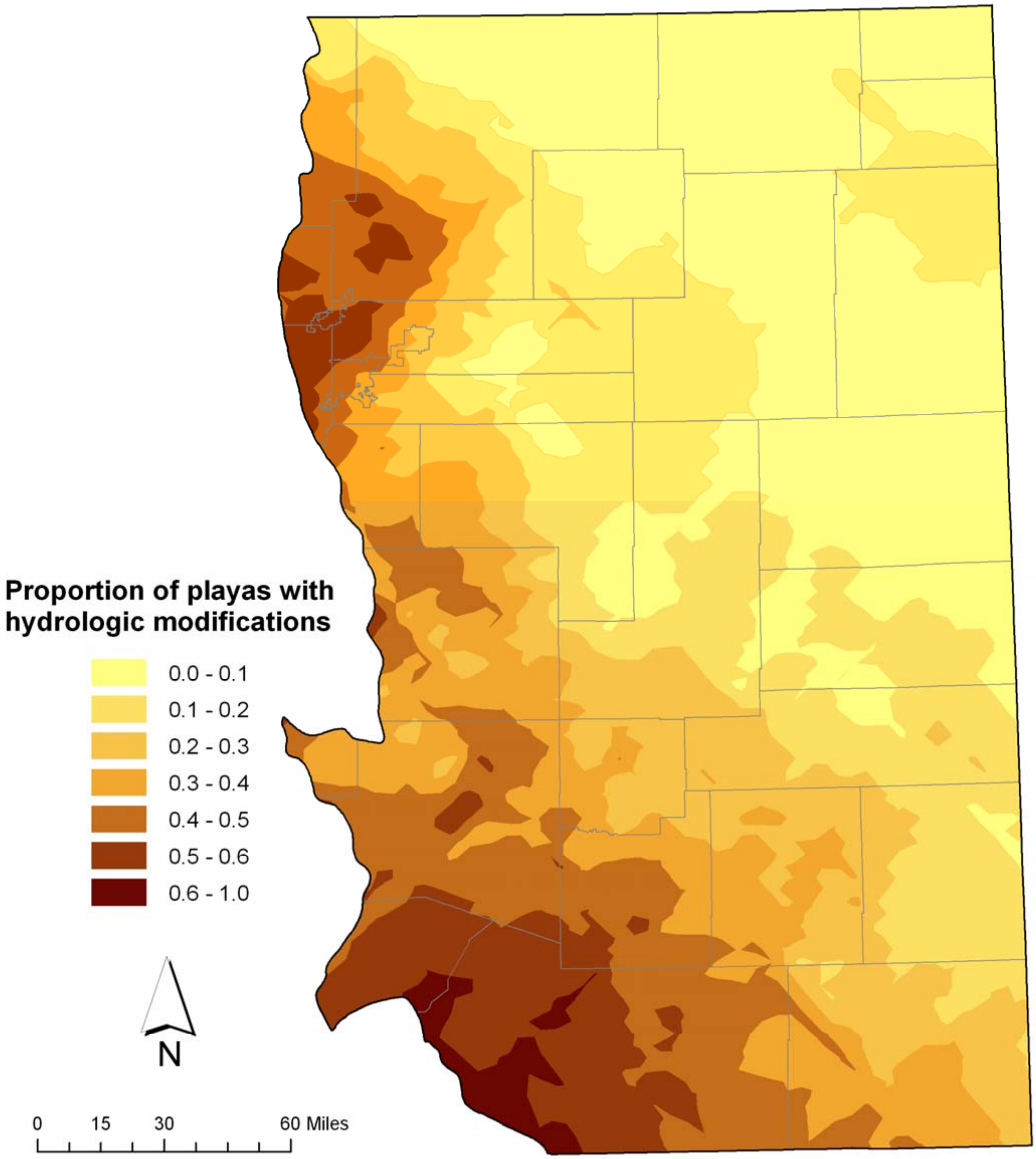


Figure 15. A spatial representation of the probabilities that Colorado playas are hydrologically modified, based on extrapolating from our field survey data.

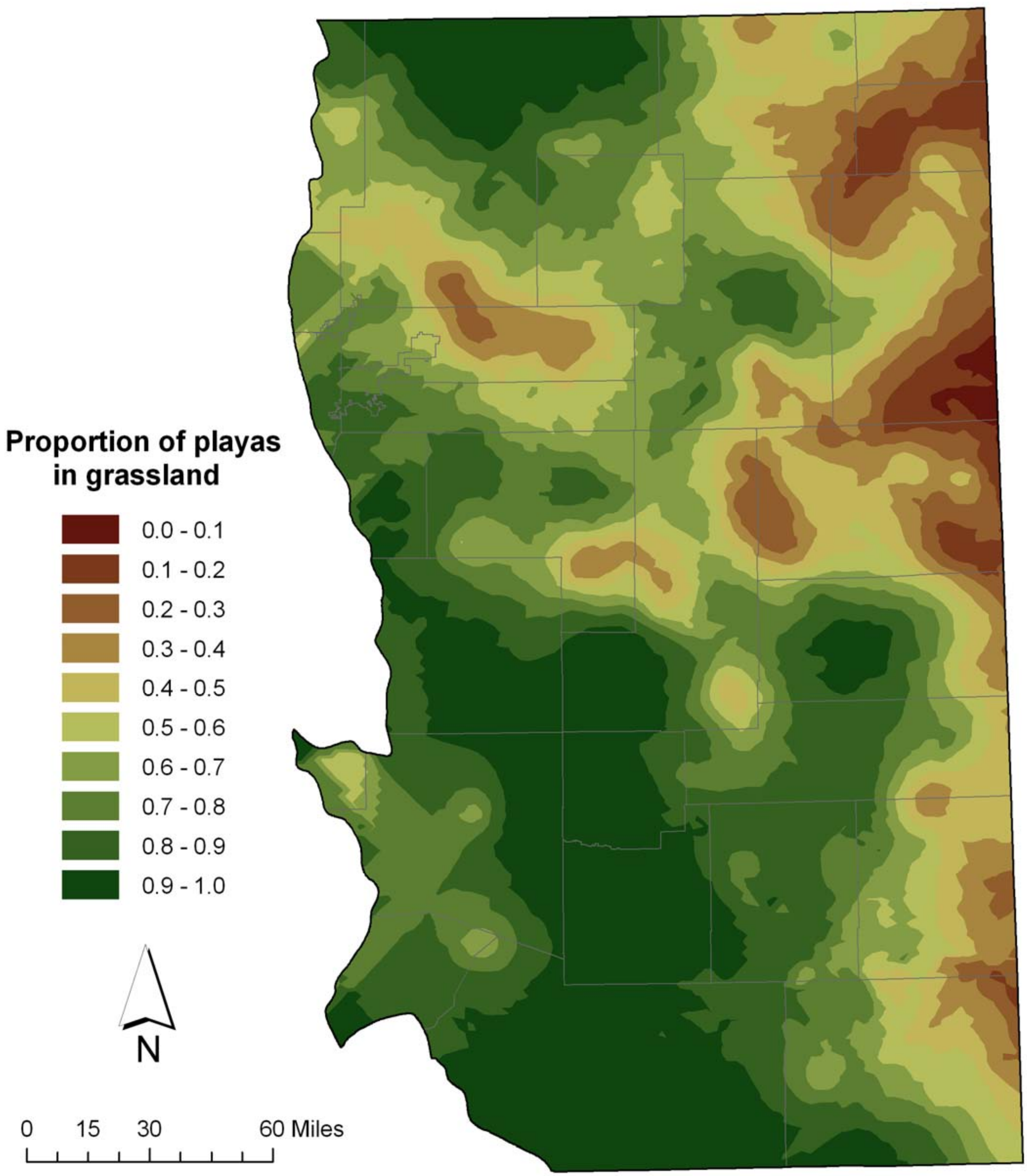


Figure 16. A spatial representation of the probabilities that Colorado playas are surrounded by grassland (shaded green) or farmland (brown).

Discussion

Eastern Colorado playa

We found significant spatial variation in the main factors that appear to influence bird use of playas: size, proximity to other playas, hydrologic modifications, and dominant land use. The variables seemed to vary most noticeably along a southwest-northeast gradient. In the southwestern part of the study area, playas are more commonly found in grassland (somtimes with pits), while cropland playas are more prevalent in the northeast. There appear to be several centers of large playa sizes and high abundances of verified playas. However, it is possible that as more spatial data become available, areas now depicted as having low playa densities may shift.

This spatial information is instrumental in guiding practitioners to where conservation practices might be applied. However, it should also be remembered that our GIS database only contains fewer than half of the playa locations that we estimate to be present in the study area. Therefore, continued work looking for more playas is warranted. We suggest using aerial photography such as the NAIP might be an effective way to identify potential playa locations. In addition, private landowners are an excellent source of knowledge about the locations and also histories associated with playas in eastern Colorado.

Playa size is an important determinant of bird use, for landbirds, shorebirds, and waterfowl. The general trend is lower playa size in the central area of eastern Colorado, with three local areas characterized by very small playa sizes (Fig. 12). Although playa sizes were spatially aggregated, the distribution of playa sizes was more uniform than the other playa attributes. In addition, the distribution of playa sizes is such that small ones are most common, and larger ones are rarer. Furthermore, a number of studies have found that larger water bodies hold water for longer time periods. Thus, there are several reasons to suggest prioritizing the conseravation of larger playas.

Shorebird and waterfowl abundance was also related to the percent of playa cover in the surrounding landscape, suggesting playas complexes are important during migration. The interaction between playa size and density is likely to play an important role in the landscape structure of playa complexes. The broad trend for the density of verified playas in the GIS database is opposite that for playa size, with more abundant playas found in central region of eastern Colorado (Fig. 13). The density of playas in the GIS database was tightly clustered, but was represented by several aggregations rather than a single cluster. It may be possible to protect many more playas for any given conservation area in the high density regions, but the best conservation outcome for migratory birds may be the protection of high density regions with larger playa sizes.

Pit removal and other hydrologic restorations may are effective ways to enhance shallow water foraging habitat conditions for migrating shorebirds. We found evidence of greater shorebird numbers in playas without hydrological modifications. These projects are also relatively affordable, and, when done with the development of alternative water sources, provide landowners with more reliable, cleaner alternative for watering their livestock. The broad trend showed the proportion of playas with hydrological modifications declined from the southwest corner to the northeast corner of eastern Colorado (Fig. 14). This pattern of playa modification may be due to the practice of using pit excavations to improve water sources for livestock in grassland of south-central Colorado.

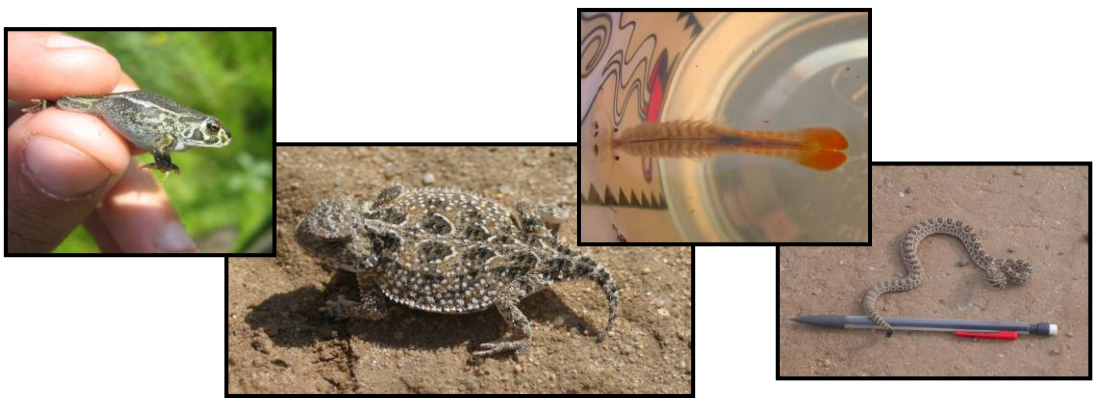
Our data indicate that grassland playas are important because they because they support higher plant species richness than cropland playas and because greater numbers of landbirds use them. Playas in shortgrass prairie are also valuable because they are not at direct risk for filling in due to sedimentation, and the native vegetation surrounding them facilitates inundation by sheet flows during heavy rainfall events. Our findings echo those of Smith and Haukos (2002), who recommended that to conserve biodiversity in the Southern Great Plains conservationists should focus on large playas with intact native prairie watersheds. The general trend was lower proportions of playas in grassland for central-eastern Colorado (Fig. 15). The proportion of playas in grassland was tightly clustered with one large aggregation in the southwest and a smaller grassland aggregation in the northwest.

Farmed playas present conservation opportunities because retiring and buffering farmed playas is an effective way to reduce the likelihood they will fill in by sedimentation. We are encouraged to see the numbers of such projects on the rise both here in Colorado as well as in other states within the range of playas. Care should be taken when selecting buffer plantings to ensure that the vegetation stature is appropriate for the site and does not impede natural flows of water to the playas.

