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Abstract
Large expanses of land across midcontinental North America have been heavily modified by installation of artificial drainage to convert prairie pothole wetlands into tillable areas. Drained potholes are observed as sheetwater wetlands in agricultural fields, are valued by migratory waterbirds, and have only been studied in limited contexts. We evaluated the use of agricultural sheetwater to migratory waterbirds in Iowa's Prairie Pothole Region and hypothesized that wetland size would be an important predictor of waterbird use. We observed 1913 unique wetlands and documented waterbird use on 31% of observations of those wetlands. The most frequently detected waterbirds were Killdeer, Mallard, Blue-winged Teal, and Lesser Yellowlegs. Wetland size had a positive effect ($P < 0.05$) on waterbird species richness and abundance. The findings from this study will help inform future decisions on drainage practices and their impact on wildlife and indicate the need to examine this habitat type at larger temporal and spatial scales.

Keywords
agriculture, Prairie Pothole Region, sheetwater, shorebird, drainage tile, waterbird, wetland

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Comments
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WATERBIRD USE OF SHEETWATER WETLANDS IN IOWA'S PRAIRIE POTHOLE REGION

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ABSTRACT: Large expanses of land across midcontinental North America have been heavily modified by installation of artificial drainage to convert prairie pothole wetlands into tillable areas. Drained potholes are observed as sheetwater wetlands in agricultural fields, are valued by migratory waterbirds, and have only been studied in limited contexts. We evaluated the use of agricultural sheetwater to migratory waterbirds in Iowa's Prairie Pothole Region and hypothesized that wetland size would be an important predictor of waterbird use. We observed 1913 unique wetlands and documented waterbird use on 31% of observations of those wetlands. The most frequently detected waterbirds were Killdeer, Mallard, Blue-winged Teal, and Lesser Yellowlegs. Wetland size had a positive effect ($P < 0.05$) on waterbird species richness and abundance. The findings from this study will help inform future decisions on drainage practices and their impact on wildlife and indicate the need to examine this habitat type at larger temporal and spatial scales.

KEY WORDS: agriculture, Prairie Pothole Region, sheetwater, shorebird, drainage tile, waterbird, wetland

INTRODUCTION

With the expansion of European settlement across North America from the 18th Century until present date there have been substantial habitat losses and alterations that have impacted wildlife including loss of wetland habitats across the continent (Dahl 1990). Roughly 30% of all historical wetlands in North America have been drained or otherwise transformed, although this figure climbs to 50% of wetlands when only considering the Continental United States (Dahl 1990). This widespread loss of wetlands has been disproportionately focused on the Midwest and in Iowa, which has lost more than 3.5 million acres that represent 89% of historical wetlands lost (Dahl 1990). Recently the rate of wetland loss has been greatly reduced throughout North

America and can be largely attributed to key legislative actions such as the Clean Water Act and 1985 Food Security Act to protect wetlands as well as conservation efforts through programs like the Conservation Reserve Program and the Wetland Reserve Program (Dahl 2000).

Despite these efforts toward conservation, losses due to agricultural and urban expansion are still the greatest threat to freshwater wetlands in the Continental United States (Dahl 2000). Additionally, shallow and temporary wetlands in agricultural fields—often referred to as sheetwater wetlands—are usually the primary target of enhanced drainage because they can reduce agricultural productivity and limit access for agricultural equipment (Euliss and Mushet 1999). Although modification and expansion of drainage to wetlands throughout the Prairie Pothole Region (PPR) has been largely reduced compared to historical rates there are projects underway in Iowa that advocate for increased drainage across the landscape and consolidation of sheetwater wetlands into larger and more permanent wetlands for purposes of de-nitrification and increased agricultural productivity on drained lands (IDALS 2010). Increased drainage will undoubtedly alter the extent and frequency of sheetwater wetlands on the landscape, and the potential effects of this action on wildlife are largely unknown.

Thirty-two species of waterfowl and thirty-four species of shorebirds are regularly observed in Iowa (Kent and Dinsmore 1996), often during bi-annual migratory journeys to and from productive breeding grounds that span the Great Plains to the Palearctic (Myers et al. 1987, Baldassarre and Bolen 1994). Both waterfowl and shorebirds use wetlands as a primary natural habitat for foraging, resting, and reproduction (Baldassarre and Bolen 1994, Colwell 2010). Sheetwater wetlands have the potential to be highly valuable to both species groups during spring migration, although the extent of this value is largely unexamined. Waterfowl and specifically the Anatidae (puddle ducks that prefer shallower water) are a well-studied taxonomic group, but there is a paucity of knowledge of their spring ecology in regard to migration and stopover ecology (Lindström 1995, Arzel et al. 2006). The body of knowledge about the spring migration of shorebirds is larger than that for waterfowl, but is still relatively sparse. Shorebirds are a diverse yet specialized group that are heavily tied to shallow aquatic habitats and mudflats that support a variety of invertebrates that make up their primary forage (Helmers 1992).

