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USE OF WETLANDS BY SPRING-MIGRANT SHOREBIRDS IN AGRICULTURAL LANDSCAPES OF NORTH DAKOTA'S DRIFT PRAIRIE

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Abstract: Small, isolated wetlands in the Prairie Pothole Region of North America may be of critical importance to migrating shorebirds but are at high risk of drainage for agricultural production. We evaluated shorebird use of 1,181 temporary and seasonal wetlands within agricultural fields in the Drift Prairie physiographic region of North Dakota, USA over a 10-week period in spring of 2001. A total of 4,050 shorebirds of 25 species was observed on sampled wetlands. Shorebirds selected temporary wetlands that had water present during multiple visits, little emergent vegetation, large perimeters, and other wetlands in the surrounding landscape. Shorebirds were less likely to use wetlands showing evidence of drainage. Observed use of wetland basins suggests that small wetlands in the Prairie Pothole Region host millions of migrant shorebirds each spring. Continued existence of many of these wetlands may be threatened by a recent U.S. Supreme Court ruling that removed federal protection from certain isolated wetlands. Our results show the importance of current wetland protection provisions such as ''Swampbuster'' and other conservation practices of the United States Department of Agriculture Farm Program.

Key Words: Farm Bill, landscape ecology, migration chronology, Prairie Pothole Region, wetland complex

INTRODUCTION

Stopover sites and staging areas are critically important to shorebirds for replenishment of energy reserves necessary to complete long-distance migrations between wintering and breeding grounds (Skagen and Knopf 1993, Skagen and Knopf 1994a, Tsipoura and Burger 1999). Some staging areas, such as San Francisco Bay and Delaware Bay, are located along major coastal migration routes, have high availability of energy-rich food, and are visited by hundreds of thousands of shorebirds annually (Clark et al. 1993, Page et al. 1999). Many of the large wetlands and estuaries with high shorebird use are protected as wildlife refuges or are recognized through programs such as the Western Hemisphere Shorebird Reserve Network (Page et al. 1999, Harrington et al. 2002).

Small wetlands in the Prairie Pothole Region (PPR) also may be of critical importance to migrating shorebirds. Most wetlands in this region are < 0.5 ha, and wetland density can exceed 40/km^2 in some areas (Kantrud et al. 1989). These wetlands typically contain water only on a temporary or seasonal basis (Kantrud et al. 1989), and the number of basins containing water can vary greatly among years (Niemuth and Solberg 2003). Because of their small size, dispersion, and dynamic nature, few individual wetlands in the PPR host large concentrations of migrant shorebirds. Instead, shorebirds migrating through the PPR are widely dispersed, with small numbers of birds at stopover locations that can vary among years depending on water levels (Skagen and Knopf 1993, Skagen 1997).

Despite their unpredictability, these wetlands are vital to many species of shorebirds that migrate through the mid-continental portion of North America. During migration, many shorebirds select wetlands that are shallow, sparsely vegetated, and have substantial mudflats (Colwell and Oring 1988, DeLeon 1996). Foraging is the dominant behavior on prairie wetlands during spring migration (Davis and Smith 1998a, DeLeon and Smith 1999) as birds acquire energy reserves (Johnston and McFarlane 1967, Morrison 1984). Shorebirds may reduce foraging costs and increase foraging efficiency by selecting wetlands in proximity to other wetlands (Farmer and Parent 1997).

Small, shallow wetlands in cultivated fields are considered at high risk of drainage because of the inconvenience of tilling around wetlands and the incentive to grow crops on what is considered unutilized ground within existing crop fields. Since settlement by Europeans, 49% of the wetlands in North Dakota have been lost (Dahl 1990). Following the 2001 ruling of the U.S. Supreme Court in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers* (SWANCC), ''isolated'' wetlands, such as those typical of the PPR, may no longer have the same level of protection under the U.S. 1972 Clean Water Act (Leibowitz and Nadeau 2003, van der Valk and Pederson 2003), which increases risk of further loss. Wetlands vulnerable to drainage for agriculture receive some protection under the Swampbuster Provision of the 1985 U.S. Food Security Act (Swampbuster) and subsequent farm bills, but protection is subject to farmer participation in the U.S. Farm Program as well as continuation of the Swampbuster provision in future farm legislation (Brady 2000). Some farm organizations have proposed that the U.S. Congress revise the Food Security Act to exempt basins < 0.4 ha and ''frequently cropped'' basins of any size from Swampbuster protection (Johnson et al. 1996).