We held a meeting in July 2008 with conservation partners to address the topic of how to disseminate data to best inform conservation. A variety of information needs were represented at meeting, as well as a variety of spatial scales. Through discussion, we determined that stakeholders have different conservation priorities and therefore require different inputs to meet their conservation goals. For instance, a land trust organization such as The Nature Conservancy may prioritize large tracts of native shortgrass prairie with relatively undisturbed playas for conservation, while an NRCS soils conservationist may prioritize farmed playas within their county for restoration. Therefore, we provided important data layers (playa locations, sizes, densities, human impacts) that can be tailored to the specific conservation goals of various stakholders. Thus, we determined that each conservation entity would need to pursue the final model of "where to work" but we should provide all of the relevant data from our project in a user-friendly format for them to do so.

We collectively determined the most important data layers that should be produced (playa locations, sizes, densities, human impacts) and that a set of conservation recommendations should be drafted to accompany the data provided. We determined that there would two outlets for the information. First, we posted an interactive, non-technical pdf document on-line to increase public awareness about playa wetlands, including their values, threats, and conservation opportunities. This document will contained most of the map figures from this report and will be posted to the RMBO website (www.rmbo.org) in January 2009. The second way we disseminated the data was in an ESRI ArcGIS 9.x geodatabase, which provides the relevant datasets to conservation partners for use in their own GIS planning environments. We discussed the importance of protecting the private landowners who own most of the playas in the study area, and agreed that landowner contact information and any information about sensitive species would remain protected by the conservation partnership.

To summarize, Colorado playas are centers of biodiversity, supporting 245 species of plants including 85 wetland species, 148 species of birds including 27 Colorado Species of Greatest Conservation Need, as well as other species of wildlife including black-tailed jack rabbit (*Lepus californicus*), coyote (*Canis latrans*), horned lizards (*Phrynosoma* spp.), spadefoot toad (*Spea hammondii*), Woodhouse's toad (*Bufo woodhousii*), lesser earless lizard (*Holbrookia maculate*), snakes, damselflies, butterflies, and clams. We hope that the information provided by our study assists in the future conservation of this vital resource for Colorado.



Wildlife found in playas: prairie rattlesnake, horned lizard, a toad, and a fairy shrimp

LITERATURE CITED

Anderson, D. R., K. P. Burnham, and G. C. White. 1994. AIC model selection in overdispersed capture-recapture data. Ecology 75:1780-1793.

Anderson, J.T. and L.M. Smith. 1999. Carrying capacity and diel use of managed playa wetlands by nonbreeding waterbirds. Wildlife Society Bulletin 27:281-291.

Anderson, J.T. and L.M. Smith. 2000. Invertebrate response to moist-soil management of playa wetlands. Ecological Applications 10:550-558.

Andres, B.A. 2007. Reservoir use by post-breeding shorebirds in the South Platte River valley of northeastern Colorado. Colorado Birds 41(1):29-35.

Baldassarre, G.A. and D.H. Fischer. 1984. Food habits of fall migrant shorebirds on the Texas High Plains. Journal of Field Ornithology 55:220-229.

Bolen, E.G., L.M. Smith, and H. L. Schramm Jr. 1989. Playa lakes: prairie wetlands of the Southern High Plains. Bioscience 39:615–623.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, UK.

Burger, J., M.A. Howe, D.C. Hahn, and J. Chase. 1977. Effects of tidal cycles on habitat selection and habitat partitioning by migrant shorebirds. Auk 94:743-758.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York.

Colorado Division of Wildlife. 2006. Colorado's Comprehensive Wildlife Conservation Strategy. Denver, CO. 328 pp.

Colwell, M.A. and L.W. Oring. 1988. Habitat use by breeding and migrating shorebirds in southcentral Saskatchewan. Wilson Bulletin 100(4):554-556.

Commission for Environmental Cooperation (CEC). 1997. Ecological regions of North America: toward a common perspective. Commission for Environmental Cooperation, Montréal, Québec.

Cressie, N. 1988. Spatial prediction and ordinary kriging. Mathematical Geology 20:405-421.

Curtis, D. and H. Beierman. 1980. Playa lakes characterization study. Fort Worth: Ecological Services, U.S. Fish and Wildlife Service.

Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. Northwest Scientist 33:43–64.

Davis, C.A., and L.M. Smith. 1998. Behavior of migrant shorebirds in playas of the southern high plains, Texas. The Condor 100:266-276.

Ducks Unlimited (DU). 2003. Playa Lakes Joint Venture Geographic Information System. Ducks Unlimited, Incorporated, Bismarck, North Dakota.

Environmental Lab. 1987. Corps of Engineers Wetland Delineation Manual, Technical Report Y-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Environmental Systems Research Institute (ESRI). 2005. ArcGIS, version 9.1. Environmental Systems Research Institute, Incorporated, Redlands, California.

Farmer, A. H. and A.H. Parent. 1997. Effects of the landscape on shorebird movements at spring migration stopovers. Condor 99: 698-707.

Flowers, T.L. 1996. Classification and occurrence of the birds of the playa lakes of Meade County, Kansas. Kansas Ornithological Bulletin 47:21–28.

Gauthier, D. A., and E. Wilken. 1998. The Great Plains of North America. PARKS 8:9-20.

Guisan, A., and N. E. Zimmermann. 2000. Predictive habitat distribution models in ecology. Ecological Modelling 135:147-186.

Guisan, A., and W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models. Ecology Letters 8:993-1009.

Guthery, F.S., F.C. Bryant, B. Kramer, A. Stocker, and M. Dvoracek. 1981. Playa Assessment Study. Amarillo: U.S. Water and Power Resources Service.

Guthery, F.S., and F.C. Bryant. 1982. Status of playas in the Southern Great Plains. Wildlife Society Bulletin 10:309–317.

Haukos, D.A., and L.M. Smith. 1994. The importance of playa wetlands to biodiversity of the Southern High Plains. Landscape and Urban Planning 28:83–98.

Haukos, D.A., and L.M. Smith. 1997. Common flora of the playa lakes. Lubbock: Texas Tech University Press.

Haukos, D.A., and L.M. Smith. 2001. Temporal emergence patterns of seedlings in playa wetlands. Wetlands 21:274-280.

Haukos, D.A., and L.M. Smith. 2003. Past and future impacts of wetland regulations on playa ecology in the southern Great Plains. Wetlands 23:577-589.

Haukos, D.A., and L.M. Smith. 2004. Plant communities of playa wetlands in the Southern Great Plains. Special Publications Number 47, Museum of Texas Tech University, Lubbock, Texas, 63 pp.

Helmers, D.L. 1991. Habitat use by migrant shorebirds and invertebrate availability in a managed wetland complex. M.S. thesis, University of Missouri, Columbia, 135 pp.

Helmers, D.L. 1993. Shorebird management manual. Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts.

Howard, T., G. Wells, L. Prosperie, R. Petrossian, H. Li, and A. Thapa. 2003. Characterization of playa basins on the high plains of Texas. Report 357. Texas Water Development Board, Austin, TX, 24 pp.

Hoagland, B.W. 1991. Final report, Colorado playa lake study. The Nature Conservancy, Denver, CO 21 pp.

Hoagland, B.W., and S.L. Collins. 1997. Heterogeneity in shortgrass prairie vegetation: the role of playa lakes. Journal of Vegetation Science 8:277–286.

Hutton, K.A and A.B. Cariveau. 2005. Survey and assessment of playas in Colorado. Rocky Mountain Bird Observatory, Brighton, CO.

Luo, H.R., L.M. Smith, B.L. Allen, D.A. Haukos. 1997. Effects of sedimentation on playa wetland volume. Ecological Applications 7:247-252.

McCullagh, P., and J. A. Nelder. 1989. Generalized Linear Models. Chapman and Hall, London, UK.

McCulloch, C. E. 2003. Generalized Linear Mixed Models. Institute of Mathematical Statistics, Beachwood, Ohio.

Moran, P. A. P. 1950. Notes on continuous stochastic phenomena. Biometrika **37**:17-23.

Marx, D. 2004. Survey and assessment of playas in Colorado. Rocky Mountain Bird Observatory, Brighton, CO.

Melcher, C.P. and S.K. Skagen. 2005. Grass buffers for playas in agricultural landscapes: a literature synthesis. U.S. Geological Survey, Biological Resources Division, Open-File Report 2005-1220, 35 p.

Nelder, J. A., and R. W. M. Wedderburn. 1972. Generalized linear models. Journal of the Royal Statistical Society. Series A 135:370-384.

Nelson, R.W., W.J. Logan, and E.C. Weller. 1983. Playa wetlands and wildlife on the Southern Great Plains: a characterization of habitat. US Fish and Wildlife Service, Albuquerque, NM.

Niemuth, N.D., M.E. Estey, R.E. Reynolds, C.R. Loesch, and W.A. Meeks. 2006. Use of wetlands by spring-migrant shorebirds in agricultural landscapes of North Dakota's drift prairie. Wetlands 26: 30-39.

North American Waterfowl Management Plan (NAWMP) Plan Committee. 2004. North American Waterfowl Management Plan 2004. Strategic Guidance: Strengthening the Biological Foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales.

Ostercamp, W.R. and W.W. Wood. 1987. Playa-lake basins on the Southern High Plains of Texas and New Mexico, Part I. Hydrologic, geomorphic, and geologic evidence of their development. Geological Society of America Bulletin 99:215-223.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. Condor 109:949-954.

Reed, P.B., Jr. 1988. National list of vascular plant species that occur in wetlands: national summary. U.S. Fish Wildlife Service Biological Report 88(24). 244 pp.

Reed, E.L. 1930. Vegetation of the playa lakes in the Staked Plains of western Texas. Ecology 11:597-600.

Reddell, D.L. 1965. Water resources of playa lakes. Cross Section 12:1.

Rhodes, M.J., and J.D. Garcia. 1981. Characteristics of playa lakes related to summer waterfowl use. Southwestern Naturalist 26:231-235.

Rice, W. R. 1989. Analyzing tables of statistical tests. Evolution 43:223-225.

Rivers, J. W., and T. E. Cable. 2003. Evaluation of farmed playa wetlands as avian habitat using survey data and two rapid assessment techniques. Transactions of the Kansas Academy of Science 106:155–165.

SAS Institute. 2008. SAS/STAT. Version 9.2. SAS Institute, Incorporated, Cary, North Carolina.

Sheeley, D.G., and L.M. Smith. 1989. Tests of diet and condition bias in hunter-killed northern pintails. Journal of Wildlife Management 53:765-769.

Skagen, S.K., and F.L. Knopf. 1993. Toward conservation of midcontinental shorebird migration. Conservation Biology 7:533-541.

Skagen, S.K. and F.L. Knopf. 1994a. Residency patterns of migrating sandpipers at a midcontinental stopover. Condor 1996: 949-958.

Smith, L.M., and D.A. Haukos. 2002. Floral diversity in relation to playa wetland area and watershed disturbance. Conservation Biology 16:964–974.

Smith, L.M. 2003. Playas of the Great Plains. University of Texas, Austin, TX.

Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2006. Distance 5.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, St. Andrews, UK.

US Census Bureau. 2007. TIGER/Line shapefiles. US Department of Commerce, US Census Bureau, Washington, D.C.

US Department of Agriculture (USDA). 1995. Soil survey geographic (SSURGO) data base. Miscellaneous Publication 1527, United States Department of Agriculture, National Soil Survey Center, National Resources Conservation Service, Fort Worth, Texas.

US Geological Survey (USGS). 2000. National Hydrography Dataset. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency, Reston, Virginia.

US North American Bird Conservation Initiative Committee (US NABCI Committee). 2000a. Bird conservation regions descriptions: a supplement to the North American bird conservation initiative: bird conservation regions map. US Fish and Wildlife Service, Arlington, Virginia.

US North American Bird Conservation Initiative Committee (US NABCI Committee). 2000b. North American bird conservation initiative: bird conservation regions map. US Fish and Wildlife Service, Arlington, Virginia.

United States Shorebird Conservation Plan (USSCP). 2004. High Priority Shorebirds - 2004. Unpublished Report, U. S. Fish and Wildlife Service: Arlington, VA.

Wilson, S.L. 1999. The Wetland status of cropped playa lakes in Western Kansas. M.S. thesis, 16 pp.

Wood, W.W. 2000. Ground-water recharge in the Southern High Plains of Texas and New Mexico. U.S. Geological Survey. FS-127-99.

Zartman, R.E. 1994. Playa lakes on the Southern High Plains: reevaluating infiltration. Journal of Soil and Water Conservation 49:299–301.

APPENDIX A

REPRESENTATIVE PLAYA PHOTOS

*Note: Photo records from all photos taken during roadside or on-site visits are on file and available from RMBO upon request. Photos taken of sites owned by private landowners will be shared following approval from landowner.

The following photos depict common playa landscape setting and conditions in eastern Colorado.

Farmed playas.

Bermed playa (top) and pitted playa (bottom).

Grazed playa (top) and playa bisected by power line (bottom).

Playas bisected by roads.

Waterbodies identified by the initial GIS database which were found to not be playas.

APPENDIX B

STATISTICAL TABLES

Table B-1. Model selection statistics for the data source confirmation models.