Shorebirds use a variety of agricultural habitats during nonbreeding and migratory life stages, including moist soil and flooded row crop fields (Colwell 2010). They are able to track highly ephemeral habitats such as sheetwater wetlands at a local scale (Skagen 1997) and efficiently utilize available resources (Goss-Custard 1977, 1979, Schneider and Harrington 1981). Estimated rates of resource assimilation have shown that shorebirds exhibit the highest recorded rate of energy assimilation in vertebrates (Kvist and Lindström 2003). Because of the high energy requirements of many shorebirds for long distance migration, migratory stopover sites are a crucial habitat for shorebird survival; common spring migrants such as Pectoral Sandpipers (*Calidris melanotos*), Dunlin (*C. alpina*), Semipalmated Sandpiper (*C. pusilla*), and White-rumped Sandpiper (*C. fuscicollis*) rely on stopover sites throughout the Great Plains to complete their annual migrations (Skagen and Knopf 1993) with birds in poor body condition often residing at stopover sites longer to accumulate fat reserves (Skagen and Knopf 1994). Our objective was to evaluate the use of agricultural sheetwater wetlands to migratory waterbirds throughout the PPR in Iowa. We used spatially replicated road-based surveys to document the presence of water and use by waterbirds and hypothesized that wetland size and extent would be an important driver of waterbird use in sheetwater wetland habitat. The findings from this study will be important for helping policy makers or regulators better understand the potential impacts of drainage practices on migrant waterbirds.

METHODS

Study area

This study was conducted during the spring migration period of 4 consecutive years (2011-2014) and spanned Iowa's portion of the PPR. In its entirety, the PPR extends from Alberta, Canada to central Iowa and encompasses approximately 70 million hectares of North America (Van der Valk 2005). In Iowa the PPR overlaps the Des Moines Lobe Landform Region (Miller et al. 2009), which represents the southern extent of the most recent Wisconsin Glaciation receding as recently as 12,000 years ago (IAN 2001).

Survey Methodology

Eight townships were randomly selected for surveys in 2011 and two additional townships (10 in total) were added for surveys in 2012 to 2014 to increase spatial coverage of the study area (Figure 1). Township selection was also based on three equal latitudinal strata of the Des Moines Lobe with the requirement that each strata was represented by at least 2 townships. There is a gradual reduction in annual precipitation from southeast toward northwest in the Des Moines Lobe Landform Region (PRISM Group 2006) and selection from these latitudinal strata ensured equal sampling of the entire region and its entire precipitation regime. Selected townships resided entirely or nearly entirely (>75%) within a 10-digit Hyrdrologic Unit Code (HUC-10) watershed (Watershed Boundary Dataset 2011) to ensure hydrologic isolation from other watersheds and fit hydrologic constraints set forth by project cooperators for hydrological monitoring.

A roadside survey route was established for each surveyed township using ArcGIS software (v. 9, ESRI 2006), XTools Pro for ArcGIS Desktop (v. 7.1.0, Data East Soft LLC), and Hawth's Analysis Tools for ArcGIS (Beyer 2004) that covered all roads within a township with minimum overlap or re-traveling of roads to increase survey efficiency. In general, waterfowl migration in Iowa begins in early March and the last migrant shorebirds depart by early June (Kent and Dinsmore 1996). Surveys were initiated in conjunction with spring snowmelt in March and spring migration of waterfowl and shorebirds through the region. Surveys were conducted every 6.1 days on average (SE = 0.13) from 14 March to 1 June 2011, 23 March to 23 May 2012, 16 March to 12 June 2013, and 18 March to 14 May 2014. This survey frequency of approximately 6 days coincides with known minimum stopover duration of some shorebirds (Skagen and Knopf 1994), although little is known about the residency time of shorebirds or waterfowl in this particular habitat type or time period. Survey routes were driven at a speed appropriate (generally ≤70 kilometers/hour) to adequately detect and observe wetlands within the survey townships. Upon detection of a wetland the observer stopped the vehicle to record observations of the wetland. Average survey route length was approximately 115 km, and routes generally took a minimum of two hours (minimum 1 hr 55 min, maximum 5 hrs) to complete in ideal conditions. Wetlands observed along the edges but outside of the townships surveyed were not included. Surveys were not conducted during adverse weather conditions (snow, rain) that would negatively impact detection probability of wetlands or birds present on wetlands. Surveys were completed between sunrise and sunset with consecutive visits to each individual survey route alternating between morning and afternoon visits when possible to maximize detection of bird use throughout any given day.