Drainage of small wetlands in the PPR would likely negatively affect shorebirds that migrate through mid-continental North America. However, use of wetlands in cultivated fields by migrant shorebirds in the region is poorly understood, even though $> 80\%$ of wetlands in the Drift Prairie of North Dakota are located in cropland or alfalfa hay fields (U.S. Fish and Wildlife Service [USFWS], unpublished data). Therefore, we evaluated use of wetlands in agricultural landscapes of the Drift Prairie portion of North Dakota to determine the extent such wetlands were used by migrant shorebirds and how wetland and landscape characteristics influenced wetland use by migrant shorebirds. Small and temporary wetlands are the least studied wetlands in the area (Johnson et al. 1996), and understanding how shorebirds respond to landscapes and anthropogenic changes in habitat and landscape structure is identified as a priority research need within the U.S. Shorebird Conservation Plan (Oring et al. 2000).

STUDY AREA

We sampled wetlands along 76 roadside transects primarily located in the Drift Prairie in eastern North Dakota, USA (Figure 1). The Drift Prairie is also known as the Glaciated Plains physiographic region and is characterized by rolling topography, fertile soils, and high densities of temporary and seasonal wetlands (Kantrud et al. 1989, Bluemle 1991). Crop agriculture is the dominant land use of the Drift Prairie, although intensity of cultivation varies throughout the region. Because our objective was to evaluate wetlands in cropland-dominated landscapes, we selected survey transects in areas of extensive agriculture in the eastern portion of North Dakota's Drift Prairie. We sampled wetlands from roads, balancing the potential bias of roadside surveys with the ability to increase greatly the number of basins sampled and geographic extent of the study and ensure logistically feasible repeated access to wetland basins. We used remotely sensed land-cover data (USFWS, unpublished data) to place transects in areas meeting the following criteria: 1) $\geq 75\%$ cultivated land in surrounding landscape, 2) east-west road segment ≥ 4.8 km long, and 3) ≥ 3.2 km from another transect.

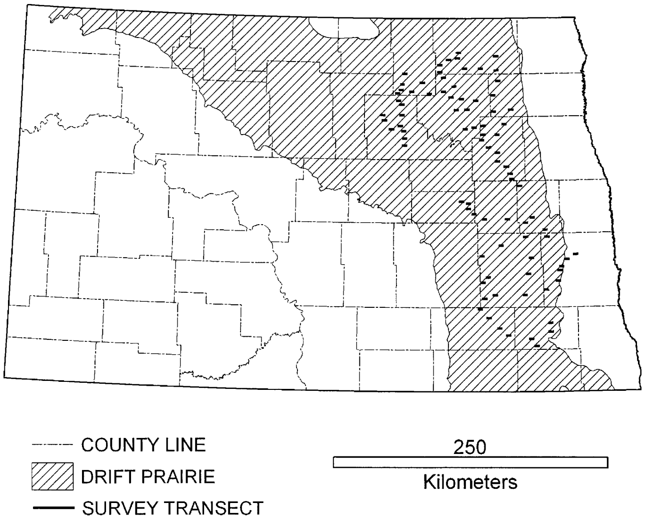

Figure 1. Location of shorebird survey transects in the Drift Prairie of North Dakota. Transects were 4.8 km long and located in areas with $\geq 75\%$ cultivated land within 800 m.

METHODS

Survey Methods

Survey crews consisted of a driver and an observer. To increase survey efficiency and accuracy, we only sampled wetlands on the north side of transects and within 300 m of roads on which transects were located. Only natural temporary and seasonal wetlands wholly or partially within cultivated fields were sampled, as these were considered at greatest risk of drainage due to their small size, shallow depth, and proximity to existing cultivation. We did not sample wetlands created by excavated roadside ditches. Wetland information was obtained from the USFWS National Wetlands Inventory (NWI) digital database, and each wetland was identified by the most permanent wetland water regime within each basin (Cowardin et al. 1995, Johnson and Higgins 1997). Survey crews were provided with maps showing transects, outlines of wetland basins, and the 300-m survey buffer.

We sampled every wetland once each week for 10 weeks, starting 9 April 2001 and ending 15 June 2001. Surveys took place from one hour after sunrise to one hour before sunset. Wetlands were observed from the road and were not sampled during snow or heavy rain. Because standing water and mudflats are important predictors of use for many species of shorebirds (Colwell and Oring 1988, Hands et al. 1991, DeLeon 1996, Long and Ralph 2001), presence of water or saturated soil in each basin was recorded during every visit. To assess the influence of vegetative cover on shorebird use, each wetland was assigned to one of four cover class categories depending on amount and pattern of coverage by emergent vegetation adapted from Stewart and Kantrud (1971). Under this system, cover classes ranged from closed stands of tall (>25 cm) emergent vegetation with open water or bare soil covering < 5% of wetland area to open water or bare soil covering > 95% of wetland area (Figure 2). Finally, any evidence of attempted wetland drainage (i.e., ditches) was noted for each wetland.