Model	K	log(L)	AICc	ΔAICc	w_i
Source County(Source) Landcover Size Distance	42	-385.66	860.04	0.00	0.589
Source County(Source) Landcover Distance	41	-388.07	862.64	2.59	0.161
Source County(Source) Landcover	40	-389.58	863.43	3.39	0.108
Source County(Source) Landcover Size	41	-388.50	863.50	3.45	0.105

Table B-2. Model parameters from the best approximating model for the effects of data source on confirmation rates.

Parameter	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL	X^2	P
Intercept		1.932	0.5033	1.0058	3.0061	14.74	0.0001
LS		0.326	0.6614	-1.0006	1.6226	0.24	0.6218
LS/NHD/SS		1.877	1.1451	-0.0553	4.8839	2.69	0.1012
LS/SS		0.575	0.7385	-0.8569	2.0992	0.61	0.4362
NHD		-2.352	0.6250	-3.6535	-1.1823	14.16	0.0002
NHD/SS		0.247	0.8014	-1.2801	1.9506	0.10	0.7577
SS		-	-	-	-	-	-
LS	Arapahoe	-0.853	0.7034	-2.2564	0.5361	1.47	0.2255
LS	Bent	-2.509	1.2004	-5.5737	-0.4123	4.37	0.0366
LS	Crowley	-0.735	0.7689	-2.2311	0.8365	0.91	0.3394
LS	Elbert	-2.538	0.6173	-3.7987	-1.3658	16.90	<.0001
LS	Kit Carson	-1.816	0.8124	-3.5527	-0.2929	5.00	0.0254
LS	Lincoln	1.145	1.1357	-0.7602	4.1418	1.02	0.3132
LS	Otero	-2.675	1.2323	-5.7797	-0.5180	4.71	0.0300
LS	Phillips	-0.097	1.2177	-2.2587	2.9812	0.01	0.9364
LS	Prowers	-2.446	0.7722	-4.1269	-1.0327	10.03	0.0015
LS	Pueblo	-1.927	0.6072	-3.1684	-0.7729	10.07	0.0015
LS	Washington	-1.142	0.8318	-2.8227	0.5129	1.89	0.1697
LS	Yuma	-	-	-	-	-	-
LS/NHD/SS	Elbert	-1.977	1.5409	-5.3892	1.4153	1.65	0.1995
LS/NHD/SS	Kit Carson	-2.166	1.2631	-5.2977	0.1139	2.94	0.0864
LS/NHD/SS	Washington	-	-	-	-	-	-
LS/SS	Arapahoe	-0.503	0.8841	-2.2526	1.3148	0.32	0.5698
LS/SS	Elbert	1.187	0.9219	-0.5582	3.2432	1.66	0.1978
LS/SS	Kit Carson	0.760	0.9353	-1.0131	2.8353	0.66	0.4164
LS/SS	Washington	-	-	-	-	-	-
NHD	Adams	-0.361	1.1405	-3.3606	1.5689	0.10	0.7519
NHD	Bent	0.549	1.0271	-1.6475	2.5663	0.29	0.5929
NHD	Logan	1.608	0.9264	-0.2645	3.4932	3.01	0.0825
NHD	Morgan	0.851	0.8350	-0.8929	2.4780	1.04	0.3079
NHD	Weld	-	-	-	-	-	-
NHD/SS	Kit Carson	1.668	1.2146	-0.5161	4.7403	1.88	0.1698
NHD/SS	Washington	-	-	-	-	-	-
SS	Adams	-1.157	0.5876	-2.3704	-0.0433	3.88	0.0490
SS	Arapahoe	0.562	1.2244	-1.6161	3.6481	0.21	0.6461
SS	Baca	-0.986	0.5957	-2.2107	0.1494	2.74	0.0977
SS	El Paso	0.687	0.8891	-0.9439	2.7060	0.60	0.4399
SS	Elbert	0.272	0.6867	-1.0804	1.6616	0.16	0.6924
SS	Kiowa	-0.171	0.8480	-1.8104	1.6003	0.04	0.8400
SS	Kit Carson	1.374	0.6503	0.0817	2.6747	4.47	0.0346
SS	Lincoln	2.502	1.1187	0.6352	5.4804	5.00	0.0253
SS	Phillips	-1.174	0.5844	-2.3820	-0.0674	4.03	0.0446
SS	Prowers	-0.642	0.7530	-2.1529	0.8354	0.73	0.3941

Table B-2. Model parameters from the best approximating model for the effects of data source on confirmation rates.

Parameter	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL	X^2	P
SS	Washington	-1.078	0.5483	-2.2212	-0.0449	3.86	0.0493
SS	Weld	-	-	-	-	-	-
CRP		-0.583	0.3930	-1.3532	0.1921	2.20	0.1383
Crop		-0.962	0.2721	-1.5061	-0.4366	12.49	0.0004
Grass		-	-	-	-	-	-
lnHectare		0.264	0.1209	0.0283	0.5031	4.78	0.0288
Near		-0.002	0.0010	-0.0043	-0.0004	5.62	0.0177

Table B-3. Pair-wise tests of differences among data sources, counties within data source and landcover type.

Effects			Estimate	SE	X^2	p-value	LCL	UCL
Data Source	Landsat	Landsat/Soils	-1.909	0.415	21.16	<.0001	-2.723	-1.096
	Landsat/Soils	NHD	2.759	0.505	29.83	<.0001	1.769	3.749
	NHD	NHD/Soils	-2.903	0.717	16.39	<.0001	-4.309	-1.498
	NHD	Soils	-1.838	0.412	19.90	<.0001	-2.646	-1.030
	Landsat/NHD/ Soils	NHD	2.319	0.679	11.65	0.0006	0.988	3.650
	Landsat	Soils	-0.989	0.303	10.67	0.0011	-1.582	-0.396
	Landsat	NHD/Soils	-2.054	0.668	9.46	0.0021	-3.363	-0.745
Data Source	**County 1**	**County 2**						
Landsat	Elbert	Yuma	-2.538	0.617	16.90	<.0001	-3.748	-1.328
	Elbert	Lincoln	-3.683	1.139	10.46	0.0012	-5.915	-1.451
	Prowers	Yuma	-2.446	0.772	10.03	0.0015	-3.959	-0.932
	Pueblo	Yuma	-1.927	0.607	10.07	0.0015	-3.117	-0.737
	Lincoln	Prowers	3.591	1.237	8.43	0.0037	1.167	6.016
	Lincoln	Pueblo	3.072	1.138	7.29	0.0069	0.842	5.302
Soils	Adams	Kit Carson	-2.531	0.541	21.86	<.0001	-3.592	-1.470
	Baca	Kit Carson	-2.361	0.566	17.42	<.0001	-3.469	-1.252
	Kit Carson	Phillips	2.548	0.538	22.43	<.0001	1.493	3.602
	Kit Carson	Washington	2.452	0.501	23.97	<.0001	1.471	3.434
	Lincoln	Phillips	3.676	1.075	11.69	0.0006	1.569	5.783
	Adams	Lincoln	-3.659	1.076	11.57	0.0007	-5.767	-1.551
	Lincoln	Washington	3.580	1.054	11.53	0.0007	1.514	5.646
	Baca	Lincoln	-3.489	1.078	10.48	0.0012	-5.601	-1.376
	Kit Carson	Prowers	2.016	0.717	7.90	0.0049	0.611	3.421

All degrees of freedom = 1 and alpha values = 0.05.

Table B-4. Estimated playa confirmation rates by data source, landcover type, and county.

Parameter	*County*	*Estimate*	*Standard Error*
LANDSAT	Arapahoe	0.655	0.1339
LANDSAT	Bent	0.266	0.2208
LANDSAT	Crowley	0.681	0.1374
LANDSAT	Elbert	0.261	0.0839
LANDSAT	Kit Carson	0.420	0.1748
LANDSAT	Lincoln	0.933	0.0656

Table B-4. Estimated playa confirmation rates by data source, landcover type, and county.

Parameter	*County*	*Estimate*	*Standard Error*
LANDSAT	Otero	0.235	0.2087
LANDSAT	Phillips	0.802	0.1818
LANDSAT	Prowers	0.279	0.1333
LANDSAT	Pueblo	0.394	0.1058
LANDSAT	Washington	0.587	0.1764
LANDSAT	Yuma	0.817	0.0682
LANDSAT/NHD/SOILS	Elbert	0.744	0.2157
LANDSAT/NHD/SOILS	Kit Carson	0.707	0.1503
LANDSAT/NHD/SOILS	Washington	0.955	0.0452
LANDSAT/SOILS	Arapahoe	0.776	0.1203
LANDSAT/SOILS	Elbert	0.949	0.0354
LANDSAT/SOILS	Kit Carson	0.924	0.0529
LANDSAT/SOILS	Washington	0.851	0.0712
NHD	Adams	0.176	0.1570
NHD	Bent	0.347	0.2120
NHD	Logan	0.605	0.2027
NHD	Morgan	0.418	0.1825
NHD	Weld	0.235	0.0754
NHD/SOILS	Kit Carson	0.956	0.0433
NHD/SOILS	Washington	0.805	0.1043
SOILS	Adams	0.503	0.0886
SOILS	Arapahoe	0.850	0.1449
SOILS	Baca	0.545	0.0863
SOILS	El Paso	0.865	0.0904
SOILS	Elbert	0.809	0.0794
SOILS	Kiowa	0.731	0.1413
SOILS	Kit Carson	0.927	0.0303
SOILS	Lincoln	0.975	0.0246
SOILS	Phillips	0.499	0.0857
SOILS	Prowers	0.629	0.1348
SOILS	Washington	0.523	0.0700
SOILS	Weld	0.763	0.0870

Table B-5. Pair-wise tests of differences among data sources, sources within counties, and landcover type.

Effects			**Estimate**	**SE**	**X^2**	**p-value**	**LCL**	**UCL**
County	Adams	Kit Carson	-2.504	0.654	14.64	0.0001	-3.787	-1.221
	Adams	Lincoln	-3.922	0.928	17.85	<.0001	-5.741	-2.102
	Bent	Lincoln	-3.980	1.034	14.81	0.0001	-6.007	-1.953
	Kit Carson	Pueblo	2.170	0.546	15.8	<.0001	1.100	3.240
	Kit Carson	Weld	1.745	0.455	14.72	0.0001	0.854	2.637
	Lincoln	Prowers	3.367	0.853	15.58	<.0001	1.695	5.040
	Lincoln	Pueblo	3.588	0.847	17.93	<.0001	1.927	5.248
	Lincoln	Weld	3.163	0.798	15.69	<.0001	1.598	4.728
	Baca	Lincoln	-2.973	0.814	13.36	0.0003	-4.568	-1.379
	Kit Carson	Prowers	1.950	0.546	12.75	0.0004	0.879	3.020
	Lincoln	Morgan	3.487	1.046	11.12	0.0009	1.438	5.537
	Pueblo	Washington	-1.762	0.530	11.04	0.0009	-2.801	-0.722
	Adams	Washington	-2.096	0.643	10.61	0.0011	-3.357	-0.835
	Adams	Yuma	-2.261	0.706	10.26	0.0014	-3.644	-0.878

Table B-5. Pair-wise tests of differences among data sources, sources within counties, and landcover type.

Effects			Estimate	SE	X^2	p-value	LCL	UCL
	Bent	Kit Carson	-2.562	0.803	10.19	0.0014	-4.136	-0.989
	Lincoln	Otero	4.335	1.367	10.05	0.0015	1.656	7.015
	Pueblo	Yuma	-1.927	0.607	10.07	0.0015	-3.117	-0.737
	Baca	Kit Carson	-1.556	0.496	9.86	0.0017	-2.527	-0.585
	Washington	Weld	1.337	0.438	9.33	0.0023	0.479	2.195
Landcover type	**Crop**	**Grass**	-0.962	0.272	12.49	0.0004	-1.495	-0.428
County	**Data Source 1**	**Data Source 2**						
Elbert	Landsat	Landsat/Soils	-3.974	0.859	21.39	<.0001	-5.658	-2.290
	Landsat	Soils	-2.483	0.659	14.21	0.0002	-3.774	-1.192
Kit Carson	Landsat	Soils	-2.864	0.824	12.09	0.0005	-4.479	-1.249
	Landsat	Landsat/Soils	-2.825	1.025	7.6	0.0058	-4.834	-0.816
	Landsat	NHD/Soils	-3.405	1.254	7.38	0.0066	-5.862	-0.948
Washington	Landsat/NHD/ Soils	Soils	2.955	1.073	7.59	0.0059	0.853	5.058
	Landsat/Soils	Soils	1.653	0.617	7.18	0.0074	0.444	2.862
Weld	NHD	Soils	-2.3519	0.625	14.16	0.0002	-3.577	-1.1269

All degrees of freedom = 1 and alpha values = 0.05.

Table B-6. Model selection statistics for the Soils data source confirmation models .

Model	K	log(L)	AICc	ΔAICc	w_i
Soil County(Soil) Landcover Distance	17	-278.63	592.25	0.00	0.480
Soil County(Soil) Landcover	16	-280.45	593.78	1.53	0.223
Soil County(Soil) Landcover Size Distance	18	-278.54	594.19	1.94	0.182
Soils County(Soil) Landcover Size	17	-280.06	595.11	2.86	0.115

Table B-7. Model parameters from the best approximating model for the effects of Soils data source on confirmation rate.