There are many definitions of conditions that define a wetland, although Cowardin et al. (1979) provided general definitions for the classification of wetlands that are widely used and accepted within the United States. The criteria defining a wetland for this study was determined primarily by the criteria of a) “visible water covering the soil surface” put forth by Cowardin et al. (1979) and b) located within a row crop agriculture field. We avoided using the term "farmed wetland" during the definition process for this study as this term has jurisdictional implications and specific definitions in the National Wetlands Inventory and 1985 Food Security Act that may not fit within the intended scope of the study. Presence of moist soil alone is not a good predictor of waterbird use of an area (Niemuth et al. 2006) and exclusion of these areas from surveys will lead to conservative estimates of waterbird use of sheetwater wetlands. These wetlands are not likely to host macrophyte plant species because they are located in perpetually disturbed agricultural fields (Niemuth et al. 2006). Only wetlands completely visible from the roadway were surveyed to avoid any assumptions about unknown characteristics of these wetlands. Upon detection of a wetland along the survey route, numerous characteristics were recorded. These measurements include a) UTM easting and northing of the observation point from a Garmin GPSmap 76 unit (Garmin LTD 2009), b) the bearing to the wetland and distance to the closest edge of the wetland using a laser rangefinder, and c) a photograph of the extent of the wetland using a Casio EX-H20G camera (Casio Computer Co. Ltd. 2010). The percentage of surface water covered in ice or emergent vegetation was visually estimated and recorded to test for relationships between relative water available and bird use. Size of the wetland was estimated via 5 increasing size bins as follows: 0-0.1 ha (Class 1), 0.1-0.25 ha (Class 2), 0.25-0.50 ha (Class 3), 0.5-1.0 ha (Class4), and >1.0 ha (Class 5). The structure of these size bins is designed to be able to detect expected variability and relatively high abundance of wetlands of smaller sizes.

We surveyed waterbird species utilizing wetlands using 10x42 binoculars and a 20-60x spotting scope. Because of access challenges on private land (>99% of surveyed wetlands in this study were privately owned) counts were only conducted from public roads and we also assumed perfect detection probability of birds present. The survey methodology of this study was a roadside survey that acts as an infinite width line transect. This methodology assumes a constant detection probability with increasing distance, and is generally only robust when species being surveyed are conspicuous and within open habitat (Bibbey 2000, Hill 2005). These wetlands were located in agricultural production fields with perpetual mechanical and chemical disturbance that prevent the establishment of macrophyte vegetation that would potentially yield imperfect detection of waterbirds. Although this study recorded all waterbird species detected, the most abundant and thus focal species were spring migrant waterfowl and shorebirds of the orders *Anseriformes* and *Charadriiformes,* respectively, present on a surveyed wetland as well as their respective abundances during each observation.

Statistical Analyses

We used a generalized linear model (GLM) framework to evaluate what attributes of sheetwater wetlands best determined waterbird use. The two models we used each express an expected value of a response variable (species richness or waterbird abundance in this study) as a linear combination of individual covariates and are robust to non-normal data and uneven sample sizes (McCullagh and Nelder 1989). The individual covariates used included wetland size class, the standardized date of a survey across all seasons (March 14 = Day 1), distance of a wetland from a road, and study year. We included wetland size to test our hypothesis that increases in wetland size would drive increases in both waterbird diversity and abundance at a wetland. We also included standardized survey date to test for a seasonal effect during migration, distance from a road to test for potential disturbance effects on waterbirds from roadways, and survey year to test for a year effect on both waterbird diversity and abundance. A negative binomial distribution was specified for these analyses to account for the heavy right skew of count data in this study (O’Hara and Kotze, 2010). We considered results to be statistically significant at α =

0.05. Rarefaction analyses were also done with EcoSim (Gotelli and Entsminger 2001) on the five different wetland size classes to test if effects of wetland size on waterbird richness were strongly influenced by an abundance effect (Gotelli and Colwell 2001).

RESULTS

Observations of wetlands and waterbirds

A total of 3661 observations of 1913 wetlands was made during the course of this study. Of this total, 1025 observations on 407 unique wetlands were made in 2011, 168 observations of 99 unique wetlands in 2012, 1350 observations of 560 wetlands in 2013, and 1284 observations of 847 wetlands in 2014. Wetlands were predominantly in the smaller size classes, with 49% (1803 wetland observations) in the 0-0.10 ha class. There was a consistent pattern across all years for the distribution of wetlands being heavily weighted toward smaller classes (Figure 2).

A total of 14,698 individual waterbirds of 53 species in the orders Anseriformes, Pelecaniformes, Gruiformes, and Charadriiformes was observed utilizing sheetwater wetlands during this study (Table 1). In total, waterbirds were observed utilizing sheetwater wetlands during 31% of all wetland observations (1154 of 3661 observations). Diversity was generally greatest in March with an expected initial surge in migrant waterfowl due to spring melt of ice and snow cover, while another peak in diversity occurred in late April and early May with the arrival of spring migrant shorebirds.