We attempted to count all individuals of all species of shorebirds present for each basin during every visit. Because of difficulties in consistently distinguishing between greater and lesser yellowlegs (scientific names for all species are listed in Table 2), the two species were lumped together, as were long-billed and short-billed dowitchers. Shorebirds, primarily *Calidris* spp., that could not be identified to species were recorded as unidentified. To reduce counting the same birds more than once on individual transects, surveys by transect were conducted seven days apart, which exceeds mean observed length of stay for many shorebirds migrating in spring (Skagen and Knopf 1994a, Alexander and Gratto-Trevor 1997).

Shorebirds respond to landscape characteristics such as the presence of wetland complexes (Skagen and Knopf 1994b, Farmer and Parent 1997), so we calculated the percentage of the landscape covered by permanent and semi-permanent wetlands within 800 m of each survey basin's center (Table 1). We found little information quantifying the scale(s) at which shorebirds perceive landscapes but chose an 800-m radius, as it was likely to identify a ''larger wetland complex'' (Skagen and Knopf 1994b:103) in proximity to study basins. We did not include temporary and seasonal wetlands in the landscape evaluation, as they often did not contain water, and we were unable to determine landscape-level water conditions during the survey period. Semi-permanent and permanent wetlands were more likely to contain water, and we believe that they were a more reliable index of wetland and water availability in the surrounding landscape.

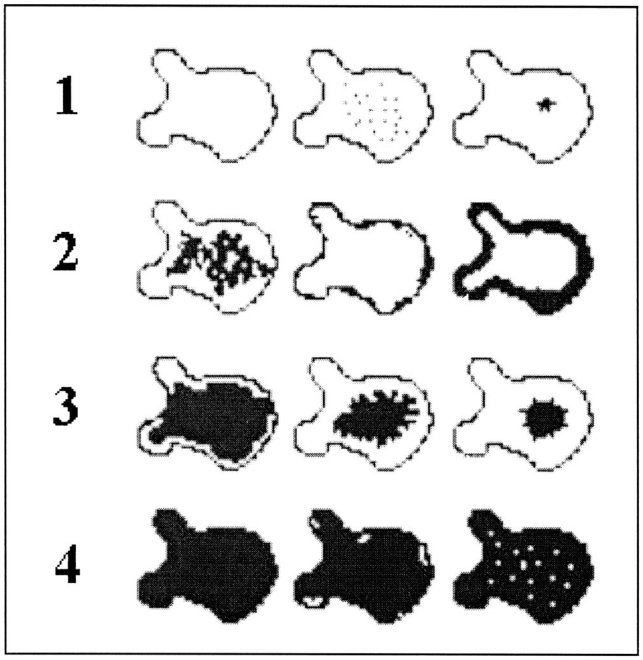

Figure 2. Cover type categories used to characterize wetland basin vegetation, adapted from Stewart and Kantrud (1971). White areas represent emergent vegetation; black areas represent open water or bare soil. Cover Type 1 had closed stands of tall (>25 cm) emergents with open water or bare soil covering < 5% of wetland area. Cover Type 2 had open water or bare soil covering 5–95% of wetland area, with scattered patches or diffuse open stands of emergents > 25 cm tall. Cover Type 3 had central expanses of open water or bare soil covering 5–95% of wetland area, surrounded by peripheral bands of emergents averaging 1.8 m wide. Cover Type 4 had open water or bare soil covering > 95% of wetland area. This cover type also included small ponds with emergents restricted to margins < 1.8 m wide.

Statistical Analyses

We used wetland characteristics sampled on-site and derived from digital data (Table 1) as predictor variables in logistic regression analyses to determine selection of wetlands by migrant shorebirds, where use was defined as the observed presence of shorebirds on a wetland during ≥1 visit. Models identifying wetland characteristics associated with the presence of individual species were developed for species that were observed on >30 wetlands. We only included one variable of pairs of predictor variables that were highly (r_s

Table 1. Wetland characteristics included in analysis of wetland selection by migrating shorebirds in the Drift Prairie of North Dakota.