Parameter	County	Estimate	SE	Lower 95% CL	Upper 95% CL	X^2	*P*
Intercept		2.091	0.3761	1.3786	2.8574	30.91	<.0001
APIS		3.130	1.0326	1.5394	6.0244	9.19	0.0024
IW		-0.704	0.3778	-1.4571	0.0299	3.47	0.0625
PLAYA		0.136	0.4783	-0.7787	1.1168	0.08	0.7768
PLSC		-	-	-	-	-	-
APIS	Lincoln	-	-	-	-	-	-
IW	Adams	0.045	0.4588	-0.8559	0.9498	0.01	0.9222
IW	Arapahoe	1.355	0.6701	0.1008	2.7780	4.09	0.0432
IW	Crowely	0.983	1.2563	-1.2323	4.1115	0.61	0.4342
IW	Logan	1.084	0.9051	-0.5855	3.1243	1.43	0.2313
IW	Phillips	-	-	-	-	-	-
PLAYA	Baca	-0.709	0.5602	-1.8386	0.3739	1.60	0.2053
PLAYA	El Paso	1.121	0.8703	-0.4488	3.1187	1.66	0.1979
PLAYA	Elbert	1.121	0.5796	-0.0220	2.2769	3.74	0.0530
PLAYA	Kiowa	0.503	0.7369	-0.9080	2.0312	0.47	0.4945
PLAYA	Prowers	-0.560	0.7097	-1.9807	0.8294	0.62	0.4297

Table B-7. Model parameters from the best approximating model for the effects of Soils data source on confirmation rate.

Parameter	County	Estimate	SE	Lower 95% CL	Upper 95% CL	X^2	*P*
PLAYA	Weld	-	-	-	-	-	-
PLSC	Kit Carson	1.677	0.3665	0.9857	2.4321	20.93	<.0001
PLSC	Washington	-	-	-	-	-	-
CRP		-0.780	0.4275	-1.6219	0.0626	3.33	0.0682
Crop		-1.512	0.3120	-2.1513	-0.9224	23.49	<.0001
Grass		-	-	-	-	-	-
Near		-0.002	0.0011	-0.0041	0.0001	3.64	0.0565

Table B-8. Model averaged estimates of playa density mi^{-2} and abundance by county for eastern Colorado.

County	n	Parameter	Estimate	SE	CV	Lower 95% CI	Upper 95% CI
Adams	8	Density	0.160	0.1540	96.26	0.0324	0.7903
		Abundance	189	182	96.27	38	935
Arapahoe	2	Density	-	-	-	-	-
		Abundance	-	-	-	-	-
Baca	10	Density	0.086	0.0428	49.65	0.0341	0.2174
		Abundance	220	109	49.65	87	556
Bent	5	Density	0.238	0.2374	99.67	0.0463	1.2261
		Abundance	367	366	99.67	71	1889
Cheyenne	5	Density	0.462	0.2218	48.01	0.1881	1.1344
		Abundance	823	395	48.01	335	2021
Crowley	3	Density	1.909	1.0763	56.37	0.6774	5.3818
		Abundance	1528	861	56.37	542	4306
Douglas	2	Density	0.375	0.1070	28.51	0.2161	0.6511
		Abundance	213	61	28.50	123	369
El Paso	3	Density	0.370	0.2030	54.90	0.1344	1.0177
		Abundance	677	372	54.90	246	1863
Elbert	11	Density	0.932	0.4217	45.23	0.3981	2.1838
		Abundance	1725	780	45.23	736	4039
Fremont	1	Density	-	-	-	-	-
		Abundance	-	-	-	-	-
Kiowa	4	Density	0.376	0.2533	67.46	0.1122	1.2569
		Abundance	671	453	67.46	200	2245
Kit Carson	8	Density	0.662	0.1686	25.47	0.4038	1.0858
		Abundance	1432	365	25.47	873	2348
Las Animas	8	Density	0.083	0.0725	87.72	0.0186	0.3669
		Abundance	304	267	87.72	69	1351
Lincoln	4	Density	0.838	0.5935	70.84	0.2381	2.9477
		Abundance	2166	1534	70.84	616	7620
Logan	2	Density	0.563	0.2195	38.97	0.2683	1.1827
		Abundance	1039	405	38.97	495	2181
Morgan	3	Density	0.203	0.1091	53.76	0.0751	0.5484
		Abundance	262	141	53.75	97	709

Table B-8. Model averaged estimates of playa density mi^{-2} and abundance by county for eastern Colorado.

County	n	Parameter	Estimate	SE	CV	Lower 95% CI	Upper 95% CI
Otero	5	Density	-	-	-	-	-
		Abundance	-	-	-	-	-
Phillips	4	Density	0.320	0.0659	20.58	0.2143	0.4786
		Abundance	221	45	20.59	148	330
Prowers	4	Density	-	-	-	-	-
		Abundance	-	-	-	-	-
Pueblo	3	Density	0.929	0.6558	70.56	0.2653	3.2566
		Abundance	2076	1465	70.56	593	7275
Sedgwick	3	Density	0.408	0.1018	24.95	0.2513	0.6625
		Abundance	224	56	24.95	138	364
Washington	9	Density	0.928	0.4004	43.12	0.4111	2.0968
		Abundance	2343	1010	43.12	1037	5291
Weld	15	Density	0.563	0.1930	34.30	0.2915	1.0865
		Abundance	2259	775	34.30	1170	4361
Yuma	8	Density	0.460	0.2112	45.94	0.1939	1.0896
		Abundance	1089	500	45.94	459	2582

Table B-9: Model selection statistics for all birds, dry playas

Model	K	Log(L)	AICc	ΔAICc	w_i
Size Hydro Landcover Road Wetland	17	-2698.74	2731.77	0.00	0.516
Size Hydro Landcover Road Area Wetland	18	-2698.11	2733.28	1.51	0.242
Size Hydro Landcover Road	16	-2702.33	2735.37	3.60	0.085

Table B-10: Model parameters for best approximating model for all birds, dry playas

Effect	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL
Intercept		-0.63	0.541	-1.689	0.437
Year	2004	0.16	0.445	-0.723	1.042
Year	2005	0.35	0.513	-0.672	1.366
Year	2006	2.14	0.445	1.255	3.020
Year	2007	-	-	-	-
Season	Fall	1.22	0.365	0.491	1.940
Season	Spring	-	-	-	-
Date		0.33	0.132	0.071	0.593
Date^2		0.62	0.209	0.208	1.036
Date^2*year	2004	-0.29	0.226	-0.738	0.160
Date^2*year	2005	-0.32	0.259	-0.832	0.197
Date^2*year	2006	-1.31	0.300	-1.909	-0.720
Date^2*year	2007	-	-	-	-
Playa Size		0.09	0.026	0.042	0.144
Hydro	Altered	0.60	0.266	0.073	1.130
Hydro	Not Altered	-	-	-	-
Landcover	Ag	-0.53	0.190	-0.906	-0.153

Table B-10: Model parameters for best approximating model for all birds, dry playas

Effect	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL
Landcover	Grass	-	-	-	-
Distance from Road		0.64	0.342	-0.036	1.323
Distance from Wetland		-0.06	0.022	-0.099	-0.013
Playa ID [a]		0.38	0.158	0.191	0.665
Scale [b]		2.37	0.240	1.997	2.812

[a] Covariance parameter for the random effect of Playa ID.
[b] Dispersion parameter for the negative binomial distribution.

Table B-11: Estimated mean bird count for all birds, dry playas

Parameter	Parameter	Estimate	SE
Year	2004	1.98	0.403
Year	2005	2.30	0.591
Year	2006	3.57	0.897
Year	2007	2.50	0.795
Season	Fall	4.64	0.878
Season	Spring	1.38	0.413
Hydro	Altered	3.41	0.900
Hydro	Not Altered	1.87	0.297
Landcover	Ag	1.94	0.432
Landcover	Grass	3.29	0.546

Overall mean bird count: mean = 4.31, SE = 0.496

Table B-12: Model selection statistics for all birds, wet playas

Model	K	Log(L)	AICc	ΔAICc	w_i
Size Hydro Area	12	-2787.32	5599.15	0.00	0.337
Size Hydro Area Wetland	13	-2787.30	5601.22	2.07	0.120
Size Hydro	11	-2789.72	5601.88	2.73	0.086
Size Hydro Road	12	-2788.93	5602.39	3.24	0.067
Size Road	11	-2790.19	5602.83	3.68	0.053

Table B-13: Model parameters for best approximating model for all birds, wet playas

Effect	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL
Intercept		2.95	0.837	1.305	4.603
Year	2004	0.64	0.556	-0.457	1.727
Year	2005	1.13	0.560	0.032	2.235
Year	2006	1.31	0.529	0.272	2.351
Year	2007	-	-	-	-
Season	Fall	-1.27	0.649	-2.547	0.004
Season	Spring	-	-	-	-

Date		-0.27	0.155	-0.576	0.031
Date^2		-0.49	0.118	-0.725	-0.260
Playa Size		0.12	0.028	0.069	0.180
Hydro	Altered	0.49	0.256	-0.013	0.995
Hydro	Not Altered	-	-	-	-
Playa Area-Landscape		0.20	0.087	0.030	0.372
Playa ID [a]		0.78	0.208	0.500	1.199
Scale [b]		1.90	0.129	1.689	2.151

[a] Covariance parameter for the random effect of Playa ID.
[b] Dispersion parameter for the negative binomial distribution.

Table B-14: Estimated mean bird count for all birds, wet playas

Parameter	Parameter	Estimate	SE
Year	2004	36.23	12.705
Year	2005	59.66	20.027
Year	2006	71.27	22.793
Year	2007	19.20	11.238
Season	Fall	21.96	4.565
Season	Spring	78.31	47.199
Hydro	Altered	53.01	19.429
Hydro	Not Altered	32.44	9.979

Overall mean bird count: mean = 25.75, SE = 3.741

Table B-15: Model selection statistics for landbirds

Model	K	Log(L)	AICc	ΔAICc	w_i
Size Hydro Landcover Road Wetland	19	-3281.91	6602.49	0.00	0.416
Size Hydro Landcover Road Area Wetland	20	-3281.34	6603.42	0.93	0.261
Size Hydro Landcover Road	18	-3284.22	6605.04	2.55	0.116
Size Hydro Landcover Road Area	19	-3281.91	6605.74	3.25	0.082

Table B-16: Model parameters for best approximate model for landbirds

Effect	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL
Intercept		0.48	0.509	-0.523	1.476
Season	Fall	0.73	0.342	0.057	1.398
Season	Spring	-	-	-	-
Year	2004	0.09	0.380	-0.654	0.839
Year	2005	0.06	0.393	-0.711	0.833
Year	2006	1.38	0.350	0.690	2.066
Year	2007	-	-	-	-
Date		0.52	0.148	0.225	0.807
Date^2		0.19	0.229	-0.263	0.637
Date^2*Year	2004	-0.26	0.195	-0.640	0.125

Date^2*Year	2005	-0.12	0.210	-0.533	0.291
Date^2*Year	2006	-1.22	0.219	-1.646	-0.785
Date^2*Year	2007	-	-	-	-
Date^2*Season	Fall	0.39	0.207	-0.017	0.796
Date^2*Season	Spring	-	-	-	-
Wetness	Dry	-0.32	0.139	-0.597	-0.050
Wetness	Wet	-	-	-	-
Playa Size		0.07	0.018	0.031	0.101
Hydro	Altered	0.73	0.182	0.377	1.092
Hydro	Not Altered	-	-	-	-
Landcover	Ag	-0.36	0.142	-0.640	-0.084
Landcover	Grass	-	-	-	-
Distance from Road		0.32	0.177	-0.023	0.671
Distance from Wetland		-0.03	0.016	-0.065	-0.001
Playa ID [a]		0.38	0.116	0.229	0.580
Scale [b]		2.45	0.154	2.199	2.728

[a] Covariance parameter for the random effect of Playa ID.
[b] Dispersion parameter for the negative binomial distribution.

Table B-17: Estimated mean bird count for landbirds

Parameter	Parameter	Estimate	SE
Season	Fall	6.71	1.023
Season	Spring	2.20	0.591
Year	2004	3.31	0.649
Year	2005	3.67	0.744
Year	2006	4.58	0.784
Year	2007	3.90	1.150
Wetness	Dry	3.27	0.517
Wetness	Wet	4.51	0.838
Hydro	Altered	5.54	1.181
Hydro	Not Altered	2.66	0.386
Landcover	Ag	3.20	0.602
Landcover	Grass	4.60	0.720

Overall mean bird count: Dry: mean = 3.59, SE = 0.403
Wet: mean = 8.29, SE = 1.070

Table B-18: Model selection statistics for shorebirds

Model	K	Log(L)	AICc	ΔAICc	w_i
Log$_e$*Size Hydro Area	10	-1223.12	2466.60	0.00	0.438
Log$_e$*Size Hydro Area Wetland	11	-1222.50	2467.43	0.83	0.289

Table B-19: Model parameters for best approximating model for shorebirds

Effect	Parameter	Estimate	SE	Lower 95% CL	Upper 95% CL
Intercept		-0.88	2.459	-5.724	3.967

Season	Fall	1.50	2.466	-3.351	6.346
Season	Spring	-	-	-	-
Date		-2.22	0.286	-2.780	-1.655
Date^2		1.49	0.714	0.089	2.896
Date^2*Season	Fall	-2.88	0.760	-4.374	-1.386
Date^2*Season	Spring	-	-	-	-
Log$_e$*Size		0.59	0.163	0.271	0.912
Hydro	Altered	-0.52	0.369	-1.248	0.204
Hydro	Not Altered	-	-	-	-
Playa Area-Landscape		0.31	0.129	0.059	0.565
Playa ID [a]		1.00	0.385	0.543	1.709
Scale [b]		4.38	0.461	3.668	5.251

[a] Covariance parameter for the random effect of Playa ID.
[b] Dispersion parameter for the negative binomial distribution.