Waterbird Use Patterns

Wetland size had a significant positive effect on both waterbird species richness (β = 0.353, SE = 0.024) and overall waterbird abundance (β = 0.691, SE = 0.040) observed utilizing sheetwater wetlands. The standardized date of a wetland observation had a slight but significant positive effect on species richness (β = 0.010, SE = 0.001) and slight but significant negative effect (β = -0.010, SE = 0.002) on abundance of waterbirds observed at sheetwater wetlands, likely reflecting the differences of migration phenology in waterfowl (generally earlier migrants) and shorebirds (generally later migrants). We also observed a slight but significant positive effect (β = 0.002, SE = 0.001) of distance of wetlands from a road on waterbird abundance. This could indicate that birds were avoiding roadways to a slight degree although we did not see significant effects of wetland distances from roadways on species richness, or significant effects of survey year on either species richness or waterbird abundance (Table 2).

Rarefaction analysis did not indicate significant differences between waterbird richness between size classes at low abundances, as confidence intervals broadly overlapped for several size classes except at high waterbird abundances (Figure 3).

DISCUSSION

This study implemented a formal road-based survey and provides initial documentation and assessment of waterbird use of sheetwater wetlands in Iowa's PPR. Extent and use of this specific type of ephemeral wetland in an overwhelmingly agricultural ecosystem by migrant waterbirds has been anecdotally documented but not assessed systematically at a scale as large as this study (LaGrange and Dinsmore 1989, Kenne 2006). Our observations of wetlands coincided with expectations that during spring migration this habitat type was readily available to migratory waterbirds, and that migratory waterbirds frequently used these wetlands.

Although there is not an explicit model to predict waterbird richness or use of these sheetwater wetlands at this time we have identified some relationships between wetland characteristics and waterbird use. We observed significant ($P<0.05$) effects of some wetland characteristics including relationships between species richness and waterbird abundance, species richness and wetland size, and waterbird abundance and wetland size. The small but significant effects of wetland distance from a road and observation date appear to be of lesser biological relevance when viewed from an absolute sense (the difference in estimated diversity from the smallest to largest wetland sizes is approximately two species) however when the relatively low diversity present in many observed wetlands an increase of two species would represent a large relative increase of diversity. The strong effect of overall abundance on species richness found by rarefaction analysis is expected in virtually any system, especially one as highly homogenized by row crop agriculture as Iowa's PPR. The more interesting relationships observed were those of increasing richness and increasing total abundance with increasing wetland size. The relationships between habitat patch area (or sampling area size) and both richness and total abundance have been extensively studied (Preston 1962, MacArthur and Wilson 1967) and an increase of richness and abundance might be expected even in a homogenous habitat patch such as sheetwater wetlands (largely devoid of vegetation, very low topographic relief, and ubiquitous agricultural disturbance help maintain this homogeneity). Rarefaction analysis indicated that increasing richness with size may be an effect of abundance rather than a true increase in diversity with increased size. This is not to say that wetland size isn't of value to migratory waterbirds; we observed a positive relationship between wetland size and waterbird richness and abundance (which rarefaction indicated would increase diversity) but increased sampling may be necessary to fully assess this relationship. The percentage of wetlands occupied by waterbirds during observation was low overall (31%) but it should be noted that our observations only represent a small fraction of available time and actual use of these wetlands may be higher.

Wetland size was the most significant predictor of biodiversity and waterbird use in this study. A related study with a similar methodology (LaGrange and Dinsmore 1989) also found that size was the most important predictor of sheetwater wetland use by Mallards in Iowa. Comparing the results of LaGrange and Dinsmore (1989) to the results of this study can also help illustrate some important factors in waterbird use of sheetwater. In two survey seasons (February-May, 1983-1984) LaGrange and Dinsmore used a single roadside survey route of 97 km to detect 455 sheetwater wetlands and 19,530 Mallard use days, most on sheetwater wetlands >2.0 ha. These two survey seasons (January-May) were the 45th and 27th wettest, respectively, in 119 years of recorded climatological data for the state (NOAA). In contrast, we used eight survey routes in 2011 and ten routes in 2012-2014 averaging 117 km in length and detected 1593 total wetlands (only 14% of which were >1.0 ha) with a minimum of 14,989 waterbird use days of 53 species. Our sampling effort was greatly increased both spatially and temporally relative to LaGrange and Dinsmore (1984) and our sampling seasons (January-May ranked as the 74th, 48th, 1st, and 70th wettest years in 119 years of climatological data (NOAA). The amount of subsurface drainage on Iowa's landscape has undoubtedly increased since 1984, with 2011-2012 having more new drainage installation than any similar recent period (Love, March 28th, 2014). The combination of drier spring conditions in 3 of 4 years and increased subsurface drainage probably explain most of the differences between our findings and those of LaGrange and Dinsmore (1984).