Variable Name	Variable Description
Water regime	Class (seasonal or temporary) of wetland as identified by National Wetlands Inventory data. Seasonal wetlands typically are deeper and have surface water present for longer periods than temporary wetlands (Cowardin et al. 1979). Coded as 0/1 indicator variable.
Cover type	Four categories characterizing vegetation characteristics of each wetland (Figure 2), with Cover Type 1 having the most vegetation and Cover Type 4 the least. Coded as 0/1 indicator variables.
Times wet	Number of times (0–10) a wetland basin contained water during 9 or 10 sample periods.
Times saturated	Number of times (0–10) soil in a wetland basin was saturated but did not contain standing water during 9 or 10 sample periods.
Area	Area (ha) of sample basin as mapped by National Wetlands Inventory (NWI).
Perimeter	Perimeter (m) of sample basin as mapped by NWI.
Water in landscape	Percent of landscape within 800 m of center of sample wetland covered by semi-permanent and permanent wetlands as identified and mapped by NWI.
Drainage	Ditch draining water from the wetland was noted. Coded as 0/1 indicator variable.

> 0.6) correlated. We used Akaike's Information Criterion (AIC) to evaluate models, selecting those that best fit the data while minimizing bias and uncertainty (Burnham and Anderson 1998). Signs of coefficients for additional variables included in models within 2 AIC units of the best model were also noted, as these models are also considered to have substantial support (Burnham and Anderson 1998). Because habitat selection by migrant shorebirds in the region is poorly known, we treat the analysis as exploratory. We used Receiver Operating Characteristics curves (ROC; Swets 1988) as an indication of model performance, with the caveat that absolute use or non-use of wetlands was not known. ROC scores range from 0 to 1 and indicate the ability of a model to discriminate between two groups; a score of 0.5 indicates random performance, and higher values indicate better discrimination (Swets 1988). Statistics were calculated with Number Cruncher Statistical System (NCSS 2001).

RESULTS

Because the number of wetlands surveyed each week varied slightly due to road closures, changes in personnel, and human error, only wetlands sampled nine or ten times during the sample period ($n = 243$ and 938, respectively) were included in analysis, for a total of 1,181 wetlands. Wetlands that were not completely visible from the road ($n = 41$) were not included in habitat selection analyses. The number of wetlands surveyed along each of the 76 transects ranged from 1 to 40 ($\bar{x} = 15.5$). A total of 4,050 shorebirds of 25 species were observed on sample wetlands (Table 2). Additional species might have been present, as 371 birds were unidentified. Number of birds observed on a wetland during any one sample period ranged from one (many species) to 400 (ruddy turnstone, week of May 28) and 470 (dunlin, week of May 21). Number of individuals and number of species peaked the week beginning May 21 (Figure 3). Use of wetlands by shorebirds is a minimum, as each wetland was viewed for literally only a few minutes each week, and wetlands almost certainly experienced use that was not detected.

The percentage of sample wetlands containing water generally decreased throughout the sample period (Figure 4), and shorebird use of wetlands generally increased with the presence of water in a basin (Tables 3 and 4). Sixteen wetland basins never contained water during the sample period, and we observed no shorebird use in these basins. Conversely, shorebirds were observed in $\geq 42\%$ of basins that contained water seven or more times during the 10-week sample period (Table 3). The number of times a wetland contained standing water was negatively correlated with the number of times only saturated soil was present ($r_s = -0.49$) and was a stronger predictor of shorebird presence, as the AIC value in the model best describing presence of any shorebird species (Table 4) increased 90 points when times saturated was substituted for times wet.

Mean (SE) mapped size of temporary ($n = 666$) and seasonal ($n = 515$) basins in the sample was 0.22 (0.02) and 0.81 (0.07) ha, respectively. Mean number of times seasonal basins contained water was 8.2 (0.1), whereas the mean number of times temporary basins contained water was 5.8 (0.1). Of the 1,140 wetlands included in habitat selection analyses, 36 were classified as a Stewart and Kantrud (1971) Type 1 cover class, 55 as Type 2, 19 as Type 3, and 1,030 as Type 4. Evidence of surface drainage was observed at 46 basins; these basins were wet fewer times than undrained basins ($\bar{x} = 4.7$ and 6.9, respectively).

Regression analysis indicated that shorebirds consistently selected temporary wetlands with water present multiple times, little emergent vegetation, and large

Table 2. Species and number of shorebirds observed on temporary and seasonal sample wetlands (n = 1,181) in the Drift Prairie of North Dakota during 10-week sample period in spring of 2001. Species ranked by abundance along transects.