Table B-20: Estimated mean bird count for shorebirds

Parameter	Parameter	Estimate	SE
Season	Fall	1.13	0.272
Season	Spring	1.81	3.626
Hydro	Altered	1.10	1.161
Hydro	Not Altered	1.85	1.845

Overall mean bird count: mean = 4.17, SE = 0.709

Table B-21: Model selection statistics for waterfowl

Model	K	Log(L)	AICc	ΔAICc	w_i
Size Area	8	-1528.00	3072.24	0.00	0.569
Size Area Wetland	9	-1527.84	3073.97	1.73	0.240

Table B-22: Model parameters for best approximating model for waterfowl

Effect	Estimate	SE	Lower 95% CL	Upper 95% CL
Intercept	0.61	0.593	-0.559	1.779
Date	0.05	0.230	-0.406	0.501
Date^2	-0.81	0.183	-1.166	-0.447
Playa Size	0.21	0.068	0.073	0.341
Playa Area-Landscape	0.55	0.233	0.091	1.007
Playa ID [a]	5.13	1.524	3.339	7.905
Scale [b]	7.28	0.816	6.088	8.747

[a] Covariance parameter for the random effect of Playa ID.
[b] Dispersion parameter for the negative binomial distribution.

APPENDIX C

PLANT SPECIES DOCUMENTED ON EASTERN COLORADO PLAYAS, 2004-2005

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	Common Name[2]	Found in Playa	Found in Upland	Percent Playas Occupied	Wetland Status[3]	Nativity
*Acanthoxanthium spinosum (L.) Fourreau**	spiny cocklebur	x	x	8	FACU	Exotic
*Achnatherum hymenoides - (Roemer & J.A. Schultes) Barkworth**	Indian ricegrass	x		1	FACU	Native
Agaloma marginata (Pursh) Loeve & Loeve	snow-on-the-mountain	x		8	FACU	Native
Agropyron cristatum (L.) Gaertner (sensu lato)	crested wheatgrass	x	x	5		Exotic
Amaranthus albus L.	prostrate pigweed	x	x	25	FACU	Exotic
*Amaranthus blitoides S. Watson**	mat amaranth	x		2	FACW	Native
*Amaranthus hybridus L.**	slim amaranth	x		1		Native
Amaranthus retroflexus L.	redroot pigweed	x	x	36	FACU	Exotic
Amaranthus sp.	Amaranth sp.	x	x	6		
*Ambrosia acanthicarpa Hooker**	slimleaf bursage	x	x	5		Native
Ambrosia artemisiifolia L. var. elatior (L.) Descourtils	annual ragweed, common ragweed	x	x	9	FACU	Exotic
Ambrosia grayi (A. Nelson) Shinners	woollyleaf bursage, woollyleaf burr ragweed	x	x	18	FAC	Native
*Ambrosia linearis (Rydberg) Payne**	streaked burr ragweed	x	x	19		Native
Ambrosia psilostachya De Candolle var. coronopifolia (Torrey & Gray) Farwell	western ragweed	x	x	11	FAC	Native
Ambrosia sp.	ragweed sp.	x	x	23		
*Ambrosia tomentosa Nuttall**	skeletonleaf bursage,skeletonleaf burr ragweed	x	x	35		Native
Ambrosia trifida L.	great ragweed	x		1	FACW	Exotic
*Ammannia robusta Heer & Regel**	grand redstem	x		1	OBL	Native
Anisantha tectorum (L.) Nevski	cheatgrass	x	x	11		Exotic
Apocynum sp.	dogbane sp.	x		1		
*Argemone polyanthemos (Fedde) G. Ownbey**	crested pricklypoppy	x		1		Native
*Aristida divaricata Humboldt & Bonpland ex Willdenow**	poverty threeawn	x	x	2		Native
Aristida purpurea Nuttall	purple threeawn	x	x	36		Native
Aristida sp.	threeawn sp.	x	x	14		

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name**[2]	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status**[3]	**Nativity**
*Artemisia carruthii Wood {ex} Carruth**	Carruth's sagewort	x	x	3		Native
*Artemisia frigida Willdenow**	fringed sagebrush	x	x	19		Native
*Artemisia ludoviciana Nuttall**	white sagebrush	x		2	FACU-	Native
Artemisia sp.	sagebrush sp.	x	x	6		
Asclepias subverticillata (A. Gray) Vail	horsetail milkweed		x	1	FACU	Native
*Asclepias viridiflora Rafinesque**	green comet milkweed	x		1		Native
Aster sp.	aster sp.	x	x	12		
*Astragalus adsurgens Pallas var. robustior Hooker**	prairie milkvetch	x		1		Native
*Astragalus bisulcatus (Hooker) A. Gray**	two grooved milkvetch	x		1		Native
Astragalus mollissimus Torrey	woolly locoweed	x		13		Native
Astragalus sp.	milkvetch sp.	x	x	6		
*Astragalus tenellus Pursh**	looseflower milkvetch	x	x	3		Native
*Atriplex argentea Nuttall**	silverscale saltbrush	x		2	FAC	Native
*Atriplex gardneri (Moquin) Standley**	Gardner's saltbush	x	x	2		Native
Bacopa rotundifolia (Michaux) Wettstein in Engler & Prantl	disk waterhyssop	x		2	OBL	Native
Bassia sieversiana (Pallas) W. A. Weber	kochia	x	x	71	FACU	Exotic
Bergia texana (Hooker) Seubert ex Walpers	Texas bergia	x		1	OBL	Native
Bolboschoenus maritimus (L.) Palla subsp. paludosus (A. Nelson) Loeve & Loeve	cosmopolitan bulrush	x		3	NI	Native
Bouteloua curtipendula (Michaux) Torrey	sideoats	x	x	2		Native
Bouteloua curtipendula (Michaux) Torrey var. curtipendula	sideoats grama	x		1		Native
Breea arvensis (L.) Lessing	Canada thistle	x		3	FACU	Exotic
*Brickellia eupatorioides (L.) Shinners**	false boneset	x		1		Native
*Bromopsis inermis (Leysser) Holub**	smooth brome	x		1		Exotic
Bromus japonicus Thunberg	Japanese brome	x	x	10	FACU	Exotic
Bromus sp.	brome sp.	x	x	2		
Buchloe dactyloides (Nuttall) Engelmann	buffalograss	x	x	81	FACU	Native
Cactus sp.	cactus sp.		x	1		

Table C-1: List of all plants found in playa surveys 2004-2007

***Scientific Name from CU Synonym*[1]**	**Common Name[2]**	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status[3]**	**Nativity**
*Caesalpinia jamesii (Torrey & Gray) Fisher**	James' holdback	x		1		Native
Camelina microcarpa Andrzejowski ex De Candolle	little false flax	x		1	NI	Exotic
*Cardaria latifolia (L.) Spach**	tall whitetop	x		1	FACW	Exotic
*Carex aquatilis Wahlenberg**	water sedge	x		3	OBL	Native
Carex sp.	sedge sp.	x	x	37		
*Carex stenophylla Wahlenberg subsp. eleocharis (L. H. Bailey) Hulten**	needleleaf sedge	x	x	1		Native
Cenchrus longispinus (Hackel in Kneucker) Fernald	mat sandbur	x	x	14		Native
*Chamaesaracha coronopus (Dunal) A. Gray**	greenleaf five eyes	x	x	2		Native
*Chamaesyce glyptosperma (Engelmann) Small**	ribseed sandmat	x	x	10		Native
*Chamaesyce lata (Engelmann) Small**	hoary sandmat	x		1		Native
Chamaesyce sp.	sandmat sp.	x	x	9		
Chamaesyce stictospora (Engelmann) Small	slimseed sandmat		x	1		Native
Chenopodium berlandieri Moquin	netseed lambsquarters, pitseed goosefoot	x	x	14		Native
*Chenopodium cycloides A. Nelson**	sandhill goosefoot	x		1		Native
*Chenopodium desiccatum A. Nelson**	aridland goosefoot, desert goosefoot	x	x	10		Native
Chenopodium incanum (S. Watson) Heller	mealy goosefoot	x	x	11		Native
Chenopodium leptophyllum (Nuttall ex Moquin) S. Watson	narrowleaf goosefoot	x	x	28	NI	Native
Chenopodium sp.	goosefoot sp.	x	x	72		
Chenopodium watsonii A. Nelson	Watson's goosefoot	x		1		Native
Chloris verticillata Nuttall	tumble windmill grass	x		2		Native
Chondrosum barbatum (Lagasca) Clayton	sixweeks grama	x		1		Native
Chondrosum gracile Humboldt, Bonpland, & Kunth	blue grama	x	x	66		Native
*Chondrosum prostratum (Lagasca) Sweet**	matted grama	x	x	2		Exotic
Chrysothamnus nauseosus (Pallas ex Pursh)	rubber rabbitbrush	x	x	9		Native

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name**[2]	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status**[3]	**Nativity**
*Britton**						
*Cirsium flodmanii (Rydberg) Arthur**	Flodman's thistle	x		1	NI	Native
Cirsium ochrocentrum A. Gray	yellowspine thistle	x		1		Native
Cirsium sp.	thistle sp.	x		1		
Cirsium undulatum (Nuttall) Sprengel	wavyleaf thistle	x	x	32	FACU	Native
Cirsium vulgare (Savi) Tenore	bull thistle	x		1	UPL	Exotic
*Cleome serrulata Pursh**	Rocky Mountain beeplant	x		1	FACU	Native
Convolvulus arvensis L.	field bindweed	x	x	12		Exotic
Conyza canadensis (L.) Cronquist	marestail, horseweed	x	x	47	FACW	Exotic
Conyza sp.	horseweed sp.	x	x	1		
Coreopsis sp.	coreopsis sp.	x	x	5		
Coreopsis tinctoria Nuttall	plains coreopsis	x	x	20	FAC	Native
*Corydalis curvisiliqua Engelmann subsp. occidentalis (Engelmann ex A. Gray) W. A. Weber**	curved fumewort	x		1		Native
*Critesion brachyantherum (Nevski) Barkworth & Dewey**	meadow barley	x	x	7		Native
Critesion jubatum (L.) Nevski	foxtail barley	x	x	17	FACW	Native
Critesion pusillum (Nuttall) Loeve	little barley	x	x	22	FAC	Native
Croton texensis (Klotsch) Muller-Argoviensis in De Candolle	Texas croton	x		1		Native
*Cryptantha crassisepala (Torrey & Gray) Greene**	thick sepal cryptantha	x	x	3		Native
*Cryptantha crassisepala (Torrey & Gray) Greene var. elachantha I.M. Johnston**	thicksepal cryptantha	x	x	14		Native
Cryptantha minima Rydberg	little cryptantha	x		5		Native
Cryptantha sp.	cryptantha sp.	x	x	5		
Cuscuta sp.	dodder sp.	x		1		
Cylindropuntia imbricata (Haworth) Knuth	tree cholla	x		3		Native
Cylindropuntia sp.	cholla sp.	x		1		
Cyperus acuminatus Torrey & Hooker	tapertip flatsedge	x		1	OBL	Native
*Cyperus aristatus Rottboel**	bearded flatsedge	x		1	OBL	Native