Our study indicates that size and availability of sheetwater wetlands are likely to determine use by migratory waterbirds. Waterbirds were observed on 31% of all wetlands, which could suggest that these wetlands have low value. However, our ten surveyed townships comprise only 3% of the Des Moines Lobe Landform's 3 million hectares. Thus, the potential extent and abundance of wetlands available for waterbird use in this larger region is impressive, especially during a migratory season with increased precipitation. A widespread increase in subsurface drainage across this landscape (like those proposed by the Iowa Drainage and Wetlands Landscape Systems Initiative, commonly known as the "Iowa Plan" (IDALS 2010) would reduce the extent and availability of sheetwater to migratory waterbirds. The Iowa Plan also proposes to construct large wetlands for the purposes of de-nitrification and increased wildlife value. An important question is what specific wildlife or habitat value these wetlands offer (Brown and Phillips 2004, O'Neal et al 2008), and if they offer synonymous habitat type and extent compared to the existing networks of sheetwater wetlands that are widespread, highly variable, and change substantially in depth and extent in short periods of time. Previous research has suggested that these larger and more permanent basins do not offer this equivalent value to migratory waterbirds by reducing water level fluctuations and lowering wetland productivity (Anteau 2012, McCauley et al. 2015). Consolidation drainage of many existing sheetwater wetlands into larger more stable basins could result in lower wetland densities on the landscape and reduce connectivity between these wetlands. Networks of small scattered wetlands with apparent low numbers of birds can also provide critical stopover habitat or connectivity between larger breeding and wintering sites for many species, but have not yet received prioritization for conservation actions (Skagen and Knopf 1994, Farmer and Parent 1997, Haig et al 2008).

The design of this study also limited the characteristics that could be observed for each sheetwater wetland. The majority of land in Iowa's PPR is privately owned and requires permission to access. Furthermore, sheetwater wetlands vary in their appearance and persistence in response to changes in subsurface drainage (e.g., temporary blockage of tile lines), precipitation events, soil infiltration rates, and evapotranspiration rates. The ability to measure resource availability (e.g., food resources) within each wetland and differences in resources between wetlands may have helped better assess waterbird use of these wetlands. Shorebirds aggregate around and readily respond to areas of high invertebrate availability (Recher 1966, Safran et al. 1997, Knapp 2001, Playck and Harrington 2004) and agricultural wetlands can host invertebrate resources sufficient to support foraging shorebirds (Taft and Haig 2005). More direct measures of food resources for waterbirds could help gauge the magnitude of value of sheetwater wetlands individually and as a whole. An additional potential confounding factor to our results is the effect of hydroperiod on both wetland size and wetland biological community present, which could potentially be solved with direct sampling of wetlands and knowledge of food resources and drainage paradigm for each wetland.

This study documented use of sheetwater wetlands by spring migrant waterbirds and confirmed that wetland size is an important driver of waterbird use of this habitat. Larger wetlands are more likely to be used by waterbirds and host more individuals of a greater diversity than smaller wetlands. We anticipate that these trends would also hold in years with average to above-average precipitation except that diversity and abundance of waterbirds utilizing these wetlands could be even greater. Regional and landscape level changes in subsurface drainage practices probably have impacts on sheetwater wetlands that are not yet fully understood. The need to better assess the conservation value of stopover habitats in the PPR has been identified as a priority for migratory waterbirds (Helmers 1992, Dinsmore et al. 1999, Brown et al. 2001). As our work illustrates, these stopover habitats in Iowa's PPR include sheetwater wetlands in agricultural fields. Conservation or agricultural practices that retain some sheetwater in agricultural fields during spring migration will benefit these migratory waterbirds by providing links to other stopover sites. However, future work is needed to "upscale" the value of these wetlands to waterbirds at the regional or national level and to incorporate measures of wetland quality.

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TABLES

Table 1 List of all species observed with the overall number of occasions that species was observed (Frequency) and the total number of individuals of that species observed over all occasions (Abundance) from waterbird surveys in Iowa's Prairie Pothole Region, spring 2011-2014.