	Week of										
Species	9 Apr	16 Apr	23 Apr	30 Apr	7 May	14 May	21 May	28 May	4 Jun	11 Jun	Total
Dunlin (*Calidris alpine* Linnaeus)	0	0	0	0	1	105	498	55	0	0	659
Killdeer (*Charadrius vociferous* Linnaeus)	45	59	32	70	56	67	49	61	51	39	529
Ruddy turnstone (*Arenaria interpres* Linnaeus)	0	0	0	0	0	2	23	450	0	0	475
American avocet (*Recurvirostra americana* Gmelin)	0	0	15	73	117	65	64	53	30	17	434
Semipalmated sandpiper (*Calidris pusilla* Linnaeus)	0	0	0	59	41	173	85	39	33	0	430
Yellowlegs spp.* (*Tringa melanoleuca* Gmelin and *T. flavipes* Gmelin)	0	3	70	185	105	3	2	0	0	1	369
Least sandpiper (*Calidris minutilla* Vieillot)	0	0	0	31	79	45	80	1	0	0	236
Wilson's phalarope (*Phalaropus tricolor* Vieillot)	0	0	0	24	32	31	29	36	33	22	207
Willet (*Catoptrophorus semipalmatus* Gmelin)	0	0	0	13	8	4	7	12	3	7	54
Pectoral sandpiper (*Calidris melanotos* Vieillot)	0	0	0	0	0	53	1	0	0	0	54
Semipalmated plover (*Charadrius semipalmatus* Bonaparte)	0	0	0	0	0	37	0	0	3	0	40
Dowitcher spp.* (*Limnodromus scolopaceous* Say and *L. griseus* Gmelin)	0	14	0	0	0	17	6	0	0	0	37
Western sandpiper (*Calidris mauri* Cabanis)	0	0	0	0	0	0	4	18	4	0	26
Black-bellied plover (*Pluvialis squatarola* Linneaus)	0	0	0	0	0	0	2	22	0	0	24
Baird's sandpiper (*Calidris bairdii* Coues)	0	5	0	15	0	0	0	2	0	0	22
Solitary sandpiper (*Tringa solitaria* Wilson)	0	0	0	10	9	0	1	0	0	0	20
Spotted sandpiper (*Actitis macularia* Linnaeus)	0	0	0	0	2	5	3	1	1	5	17
White-rumped sandpiper (*Calidris fusciollis* Vieillot)	0	0	0	0	0	0	6	5	0	0	11
American golden-plover (*Pluvialis dominica* Müller)	0	0	0	0	0	7	3	0	0	0	10
Upland sandpiper (*Bartramia longicauda* Bechstein)	0	0	0	0	0	1	6	0	1	2	10
Red-necked phalarope (*Phalaropus lobatus* Linnaeus)	0	0	0	0	0	0	9	0	0	0	9
Marbled godwit (*Limosa fedoa* Linnaeus)	0	0	0	2	0	3	0	0	0	0	5
Wilson's snipe (*Gallinago delicata* Linnaeus)	0	1	0	0	0	0	0	0	0	0	1
Unidentified	0	0	2	20	29	29	93	91	10	5	371
									2		
Total birds	45	82	119	502	479	647	971	846	26	98	4050
								1			
Species (n)*	1	5	3	10	10	16	19	13	9	7	23

* Greater and lesser yellowlegs were lumped together for identification, as were long-billed and short-billed dowitchers. All 4 species were observed on sample wetlands, and species totals do not reflect the presence of separate yellowlegs and dowitcher species.

perimeters in landscapes that also contained semi-permanent or permanent wetlands (Table 4). In addition, wetlands showing evidence of drainage were less likely to be used by shorebirds. Receiver Operating Characteristic (ROC) values of our models ranged from 0.73 to 0.82 (Table 4), indicating useful levels of discrimination (Swets 1988). Perimeter and area of mapped basins were strongly correlated (r_s = 0.97), but perimeter was a better predictor of presence than area in all cases. For example, the AIC value for the model best describing presence of any shorebird species (Table 4) increased 9.8 points when area was substituted for perimeter.

DISCUSSION

Our results demonstrate the importance of temporary and seasonal wetlands embedded in agricultural landscapes to migrant shorebirds in the PPR. Shorebirds in our analysis typically selected temporary wetlands, which are relatively small and shallow, over seasonal wetlands (Table 4). However, temporary wetlands were less likely to contain water than seasonal wetlands, and wetland use was strongly influenced by presence of water. This suggests that birds were selecting for the shallow water more likely to be present in temporary wetlands (*sensu* Davis and Smith 1998b). Wetlands that showed evidence of drainage were less likely to be used, which may reflect reduced availability of water and shoreline, or possibly the absence of recently exposed mudflats, which could be caused by water levels that are static relative to undrained wetlands. Saturated soil without standing water present was not a strong predictor of shorebird presence, likely because bare soil was widely available and basins were more attractive to shorebirds when water was also