Table C-1: List of all plants found in playa surveys 2004-2007

***Scientific Name from CU Synonym*[1]**	**Common Name[2]**	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status[3]**	**Nativity**
Dalea purpurea Ventenat	purple prairie clover		x	1		Native
Descurainia pinnata (Walter) Britton	paradise tansymustard	x	x	11		Native
*Descurainia sophia (L.) Webb ex Prantl**	herb sophia	x		2		Exotic
Descurainia sp.	tansymustard sp.	x		9		
Diplachne dubia (Kunth) Scribner	green spangletop		x	1		Native
Diplachne fascicularis (Lamarck) P. Beauvois	bearded spangletop	x		1	OBL	Native
Distichlis stricta (Torrey) Rydberg	inland saltgrass	x	x	16	NI	Native
Dyssodia papposa (Ventenat) A. S. Hitchcock	fetid marigold	x		3		Native
Echinocereus viridiflorus Engelmann	nylon hedgehog cactus		x	1		Native
Echinochloa crus-galli (L.) P. Beauvois	barnyard grass	x	x	28	FACW	Exotic
Eleocharis acicularis (L.) Roemer & Schultes	needle spikerush	x	x	40	OBL	Native
*Eleocharis palustris (L.) Roemer & Schultes**	common spikerush	x	x	47	OBL	Native
Eleocharis sp.	spikerush sp.	x	x	22		
Eleocharis xyridiformis (Fernald) Brackett	creeping spikerush	x		2	OBL	Native
Elymus canadensis L.	Canada wildrye	x		3	FACU	Native
*Elymus elymoides (Rafinesque) Swezey**	squirreltail	x	x	18	FACU	Native
Eragrostis cilianensis (Allioni) F. T. Hubbard	stinkgrass	x	x	22	FACU	Exotic
Eragrostis curvula (Schrader) Nees	weeping lovegrass	x		1		Exotic
Eragrostis pilosa (L.) P. Beauvois	Indian lovegrass	x	x	4	FACU	Exotic
Eragrostis sp.	lovegrass sp.	x	x	7		
Erigeron bellidiastrum Nuttall	western daisy fleabane	x		2		Native
*Erigeron colo-mexicanus A. Nelson**	running fleabane	x	x	2		Native
*Erigeron divergens Torrey & Gray**	spreading fleabane, spreading daisy	x	x	8		Native
*Erigeron pumilus Nuttall**	Navajo fleabane	x		1		Native
Erigeron sp.	fleabane sp.	x	x	5		
*Eriogonum annuum Nuttall**	annual buckwheat	x		2		Native
Eriogonum effusum Nuttall	spreading buckwheat	x	x	6		Native
*Eriogonum microthecum Nuttall**	slender buckwheat	x	x	4		Native
Erodium cicutarium (L.) L'Heritier	redstem stork's bill	x		1		Exotic
Erysimum asperum (Nuttall) De Candolle	western wallflower	x	x	5		Native

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name[2]**	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status[3]**	**Nativity**
Euphorbia sp.	sandmat sp.	x	x	4		
Evolvulus nuttallianus Schultes	shaggy dwarf morning-glory	x	x	3		Native
Fabaceae		x		1		
*Fallopia convolvulus (L.) Loeve**	black bindweed	x	x	5	FACU	Exotic
Ferocactus sp.	barrel cactus sp.	x	x	5		
Fragaria sp.	strawberry sp.	x		1		
*Froelichia gracilis (Hooker) Moquin**	slender snakecotton	x		1		Native
*Gaillardia pinnatifida Torrey**	red dome blanket flower	x	x	5		Native
*Galinsoga parviflora Cavanilles**	galliant soldier	x		3		Exotic
Gaura coccinea Nuttall ex Pursh	scarlet beeblossom	x	x	4		Native
*Gaura mollis James**	velvety guara, velvetweed	x		1	NI	Native
Gaura sp.	beeblossom sp.	x		1		
*Glandularia bipinnatifida (Nuttall) Nuttall**	showy vervain, Dakota mock vervain	x		3		Native
*Glycyrrhiza lepidota Pursh**	wild licorice	x		1	FACU	Native
*Gnaphalium palustre Nuttall**	western marsh cudweed	x		3	OBL	Native
Grammica indecora (Choisy) W. A. Weber var. neuropetala (Engelmann) W. A. Weber	bigseed dodder	x		3		Native
*Grindelia inornata Greene**	Colorado gumweed	x		1		Native
Grindelia sp.	gumweed sp.	x		1		
Grindelia squarrosa (Pursh) Dunal	curlycup gumweed	x	x	37	FACU-	Native
Gutierrezia sarothrae (Pursh) Britton & Rusby	broom snakeweed	x		6		Native
Gutierrezia sp.	snakeweed sp.		x	3		
*Hedeoma hispidum Pursh**	rough false pennyroyal	x		3		Native
Helianthus annuus L.	common sunflower	x	x	14	FACU	Native
Helianthus petiolaris Nuttall	prairie sunflower	x		4		Native
Helianthus sp.	sunflower sp.	x	x	7		
Heliotropium curassavicum L. subsp. oculatum (Heller) Thorne	seaside heliotrope	x		3	OBL	Exotic
*Hesperostipa comata (Trinius & Ruprecht) Barkworth**	needle and thread	x		1		Native

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	Common Name[2]	Found in Playa	Found in Upland	Percent Playas Occupied	Wetland Status[3]	Nativity
Hesperostipa sp.	needle and thread sp.	x	x	2		
Heteranthera limosa (Swartz) Willdenow	blue mud plantain	x		2	OBL	Native
Heterotheca latifolia Buckley	camphorweed	x		1	FACU	Native
Heterotheca sp.	goldenaster sp.	x	x	3		
*Heterotheca villosa (Pursh) Shinners**	hairy false golden aster	x	x	24		Native
Hilaria jamesii (Torrey) Bentham	James' galleta		x	1		Native
Hordeum sp	barley sp.	x	x	3		
*Hymenopappus filifolius Hooker**	fineleaf hymenopappus	x		2		Native
*Hymenopappus filifolius Hooker var. polycephalus (Osterhout) B. Turner**	manyhead hymenopappus	x		1		Native
*Hymenopappus tenuifolius Pursh**	Chalk Hill hymenopappus	x	x	2		Native
*Ipomoea leptophylla Torrey**	bush morning glory	x		2		Native
*Ipomopsis laxiflora (Coulter) V. Grant**	iron ipomosis	x	x	7		Native
Iva axillaris Pursh	poverty sumpweed	x	x	28	FAC	Native
Juncus sp.	rush sp.	x		1		
*Koeleria macrantha (Ledebour) Schultes**	prairie Junegrass	x	x	2		Native
*Krascheninnikovia lanata (Pursh) Meeuse & Smit**	winterfat	x		2		Native
Lactuca serriola L.	prickly lettuce	x	x	22	FAC	Exotic
*Lappula redowskii (Hornemann) Greene**	flatspine stickseed	x	x	4		Native
Lepidium densiflorum Schrader	common pepperweed	x	x	32	FAC	Exotic
Leptochloa sp.	sprangletop sp.	x	x	3		
Lesquerella alpina (Nuttall ex Torrey & Gray) S. Watson	alpine bladderpod		x	1		Native
*Leucanthemum vulgare Lamarck**	oxeye daisy	x		1	NI	Exotic
*Liatris punctata Hooker**	dotted blazing star	x		1		Native
Lygodesmia juncea (Pursh) D. Don	skeletonweed	x	x	19		Native
*Machaeranthera pinnatifida (Hooker) Shinners**	lacy tansyaster	x		5		Native
*Machaeranthera pinnatifida (Hooker) Shinners var. pinnatifida**	lacy tansyaster	x		2		Native
Machaeranthera sp.	tansyaster sp.	x		3		

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	Common Name[2]	Found in Playa	Found in Upland	Percent Playas Occupied	Wetland Status[3]	Nativity
Machaeranthera tanacetifolia (Humboldt, Bonpland, & Kunth) Nees	tansyleaf tansyaster	x		1		Native
Mammillaria sp.	cactus sp.	x	x	3		
*Mariscus schweinitzii (Torrey) Koyama**	Schweinitz's flatsedge	x		1	FACU	Native
Marsilea mucronata A. Braun	western water clover, pepperwort	x	x	30	OBL	Native
Marsilea sp.	waterclover sp.	x		2		
Medicago sativa L.	alfalfa	x	x	8	NI	Exotic
Melilotus albus Medicus	yellow sweetclover	x		2	FACU	Exotic
Melilotus officinale (L.) Pallas	yellow sweetclover	x	x	13	FACU	Exotic
Melilotus sp.	sweetclover sp.	x	x	3		
Mollugo verticillata L.	green carpetweed	x		1	FAC	Exotic
Monolepis sp.	povertyweed sp.	x		1		
Monroa squarrosa (Nuttall) Torrey	false buffalograss	x		4		Native
moss sp.	moss sp.	x	x	3		
*Muhlenbergia asperifolia (Nees & Meyen ex Trinius) Parodi**	scratchgrass muhly	x		1	FACW	Native
Muhlenbergia torreyi (Kunth) A. S. Hitchcock ex Bush	ring muhly	x		3		Native
Myosurus minimus L.	bristly mousetail	x	x	9	FACW	Native
*Oenothera albicaulis Pursh**	whitest evening primrose	x		1		Native
Oenothera canescens Torrey & Fremont	spotted evening primrose	x	x	53	FACW-	Native
Oenothera sp.	primrose sp.	x		6		
*Oenothera villosa Thunberg subsp. strigosa (Rydberg) Dietrich & Raven**	hairy evening primrose	x		1	FACU	Native
*Oligosporus caudatus (Michaux) Poljakov**	field sagewort	x		1		Native
*Oligosporus dracunculus (L.) Poljakov**	terragon	x	x	2		Native
*Oligosporus filifolius (Torrey) Poljakov**	sand sagebrush	x	x	5		Native
*Oonopsis foliosa (A. Gray) Greene**	leafy false goldenweed	x		1		Native
Opuntia sp.	cactus sp.	x	x	44		
Oxybaphus decumbens (Nuttall) Sweet	narrowleaf four o'clock	x	x	3	NI	Native

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name**[2]	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status**[3]	**Nativity**
Oxytropis lambertii Pursh	Lambert crazyweed, purple locoweed	x		3	FACU	Native
Oxytropis sericea Nuttall	white locoweed	x	x	2		Native
Oxytropis sp.	locoweed	x	x	10		
*Packera tridenticulata (Rydberg) Weber & Loeve**	threetooth ragwort	x		4		Native
Panicum capillare L.	witchgrass	x	x	27	FAC	Exotic
Panicum miliaceum L.	wild proso millet, broomcorn millet	x		3		Exotic
Panicum obtusum Humboldt, Bonpland, & Kunth	vine mesquite	x	x	2	FACW	Native
Panicum virgatum L.	switchgrass	x		1	FAC	Native
Pascopyrum smithii (Rydberg) Loeve	western wheatgrass	x	x	78	FACU	Native
*Pectis angustifolia Torrey**	lemonscent	x		1		Native
Pediomelum sp.	Indian breadroot sp.		x	2		
Penstemon albidus Nuttall	white penstemon	x		2		Native
*Penstemon angustifolius Nuttall ex Pursh subsp. Angustifolius**	broadbeard beardtongue	x		1		Native
Penstemon sp.	penstemon sp.	x	x	2		
Persicaria amphibia (L.) S. Gray	water smartweed	x		2	OBL	Native
Persicaria bicornis (Rafinesque) Nieuwland	Pennsylvania smartweed	x		6	FACW+	Native
Persicaria lapathifolia (L.) S. Gray	curlytop knotweed	x		3	OBL	Exotic
Persicaria maculata (L.) S. Gray	spotted ladysthumb	x		1	OBL	Exotic
Persicaria sp.	smartweed sp.	x	x	13		
Phalaroides arundinacea (L.) Rauschert	reed canarygrass		x	1	FACW+	Exotic
Phyla cuneifolia (Torrey) Greene	frog-fruit, fogfruit	x	x	53	FAC	Native
Physalis heterophylla Nees	clammy groundcherry	x		2		Native
*Physalis virginiana P. Miller**	prairie groundcherry	x		1		Native
Picradenia odorata (De Candolle) Britton	bitter rubberweed	x		1	NI	Native
*Picradeniopsis oppositifolia (Nuttall) Rydberg**	oppositeleaf bahia	x	x	5		Native
Picradeniopsis woodhousei (A. Gray) Rydberg	Woodhouse's bahia	x		1		Native
Plantago patagonica Jacquin	woolly plantain	x	x	50	UPL	Native
Plantago sp.	plantain sp.	x	x	8		

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name**[2]	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status**[3]	**Nativity**
Pleuraphis sp.	galleta sp.		x	1		
Poa compressa L.	Canada bluegrass		x	1	FACU	Exotic
Poa sp.	grass sp.	x	x	3		
Poinsettia dentata (Michaux) Klotsch & Garcke	toothed spurge	x	x	2		Native
*Polygonum arenastrum Boreau**	oval-leaf knotweed	x		3	NI	Exotic
Polygonum aviculare L. var. aviculare	prostrate knotweed	x	x	26		Exotic
Polygonum ramosissimum Michaux	bushy knotweed	x	x	38	FAC	Native
Polygonum sp.	Polygonum sp.	x		12		
Populus deltoides H. Marshall subsp. wislizenii (S. Watson) Eckenwalder	eastern cottonwood	x		3	FAC	Native
Populus sp.	cottonwood sp.	x		1		
*Portulaca halimoides L.**	silkcotton purslane	x		1	NI	Native
Portulaca oleracea L.	common purslane	x	x	45	FAC	Exotic
Portulaca sp.	purslane sp.	x	x	11		
Potentilla rivalis Nuttall ex Torrey & Gray	brook cinquefoil	x	x	7	FACW+	Native
Potentilla sp.	cinquefoil sp.	x	x	3		
Primula sp.	primrose sp.	x	x	2		
Proboscidea louisianica (P. Miller) Thellung	ram's horn, devil's claw	x		4	FACU	Native
Proboscidea sp.	devil's claw sp.	x		1		
Psoralidium lanceolatum (Pursh) Rydberg	lemon scurfpea	x		2		Native
Psoralidium sp.	scurfpea sp.	x	x	14		
*Psoralidium tenuiflorum (Pursh) Rydberg**	slimflower scurfpea	x	x	13		Native
Pyrrocoma sp.	goldenweed sp.	x		1		
Quincula lobata (Torrey) Rafinesque	Chinese lantern	x		2		Native
Ratibida columnifera (Nuttall) Wooton & Standley	prairie coneflower	x	x	25		Native
Ratibida sp.	prairie coneflower sp.	x	x	11		
Ratibida tagetes (James) Barnhart	short-ray prairie coneflower	x	x	53		Native
*Ribes aureum Pursh**	golden currant	x		1	NI	Native
Rorippa sinuata (Nuttall in Torrey & Gray) A. S. Hitchcock	spreading yellowcress	x	x	29	FACW	Native
Rorippa sp	yellowcress sp.	x		1		