Species Observed		**Frequency**	**Abundance**
Greater White-fronted Goose	*Anser albifrons*	6	465
Snow Goose	*Chen caerulescens*	3	121
Ross's Goose	*Chen rossii*	1	2
Canada Goose	*Branta canadensis*	63	631
Trumpeter Swan	*Cygnus buccinator*	8	63
Wood Duck	*Aix sponsa*	12	24
Gadwall	*Anas strepera*	58	796
American Wigeon	*Anas americana*	19	76
Mallard	*Anas platyrhynchos*	351	4361
Blue-winged Teal	*Anas discors*	158	1195
Cinnamon Teal	*Anas cyanoptera*	1	1
Northern Shoveler	*Anas clypeata*	87	925
Northern Pintail	*Anas acuta*	32	214
Green-winged Teal	*Anas crecca*	64	904
Canvasback	*Aythya valisineria*	13	169
Redhead	*Aythya americana*	7	41
Ring-necked Duck	*Aythya collaris*	19	287
Lesser Scaup	*Aythya affinis*	20	292
Bufflehead	*Bucephala albeola*	3	6
Common Goldeneye	*Bucephala clangula*	1	2
Hooded Merganser	*Lophodytes cucullatus*	5	11
Common Merganser	*Mergus merganser*	1	2
Ruddy Duck	*Oxyura jamaicensis*	4	38
Pied-billed Grebe	*Podilymbus podiceps*	4	5
Great Blue Heron	*Ardea herodias*	2	2
White-faced Ibis	*Plegadis chihi*	1	1
American Coot	*Fulica americana*	5	76
Black-bellied Plover	*Pluvialis squatarola*	4	19
American Golden-Plover	*Pluvialis dominica*	20	199
Semipalmated Plover	*Charadrius semipalmatus*	11	27
Killdeer	*Charadrius vociferus*	644	1016

Spotted Sandpiper	*Actitis macularius*	28	33
Solitary Sandpiper	*Tringa solitaria*	30	44
Greater Yellowlegs	*Tringa melanoleuca*	79	375
Willet	*Tringa semipalmata*	5	7
Lesser Yellowlegs	*Tringa flavipes*	139	546
Upland Sandpiper	*Bartramia longicauda*	8	9
Hudsonian Godwit	*Limosa haemastica*	6	21
Marbled Godwit	*Limosa fedoa*	1	13
Ruddy Turnstone	*Arenaria interpres*	1	9
Stilt Sandpiper	*Calidris himantopus*	2	7
Dunlin	*Calidris alpina*	5	28
Baird's Sandpiper	*Calidris bairdii*	13	35
Least Sandpiper	*Calidris minutilla*	60	284
White-rumped Sandpiper	*Calidris fuscicollis*	10	30
Pectoral Sandpiper	*Calidris melanotos*	83	627
Semipalmated Sandpiper	*Calidris pusilla*	19	85
Long-billed Dowitcher	*Limnodromus scolopaceus*	7	25
Wilson's Snipe	*Gallinago delicata*	30	85
Wilson's Phalarope	*Phalaropus tricolor*	2	4
Bonaparte's Gull	*Chroicocephalus philadelphia*	4	22
Franklin's Gull	*Leucophaeus pipixcan*	3	32
Ring-billed Gull	*Larus delawarensis*	26	406

Table 2. Estimated parameters of a generalized linear model (GLM) for sheetwater wetland factors influencing waterbird species richness and abundance in Iowa's Prairie Pothole Region, spring 2011-2014. Model effects included the wetland size class (Size class; 5 size classes), standardized date of survey (Date), distance of the wetland from the nearest road (DRoad), and survey year (Year).

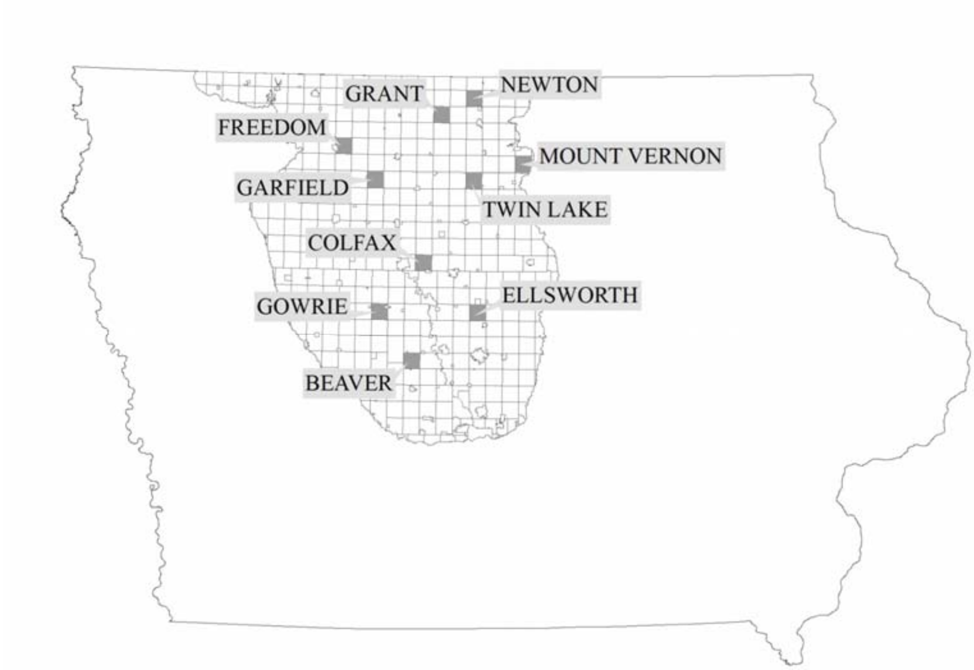
	Response Variable					
	Species Richness			**Overall Abundance**		
Predictor	β	SE	P-value	β	SE	P-value
Intercept	-2.373	0.425	<0.001	-0.171	0.608	0.778
Size class	0.353	0.024	<0.001	0.691	0.04	<0.001
Date	0.010	0.001	<0.001	-0.01	0.002	<0.001
Droad	-0.001	0	0.112	0.002	0.001	0.008
Year	-0.002	0.032	0.949	0.054	0.046	0.246