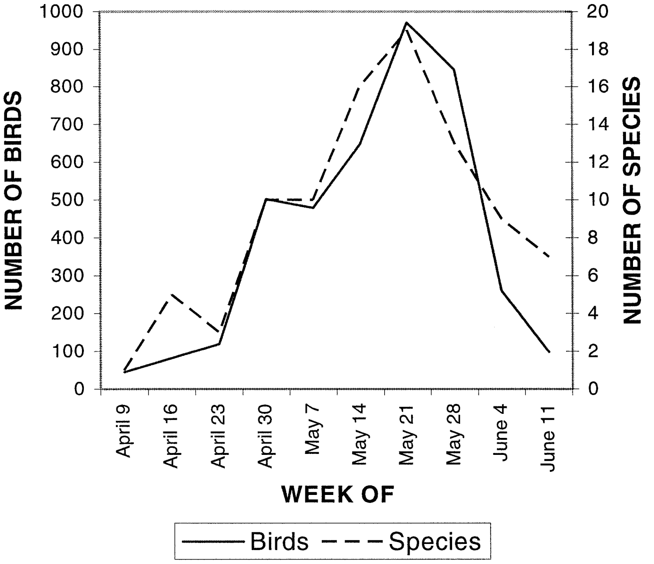

Figure 3. Number of shorebird individuals and species observed during each of 10 weekly sample periods in North Dakota drift prairie in spring of 2001. Total number of species is higher, as yellowlegs and dowitcher species were combined during sampling, and additional unidentified species might have been present.

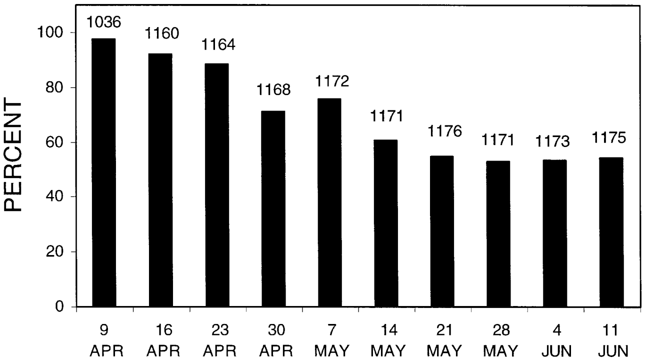

Figure 4. Percentage of basins sampled each week that contained water during the survey period. Data are only for basins that were sampled ≥ 9 times (*n* = 1,181); numbers above bars indicate number of basins sampled that week.

present. However, we only recorded presence or absence of water and mudflats; availability of these habitats will also influence use (Davis and Smith 1998b). Shorebird use of temporary and seasonal wetlands in the area was greatest for basins that were wet eight of ten times, which might reflect the presence of shallow foraging areas as water rose and ebbed. *Post-hoc* inclusion of a quadratic term for number of times water was present in basins improved the model best predicting presence of any shorebird by 22.6 AIC units, which reinforces the potential importance of dynamic water levels to migrant shorebirds.

The presence of permanent or semi-permanent water in the surrounding landscape influenced shorebird use of wetlands, indicating that migrant shorebirds respond to wetlands in association with other wetlands. Additional wetlands in the surrounding landscape provide increased foraging opportunities with relatively low search costs (Farmer and Parent 1997) and also may provide roost sites, indicate the presence of other shorebirds, or reflect an attraction to a variety of wetland habitat types. Finally, multiple wetlands in a landscape may attract migrants, which can then select shallower wetlands for foraging and roosting.

Wetland perimeter was consistently a better predictor of shorebird presence than area. This may be because wetlands with convoluted shorelines have increased land-water edge and greater foraging area. Shorebirds also were more likely to be observed on wetlands with little emergent vegetation, which may reflect a greater likelihood of observing shorebirds on wetlands with sparse vegetation as opposed to avoidance of tall vegetation by shorebirds. Lower detection of shorebirds in heavily vegetated wetlands would underestimate overall use of study wetlands by shorebirds. However, an association between short or sparse vegetation and presence of several shorebird species has been observed in a variety of habitats and locations (e.g., Rundle and Fredrickson 1981, Ryan and Renken 1987, Davis and Smith 1998b, Long and Ralph 2001).