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name**[2]	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status**[3]	**Nativity**
Rumex altissimus Wood	pale dock	x		4	FAC	Native
Rumex crispus L.	curly dock	x		9	FACW	Exotic
*Rumex stenophyllus Ledebour**	narrowleaf dock	x		1	FACW+	Exotic
*Rumex triangulivalvis (Danser) Rechinger f.**	Mexican dock	x	x	2	FAC	Native
*Rumex utahensis Rechinger**	toothed willow dock	x		1		Native
Salix amygdaloides Andersson	peachleaf willow		x	1	FACW	Native
Salsola australis R. Brown	tumbleweed, Russian thistle	x	x	79	FACU	Exotic
*Salsola collina Pallas**	slender Russian thistle	x	x	2		Exotic
*Salvia reflexa Hornemann**	lanceleaf sage	x	x	5		Native
Salvia sp.	sage sp.	x	x	1		
*Sanguisorba minor Scopoli**	small burnet	x		1	NI	Exotic
Schedonnardus paniculatus (Nuttall) Trelease	tumblegrass	x	x	29		Native
Schoenoplectus lacustris (L.) Palla subsp. creber (Fernald) Loeve & Loeve	softstem bulrush	x		4	OBL	Native
*Schoenoplectus pungens (M. Vahl) Palla**	common threesquare	x		1	OBL	Native
Schoenoplectus sp.	bulrush sp.	x		1		
Scorzonera sp.	Scorzonera sp.	x		2		
Senecio riddellii Torrey & Gray	Riddell's ragwort		x	1		Native
Senecio sp.	Senecio sp.	x		1		
Setaria glauca (L.) P. Beauvois	yellow foxtail	x	x	4		Exotic
Setaria sp.	bristlegrass or panicgrass sp.	x	x	3		
Setaria viridis (L.) P. Beauvois	green bristlegrass	x		3		Exotic
Sisymbrium altissimum L.	tumble mustard	x	x	16	FACU	Exotic
Solanum rostratum Dunal	buffalobur nightshade	x	x	22		Exotic
*Solanum triflorum Nuttall**	cutleaf nightshade	x		4		Native
Solidago sp.	goldenrod sp.	x		1		
*Solidago velutina De Candolle**	threenerve goldenrod	x		1		Native
Sorghastrum sp.	Indiangrass sp.	x	x	1		
*Sorghum vulgare Persoon**	grain sorghum	x	x	1		Exotic
*Spergula arvensis L.**	corn spurry	x		1		Exotic

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name[2]**	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status[3]**	**Nativity**
Sphaeralcea angustifolia (Cavanilles) G. Don var. cuspidata A. Gray	copper globemallow	x		1		Native
Sphaeralcea coccinea (Pursh) Rydberg	scarlet globemallow	x	x	54		Native
Sphaeralcea sp.	globemallow sp.	x	x	5		
Sporobolus airoides (Torrey) Torrey	alkali sacaton	x	x	11	FAC	Native
Sporobolus cryptandrus (Torrey) A. Gray	sand dropseed	x	x	32	FACU-	Native
Sporobolus sp.	grass sp.	x	x	3		
*Suaeda calceoliformis (Hooker) Moquin**	Pursh seepweed	x		1	FACW	Native
Suckleya suckleyana (Torrey) Rydberg	poison suckleya	x	x	17	FACW	Native
Symphyotrichum sp.	aster sp.	x	x	2		
Talinum parviflorum Nuttall ex Torrey & Gray	sunbright	x	x	12		Native
Talinum sp.	flameflower sp.	x	x	3		
*Tamarix ramosissima Ledebour**	saltcedar, tamarisk	x		2	FACW	Exotic
Taraxacum officinale G. H. Weber ex Wiggers	common dandelion	x	x	9	FACU	Exotic
*Thelesperma filifolium (Hooker) A. Gray var. intermedium (Rydberg) Shinners**	stiff greenthread	x	x	10		Native
Thelesperma megapotamicum (Sprengel) Kuntze	Colorado greenthread	x	x	6		Native
Thelesperma sp.	greenthread sp.	x	x	6		
Thlaspi arvense L.	field pennycress	x	x	10	NI	Exotic
Thymophylla aurea (A. Gray) Greene	manyawn pricklyleaf		x	1		Native
*Tithymalus spathulatus (Lamarck) W. A. Weber**	warty spurge	x		1	FACU	Native
Tragopogon dubius Scopoli subsp. major (Jacquin) Vollmann	yellow salisfy	x	x	16		Exotic
Tribulus terrestris L.	puncturevine	x	x	9		Exotic
*Trifolium repens L.**	white clover	x		1	FACU	Exotic
Trifolium sp.	clover sp.	x		3		
*Triticum aestivum L.**	common wheat	x	x	10		Exotic
Triticum sp.	wheat sp.	x	x	3		
Typha angustifolia L.	narrowleaf cattail	x		3	OBL	Exotic
Typha latifolia L.	broadleaf cattail	x		2	OBL	Native
Typha sp.	cattail sp.	x		1		

Table C-1: List of all plants found in playa surveys 2004-2007

Scientific Name from CU Synonym[1]	**Common Name[2]**	**Found in Playa**	**Found in Upland**	**Percent Playas Occupied**	**Wetland Status[3]**	**Nativity**
*Verbascum thapsus L.**	common mullein	x		1	NI	Exotic
Verbena bracteata Lagasca & Rodriguez	prostrate vervain,bigtract verbena	x	x	55	FACU	Exotic
Verbena sp.	vervain sp.	x		3		
Veronica peregrina L. subsp. xalapensis (Humboldt, Bonpland, & Kunth) Pennell	speedwell purslane	x	x	18	OBL	Exotic
Vexibia nuttalliana (B. Turner) W. A. Weber	silky sophora	x	x	9		Native
Vicia sp.	vetch sp.	x	x	4		
*Virgulus ericoides (L.) Reveal & Keener**	manyflowered aster	x	x	4	FACU	Native
Vulpia octoflora (Walter) Rydberg	sixweeks fescue	x	x	37	UPL	Native
Xanthisma sp.	sleepydaisy sp.	x		1		
Xanthium strumarium L.	rough cockleburr	x	x	16	FAC	Exotic
Xanthoparmelia sp.	lichen sp.	x	x	3		
*Ximenesia encelioides Cavanilles**	golden crownbeard/goldweed	x		3	FAC	Exotic
*Yucca glauca Nuttall in Fraser**	soapweed yucca	x	x	6		Native
Zea mays L.	corn	x	x	3		

1 Scientific names follow those of the University of Colorado at Boulder Herbarium, based upon those of Weber, as provided by Colorado Natural Heritage Program, Floristic Quality Assessment Database (7 February 2008)

2 Scientific name as assigned in USDA, NRCS. 2006. The PLANTS Database (http://plants.usda.gov, 3 Dec. 2008). National Plant Data Center, Baton Rouge, LA
.
3 US Fish and Wildlife Service. Reed, PB. 1988. National List of Plant Species That Occur in Wetlands --
Central Plains (Region 5). National Wetland Inventory, U.S. Department of the Interior, Fish and Wildlife Service, St. Petersburg, FL. 90 pp. OBL=Obligate, FACW=Facultative Wetland, FAC=Facultative, FACU=Facultative Upland, UPL=Obligate Upland. Blank indicates species not on list.

*Indicates plant species we found that were not previously published by Haukos and Smith (1997)

Table C-2: Dominant cover types for all playas surveyed three or four years

	2004		2005		2006		2007	
Playa	**Cover Type**	**%**	**Cover Type**	**%**	**Cover Type**	**%**	**Cover Type**	**%**
24	Bare Ground	38	Bare Ground	53	Bare Ground	43	x	x
	Unknown Spikerush	12	Buchloe dactyloides	13	Buchloe dactyloides	32	x	x
	Phyla cuneifolia	11	Phyla cuneifolia	11	Phyla cuneifolia	16	x	x
66	Pascopyrum smithii	54	Bare Ground	55	Bare Ground	67	x	x
	Bare Ground	16	Pascopyrum smithii	21	Pascopyrum smithii	20	x	x
	Poinsettia dentata	6	Ambrosia grayi	1	Poinsettia dentata	7	x	x
85	Buchloe dactyloides	71	Bare Ground	33	Buchloe dactyloides	60	x	x
	Bare Ground	19	Buchloe dactyloides	22	Bare Ground	37	x	x
	Pascopyrum smithii	2	Vulpia octoflora	14	Phyla cuneifolia	3	x	x
180	Bare Ground	62	Bare Ground	53	Bare Ground	71	x	x
	Ambrosia sp.	11	Ambrosia tomentosa	13	Pascopyrum smithii	8	x	x
	Pascopyrum smithii	3	Buchloe dactyloides	11	Buchloe dactyloides	7	x	x
246	Bare Ground	68	Bare Ground	49	Bare Ground	46	x	x
	Chenopodium sp.	20	Chenopodium leptophyllum	18	Chenopodium leptophyllum	14	x	x
	Buchloe dactyloides	16	Buchloe dactyloides	9	Buchloe dactyloides	6	x	x
285	Bare Ground	82	Bare Ground	67	Bare Ground	78	x	x
	Chenopodium sp.	8	Iva axillaris	13	Iva axillaris	15	x	x
	Distichlis stricta	5	Bassia sieversiana	5	Bassia sieversiana	3	x	x
369	Buchloe dactyloides	73	Buchloe dactyloides	60	Buchloe dactyloides	44	x	x
	Ratibida columnifera	18	Bare Ground	34	Bare Ground	31	x	x
	Bare Ground	10	Ratibida columnifera	13	Ratibida tagetes	6	x	x
785	Bare Ground	39	Bare Ground	39	Bare Ground	64	Bare Ground	52
	Buchloe dactyloides	31	Buchloe dactyloides	23	Buchloe dactyloides	17	Pascopyrum smithii	16
	Pascopyrum smithii	10	Pascopyrum smithii	11	Pascopyrum smithii	12	Buchloe dactyloides	14
872	Buchloe dactyloides	55	Buchloe dactyloides	43	Buchloe dactyloides	29	x	x
	Bare Ground	27	Bare Ground	32	Bare Ground	52	x	x
	Pascopyrum smithii	14	Pascopyrum smithii	9	Pascopyrum smithii	11	x	x

Table C-2: Dominant cover types for all playas surveyed three or four years								
	2004		**2005**		**2006**		**2007**	
Playa	**Cover Type**	**%**	**Cover Type**	**%**	**Cover Type**	**%**	**Cover Type**	**%**
1139	x	x	Eleocharis acicularis	32	Bare Ground	48	Eleocharis acicularis	49
	x	x	Bare Ground	49	Eleocharis acicularis	14	Ambrosia linearis	9
	x	x	Marsilea mucronata	9	Salsola australis	7	Bare Ground	13
1226	Bare Ground	60	x	x	Bare Ground	63	Bassia sieversiana	39
	Pascopyrum smithii	17	x	x	Basssia sieversiana	23	Bare Ground	24
	Salsola australis	15	x	x	Salsola australis	6	Pascopyrum smithii	4
1973	Distichlis stricta	49	x	x	Bare Ground	44	Distichlis stricta	35
	Bare Ground	34	x	x	Distichlis stricta	32	Bare Ground	28
	Chenopodium sp.	11	x	x	Bassia sieversiana	10	Bassia sieversiana	9
2174	Bare Ground	52	Pascopyrum smithii	23	Bare Ground	60	x	x
	Pascopyrum smithii	25	Bare Ground	44	Pascopyrum smithii	13	x	x
	Buchloe dactyloides	10	Buchloe dactyloides	14	Buchloe dactyloides	3	x	x
2318	x	x	Buchloe dactyloides	53	Bare Ground	45	Buchloe dactyloides	44
	x	x	Bare Ground	25	Buchloe dactyloides	20	Bare Ground	14
	x	x	Eleocharis acicularis	3	Carex sp.	2	Salsola australis	6
2350	Bare Ground	59	Bare Ground	48	Bare Ground	77	Bare Ground	65
	Pascopyrum smithii	9	Iva axillaris	12	Iva axillaris	7	Buchloe dactyloides	7
	Unknown Shrub	7	Eleocharis sp.	11	Ambrosia tomentosa	5	Pascopyrum smithii	4