FIGURE LEGENDS

Fig. 1 Map of all surveyed townships in Iowa's Prairie Pothole Region, spring 2011-2014. All townships were surveyed during each year except for the Freedom and Grant townships, which were added to the survey list in 2012

Fig. 2 Graph of the distribution of wetland observations by size classes for all wetlands surveyed in Iowa's Prairie Pothole Region, spring 2011-2014. Wetland observations for 2011 are represented by black bars, observations for 2012 are represented by gray bars, observations for 2013 are represented by black stippled bars, and observations for 2014 are represented by white bars. Size of the wetland was estimated via 5 increasing size bins as follows: 0-0.1 ha (Class 1), 0.1-0.25 ha (Class 2), 0.25-0.50 ha (Class 3), 0.5-1.0 ha (Class 4), and >1.0 ha (Class 5)

Fig. 3 Rarefaction curves for observations of waterbird species richness and abundance by size class (bars show 95% intervals) for wetlands in Iowa's Prairie Pothole Region, spring 2011-2014. Confidence intervals overlap for all size classes except for Class 1 wetlands at abundances >1400 individuals. Size of each wetland was estimated via 5 increasing size bins as follows: 0-0.1 ha (Class 1), 0.1-0.25 ha (Class 2), 0.25-0.50 ha (Class 3), 0.5-1.0 ha (Class 4), and >1.0 ha (Class 5)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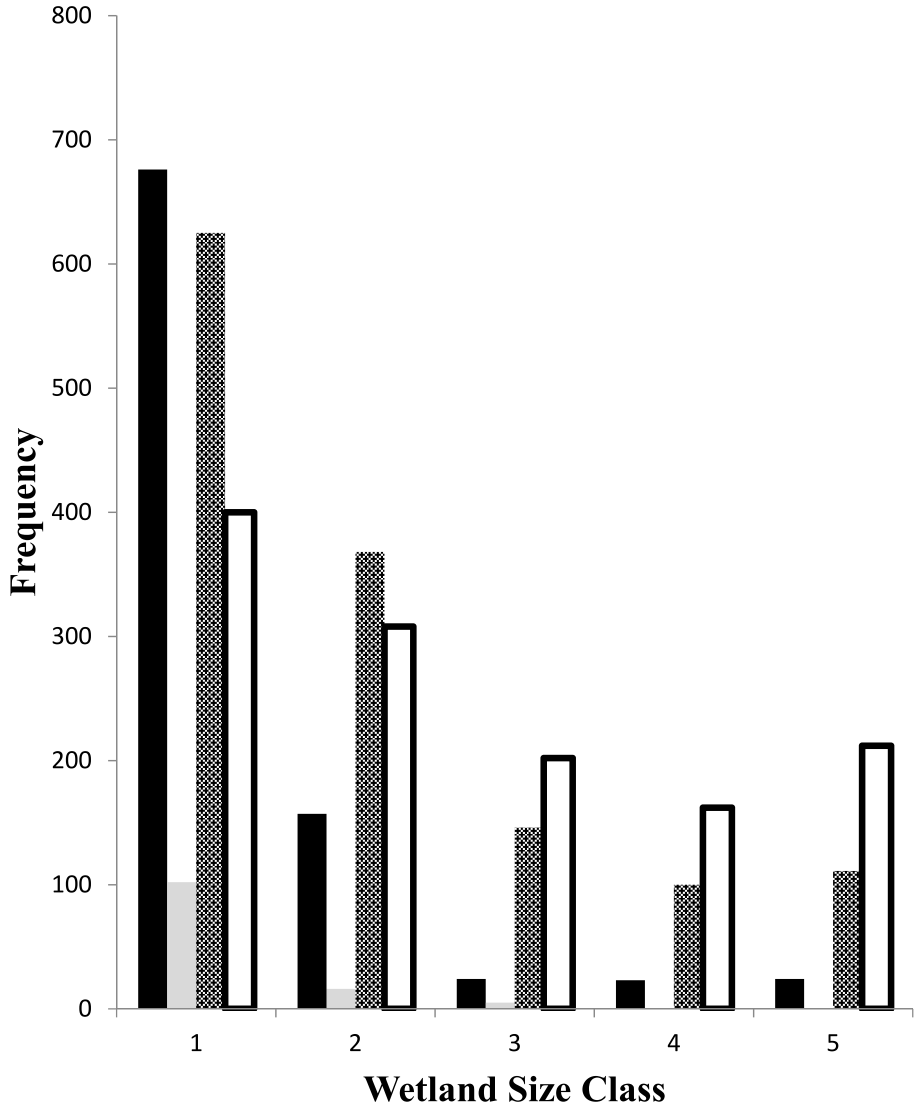
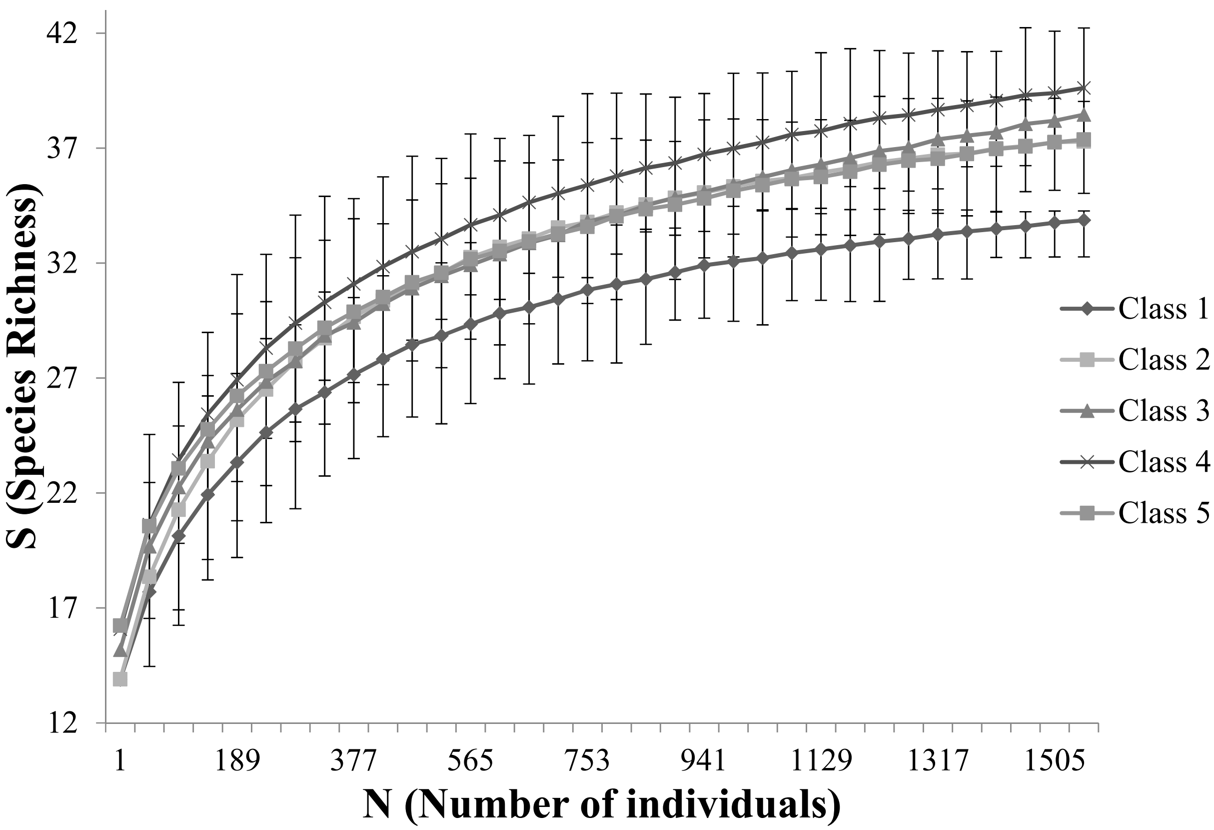
NEWTON
FREEDOM
MOUNT VERNON
GARFIELD
TWIN LAKE
COLFAX
GOWRIE
ELLSWORTH
BEAVER


800
700
600
500
400
300
200
100
0
Frequency
1
2
3
4
5
Wetland Size Class


42
37
32
27
22
17
12
S (Species Richness)
1
189
377
565
753
941
1129
1317
1505
N (Number of individuals)
Class 1
Class 2
Class 3
Class 4
Class 5