Models predicting presence of shorebirds (Table 4) were quite consistent among species, but several factors likely explain additional variation in shorebird use. First, our determination of use and non-use contains error, as wetlands where shorebirds were not observed could have harbored shorebirds at other times. Second, shorebird presence was likely influenced by other, unmeasured factors such as water depth, substrate characteristics, and abundance and diversity of

Table 3. Number and percentage of basins used by shorebirds in relation to number of times a basin contained water out of 10 visits. Data are only for basins that were sampled ≥9 times (*n* = 1,181).

Number of times wet	Number of basins	Number of basins with shorebirds	Percentage of basins with shorebirds
10	341	143	41.9
9	157	66	42.0
8	101	44	43.6
7	81	34	42.0
6	80	26	32.5
5	105	28	26.7
4	106	19	17.9
3	92	9	9.8
2	69	1	1.5
1	33	1	3.0
0	16	0	0.0

Table 4. Variables included and ROC scores for logistic regression models of wetland use by shorebirds in the Drift Prairie of North Dakota. Estimated coefficients (SE) are shown for models best explaining data as identified by AIC; + or − indicates the sign of coefficients for variables included in a model within 2 AIC units of the model with the lowest AIC value. (*n*) following response variable is the number of wetlands on which each species or group of species was observed out of 1,140 basins that were sampled ≥ 9 times and were completely visible from the road. Variable names are defined in Table 1.

Response Variable	Intercept	Perimeter	*Water Regime	*Drainage	**Cover Type 1	**Cover Type 4	Times Wet	Water in Landscape	ROC
Any shorebirds (361)	−3.8	0.0012	−0.79	−0.62 (0.43)	−3.47	1.73	0.32	0.028	0.76
	(0.41)	(0.0003)	(0.16)		(2.2)	(0.33)	(0.03)	(0.019)	
American avocet (70)	−7.11	+	−0.61	−3.96 (5.19)		5.13	0.31	0.05	0.75
	(3.5)		(0.27)			(3.5)	(0.06)	(0.03)	
Killdeer (242)	−3.34	0.0013	−0.47		−3.10	1.34	0.26	0.04	0.73
	(0.46)	(0.0003)	(0.18)		(2.24)	(0.36)	(0.034)	(0.02)	
Willet (32)	−4.2		−0.55			1.80	0.30	0.10	0.77
	(1.29)		(0.40)			(1.03)	(0.09)	(0.035)	
Yellowlegs spp. (85)	−3.77	0.001	−0.67	−3.35 (3.22)	—	2.14	0.24		0.73
	(0.85)	(0.0003)	(0.26)			(0.73)	(0.05)		
Wilson's	−7.0	0.0009	+	—	—	2.55	0.49	0.08	0.82
phalarope (53)	(1.39)	(0.0003)				(1.02)	(0.10)	(0.03)	
Semipalmated	−7.3	0.0009	−0.99			4.95	0.34		0.77
sandpiper (55)	(3.50)	(0.0004)	(0.32)			(3.47)	(0.07)		
Least sandpiper (50)	−4.36	0.0012	−0.56	−3.64 (5.30)	—	2.35	0.27	—	0.76
	(1.19)	(0.0003)	(0.33)			(1.0)	(0.07)		

* Seasonal and drained wetlands were reference classes; therefore, negative relationships indicate higher likelihood of use on temporary and undrained wetlands.

** Cover Type 3 was the reference class; therefore, negative relationships with Cover Type 1 and positive relationships with Cover Type 4 indicate higher likelihood of use of wetlands with little tall, emergent vegetation.

invertebrates (Rundle and Fredrickson 1981, Colwell and Oring 1988, Colwell and Dodd 1995, Davis and Smith 1998b). Our analysis only included one year of data, and it is possible that wetland use can vary among years. However, our results are biologically sound and consistent with other research relating to the influence of water depth and presence, vegetation structure, and landscape characteristics on shorebird use of wetlands (Rundle and Fredrickson 1981, Farmer and Parent 1997, Davis and Smith 1998b, Knapp 2001, Long and Ralph 2001). In addition, wetland availability in spring of 2001 was fairly typical, as estimated pond numbers on May waterfowl surveys in North Dakota east of the Missouri River were within 7.5% of a long-term (1974–2004) mean (J. W. Solberg, USFWS, unpublished data).