APPENDIX D

BIRD SPECIES DOCUMENTED ON EASTERN COLORADO PLAYAS, 2004-2007

Scientific Name	**Common Name**	**CO Sp. of Concern**	**Guild**	**Number Playas Occupied**	**Percent Playas Occupied**	**Number Observed**
	Light Goose (Ross' and Snow Goose)		Waterfowl	8	0.74	3049
Accipiter striatus	Sharp-shinned Hawk		Landbird	1	0.09	1
Actitis macularia	Spotted Sandpiper		Shorebird	8	0.74	8
Aechmophorus occidentalis	Western Grebe	Tier 2	Waterbird	2	0.18	2
Agelaius phoeniceus	Red-winged Blackbird		Other Wetland Dep.	69	6.35	888
Aimophila cassinii	Cassin's Sparrow	Tier 1	Landbird	11	1.01	13
Aix sponsa	Wood Duck		Waterfowl	2	0.18	3
Ammodramus bairdii	Baird's Sparrow		Landbird	1	0.09	3
Ammodramus savannarum	Grasshopper Sparrow		Landbird	10	0.92	12
Anas acuta	Northern Pintail	Tier 2	Waterfowl	45	4.14	2353
Anas americana	American Wigeon		Waterfowl	48	4.42	1135
Anas clypeata	Northern Shoveler		Waterfowl	59	5.43	1949
Anas crecca	Green-winged Teal		Waterfowl	69	6.35	7374
Anas cyanoptera	Cinnamon Teal		Waterfowl	6	0.55	80
Anas discors	Blue-winged Teal		Waterfowl	54	4.97	1422
Anas fulvigula	Mottled Duck		Waterfowl	2	0.18	3
Anas platyrhynchos	Mallard		Waterfowl	86	7.92	4530
Anas strepera	Gadwall		Waterfowl	33	3.04	1220
Anser albifrons	Greater White-fronted Goose		Waterfowl	3	0.28	22
Anthus rubescens	American Pipit		Landbird	40	3.68	257
Anthus spragueii	Sprague's Pipit		Landbird	3	0.28	4
Aquila chrysaetos	Golden Eagle	Tier 1	Landbird	1	0.09	1
Ardea herodias	Great Blue Heron		Waterbird	23	2.12	38
Athene cunicularia	Burrowing Owl	Tier 1, ST	Landbird	21	1.93	43
Aythya affinis	Lesser Scaup	Tier 2	Waterfowl	4	0.37	23
Aythya americana	Redhead		Waterfowl	12	1.10	91
Aythya collaris	Ring-necked Duck		Waterfowl	6	0.55	20
Aythya valisineria	Canvasback		Waterfowl	2	0.18	2
Bartramia longicauda	Upland Sandpiper	Tier 1	Shorebird	4	0.37	10

Scientific Name	Common Name	CO Sp. of Concern	Guild	Number Playas Occupied	Percent Playas Occupied	Number Observed
Branta canadensis	Canada Goose		Waterfowl	8	0.74	1686
Branta hutchinsii	Cackling Goose		Waterfowl	4	0.37	250
Bubo virginianus	Great Horned Owl		Landbird	2	0.18	2
Bucephala albeola	Bufflehead		Waterfowl	3	0.28	15
Buteo jamaicensis	Red-tailed Hawk		Landbird	14	1.29	15
Buteo lagopus	Rough-legged Hawk		Landbird	1	0.09	1
Buteo regalis	Ferruginous Hawk	Tier 1, SC	Landbird	14	1.29	15
Buteo swainsoni	Swainson's Hawk	Tier 1	Landbird	41	3.78	79
Calamospiza melanocorys	Lark Bunting	Tier 1	Landbird	122	11.23	561
Calcarius lapponicus	Lapland Longspur		Landbird	51	4.70	789
Calcarius mccownii	McCown's Longspur	Tier 1	Landbird	103	9.48	2028
Calcarius ornatus	Chestnut-collared Longspur	Tier 2	Landbird	115	10.59	2098
Calidris alba	Sanderling		Shorebird	1	0.09	2
Calidris bairdii	Baird's Sandpiper		Shorebird	45	4.14	328
Calidris fuscicollis	White-rumped Sandpiper		Shorebird	1	0.09	1
Calidris himantopus	Stilt Sandpiper		Shorebird	4	0.37	5
Calidris mauri	Western Sandpiper		Shorebird	1	0.09	1
Calidris melanotos	Pectoral Sandpiper		Shorebird	25	2.30	106
Calidris minutilla	Least Sandpiper		Shorebird	21	1.93	123
Calidris pusilla	Semipalmated Sandpiper		Shorebird	1	0.09	1
Callipepla squamata	Scaled Quail	Tier 1	Landbird	2	0.18	2
Carduelis pinus	Pine Siskin		Landbird	1	0.09	2
Carduelis tristis	American Goldfinch		Landbird	6	0.55	8
Carpodacus mexicanus	House Finch		Landbird	5	0.46	8
Cathartes aura	Turkey Vulture		Landbird	11	1.01	16
Chaetura pelagica	Chimney Swift		Landbird	1	0.09	1
Charadrius montanus	Mountain Plover	Tier 1, SC	Shorebird	5	0.46	13
Charadrius semipalmatus	Semipalmated Plover		Shorebird	3	0.28	5
Charadrius vociferus	Killdeer		Shorebird	217	19.98	2453
Chen caerulescens	Snow Goose		Waterfowl	7	0.64	123
Chen rossii	Ross's Goose		Waterfowl	4	0.37	14

Scientific Name	**Common Name**	**CO Sp. of Concern**	**Guild**	**Number Playas Occupied**	**Percent Playas Occupied**	**Number Observed**
Chlidonias niger	Black Tern		Waterbird	1	0.09	1
Chondestes grammacus	Lark Sparrow		Landbird	14	1.29	32
Chordeiles acutipennis	Lesser Nighthawk		Landbird	2	0.18	3
Chordeiles minor	Common Nighthawk		Landbird	6	0.55	7
Circus cyaneus	Northern Harrier	Tier 2	Landbird	89	8.20	138
Cistothorus palustris	Marsh Wren		Other Wetland Dep.	1	0.09	2
Colaptes auratus	Northern Flicker		Landbird	2	0.18	3
Colinus virginianus	Northern Bobwhite		Landbird	1	0.09	1
Columba livia	Rock Pigeon		Landbird	5	0.46	50
Coragyps atratus	Black Vulture		Landbird	1	0.09	1
Corvus brachyrhynchos	American Crow		Landbird	4	0.37	8
Corvus corax	Common Raven		Landbird	5	0.46	6
Corvus cryptoleucus	Chihuahuan Raven		Landbird	6	0.55	9
Dendroica coronata	Yellow-rumped Warbler		Landbird	2	0.18	2
Dendroica petechia	Yellow Warbler		Landbird	1	0.09	1
Eremophila alpestris	Horned Lark		Landbird	445	40.98	11473
Euphagus cyanocephalus	Brewer's Blackbird		Landbird	5	0.46	157
Falco columbarius	Merlin		Landbird	11	1.01	11
Falco mexicanus	Prairie Falcon	Tier 1	Landbird	16	1.47	23
Falco peregrinus	Peregrine Falcon	Tier 1, SC	Landbird	1	0.09	1
Falco sparverius	American Kestrel		Landbird	15	1.38	16
Fulica americana	American Coot		Waterbird	26	2.39	654
Gallinago delicata	Wilson's Snipe		Shorebird	22	2.03	71
Grus canadensis	Sandhill Crane	Tier 1, SC	Waterbird	42	3.87	6791
Haliaeetus leucocephalus	Bald Eagle	Tier 1, ST	Other Wetland Dep.	2	0.18	2
Himantopus mexicanus	Black-necked Stilt		Shorebird	2	0.18	7
Hirundo rustica	Barn Swallow		Landbird	36	3.31	178
Icterus bullockii	Bullock's Oriole		Landbird	1	0.09	1
Icterus spurius	Orchard Oriole		Landbird	1	0.09	4
Junco hyemalis	Dark-eyed Junco		Landbird	2	0.18	3
Lanius excubitor	Northern Shrike		Landbird	2	0.18	2

Scientific Name	**Common Name**	**CO Sp. of Concern**	**Guild**	**Number Playas Occupied**	**Percent Playas Occupied**	**Number Observed**
Lanius ludovicianus	Loggerhead Shrike	Tier 1	Landbird	6	0.55	9
Larus delawarensis	Ring-billed Gull		Waterbird	2	0.18	3
Larus pipixcan	Franklin's Gull		Waterbird	1	0.09	4
Limnodromus scolopaceus	Long-billed Dowitcher		Shorebird	33	3.04	699
Lophodytes cucullatus	Hooded Merganser		Waterfowl	3	0.28	4
Meleagris gallopavo	Wild Turkey		Landbird	2	0.18	3
Melospiza lincolnii	Lincoln's Sparrow		Landbird	1	0.09	1
Melospiza melodia	Song Sparrow		Other Wetland Dep.	1	0.09	2
Mimus polyglottos	Northern Mockingbird		Landbird	4	0.37	4
Molothrus ater	Brown-headed Cowbird		Landbird	11	1.01	93
Myadestes townsendi	Townsend's Solitaire		Landbird	1	0.09	1
Numenius americanus	Long-billed Curlew	Tier 1, SC	Shorebird	9	0.83	30
Oreoscoptes montanus	Sage Thrasher		Landbird	1	0.09	1
Oxyura jamaicensis	Ruddy Duck		Waterfowl	10	0.92	138
Passer domesticus	House Sparrow		Landbird	6	0.55	19
Passerculus sandwichensis	Savannah Sparrow		Landbird	28	2.58	84
Passerina cyanea	Indigo Bunting		Landbird	1	0.09	1
Pelecanus erythrorhynchos	American White Pelican	Tier 2	Waterbird	3	0.28	93
Petrochelidon pyrrhonota	Cliff Swallow		Landbird	5	0.46	15
Phalaropus lobatus	Red-necked Phalarope		Shorebird	2	0.18	2
Phalaropus tricolor	Wilson's Phalarope	Tier 2	Shorebird	15	1.38	212
Phasianus colchicus	Ring-necked Pheasant		Landbird	4	0.37	5
Philomachus pugnax	Ruff		Shorebird	1	0.09	1
Pica hudsonia	Black-billed Magpie		Landbird	5	0.46	6
Plegadis chihi	White-faced Ibis	Tier 2	Waterbird	11	1.01	23
Pluvialis dominica	American Golden-Plover		Shorebird	2	0.18	2
Pluvialis squatarola	Black-bellied Plover		Shorebird	4	0.37	9
Podiceps nigricollis	Eared Grebe	Tier 2	Waterbird	8	0.74	25
Podilymbus podiceps	Pied-billed Grebe		Waterbird	19	1.75	56
Pooecetes gramineus	Vesper Sparrow	Tier 2	Landbird	34	3.13	127
Porzana carolina	Sora		Waterbird	1	0.09	1

Scientific Name	**Common Name**	**CO Sp. of Concern**	**Guild**	**Number Playas Occupied**	**Percent Playas Occupied**	**Number Observed**
Quiscalus mexicanus	Great-tailed Grackle		Landbird	2	0.18	3
Quiscalus quiscula	Common Grackle		Other Wetland Dep.	23	2.12	59
Recurvirostra americana	American Avocet		Shorebird	37	3.41	250
Sayornis saya	Say's Phoebe		Landbird	5	0.46	5
Sialia currucoides	Mountain Bluebird		Landbird	8	0.74	41
Sialia sialis	Eastern Bluebird		Landbird	1	0.09	2
Spizella arborea	American Tree Sparrow		Landbird	1	0.09	1
Spizella breweri	Brewer's Sparrow	Tier 1	Landbird	2	0.18	5
Spizella pallida	Clay-colored Sparrow		Landbird	4	0.37	7
Spizella passerina	Chipping Sparrow		Landbird	6	0.55	15
Stelgidopteryx serripennis	Northern Rough-winged Swallow		Landbird	2	0.18	3
Streptopelia decaocto	Eurasian Collared-Dove		Landbird	3	0.28	24
Sturnella magna	Eastern Meadowlark		Landbird	1	0.09	1
Sturnella neglecta	Western Meadowlark		Landbird	253	23.30	912
Sturnus vulgaris	European Starling		Landbird	25	2.30	194
Tachycineta bicolor	Tree Swallow		Landbird	6	0.55	15
Tringa flavipes	Lesser Yellowlegs		Shorebird	37	3.41	351
Tringa melanoleuca	Greater Yellowlegs		Shorebird	38	3.50	140
Tringa semipalmata	Willet		Shorebird	5	0.46	10
Tringa solitaria	Solitary Sandpiper		Shorebird	6	0.55	8
Turdus migratorius	American Robin		Landbird	4	0.37	9
Tyrannus tyrannus	Eastern Kingbird		Landbird	7	0.64	16
Tyrannus verticalis	Western Kingbird		Landbird	45	4.14	72
Tyrannus vociferans	Cassin's Kingbird		Landbird	1	0.09	1
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		Other Wetland Dep.	6	0.55	167
Zenaida macroura	Mourning Dove		Landbird	90	8.29	368
Zonotrichia leucophrys	White-crowned Sparrow		Landbird	6	0.55	10