Our findings reinforce the idea that numerous, small wetlands may be of equal or greater cumulative importance to migrating shorebirds than few, large wetlands that are used by large numbers of migrating shorebirds in the PPR (see Skagen and Knopf 1993, Farmer and Parent 1997). The largest number of shorebirds Skagen et al. (1999) reported at any single North Dakota site was ~83,000. During our 10-week sample period, we observed 4,050 shorebirds on 1,181 temporary and seasonal wetlands, although some individuals of a few species (e.g., killdeer, willet, American avocet, Wilson's phalarope) may have been local breeders and counted more than once. Observed shorebird use per wetland was low compared to large coastal staging areas. However, the Drift Prairie of North Dakota has approximately 594,000 temporary and 453,000 seasonal wetland basins, of which >80% are in cropland and hay fields; these wetlands in agricultural fields provide approximately 70,000 and 111,000 km of shoreline habitat, respectively (USFWS, unpublished data). Extrapolating observed shorebird use to all seasonal and temporary wetlands in the Drift Prairie of North Dakota indicates use by 3.59 million shorebirds (95% CI = 2.01–5.17 million). However, this estimate is likely influenced by the minimal time spent at each wetland and possible underdetection, which could cause underestimation of use, as well as uncertain length of stay and potential differences between sample wetlands and other wetlands in the region, both of which could cause over- or underestimation of use. In addition, use of wetlands in the Drift Prairie will likely vary among years with changes in water availability. However, given the wetland use that we documented during extremely short observation periods and the large number wetlands in the region, it is likely that small, shallow wetlands in the region host millions of migrant shorebirds annually.

CONSERVATION IMPLICATIONS

Our results have several implications for conservation and management of wetlands in the PPR and possibly other areas dominated by small, dispersed wetlands. Temporary wetlands, which are small and shallow and therefore easily drained, were selected by migrant shorebirds. However, presence of water and lack of drainage were strong predictors of shorebird presence, demonstrating the importance of protecting wetlands from draining or filling. Protection of temporary wetlands would still allow for agricultural production, as these wetlands typically hold water for only a portion of the year and are often cropped without being drained. However, cultivation, sedimentation, and agricultural inputs such as fertilizer and pesticides may negatively influence wetland invertebrates and other wildlife (Grue et al. 1989, Gleason and Euliss 1998, Euliss and Mushet 1999, Knapp 2001).

Wetland basins should not be considered individually but regarded as part of the landscape (see also Skagen and Knopf 1994b, Farmer and Parent 1997). Loss of a single wetland may therefore affect a landscape, not just the basin that was drained. A variety of wetlands with different water regimes should be maintained in landscape complexes because spring migrant shorebirds used temporary and seasonal wetlands in our study, but likelihood of wetland use increased when semi-permanent and permanent wetlands were present in the surrounding landscape. In addition, semi-permanent and permanent wetlands are more likely to contain water and provide habitat in fall, when temporary and seasonal wetlands are often dry. Small wetlands and wetland complexes may also be important to migrant birds in other areas for these same reasons (see Haig et al. 1998).

Our findings demonstrate the importance of Swampbuster and associated Farm Bill protection to migrant shorebirds (see also Hohman and Halloum 2000). However, protection under Swampbuster is limited (Brady 2000), and other actions may be necessary to protect wetlands. At present, all the ramifications of the SWANCC decision are unknown, but protection of small wetlands typical of those in North Dakota is probably reduced (van der Valk and Pederson 2003), which does not bode well for conservation efforts. As Johnson and Higgins (1997:4) pointed out, ‘‘benefits of wetland functions typically accrue to society at large and not to individual landowners with whom rest the costs of preserving wetlands and the decision to preserve or destroy them.’’ The many economic and social forces that influence wetland drainage must be considered and supported by society at large for shorebird conservation to work in the PPR or other areas where wetlands are at risk of conversion (see also Andrew and Andres 2002).

Migrant shorebirds made extensive use of wetlands in our study area, but small, isolated wetlands in agricultural landscapes are also used by many species of breeding and migrant waterbirds, waterfowl, passerines, and breeding shorebirds (Kantrud and Stewart 1984, LaGrange and Dinsmore 1989, Ratti et al. 2001). Our understanding of avian ecology in the region is incomplete, but bird and wetland conservation in the PPR should consider multiple species and the dynamic nature of prairie wetlands. Many species of waterfowl, waterbirds, shorebirds, and passerines use a variety of wetlands throughout the region for migration, breeding, brood rearing, and staging (Kantrud and Stewart 1984, Naugle et al. 2001). Wetland numbers and condition in the region are highly dynamic in space and time (Kantrud et al. 1989, Niemuth and Solberg 2003), and wetland conservation efforts must meet the needs of a variety of species over broad areas under a variety of environmental conditions. Because of the dispersed and dynamic nature of wetlands in the interior U.S. and the response of birds to these dynamics, wetland conservation should focus on landscapes over broad regions rather than few sites (see also Skagen and Knopf 1993, Haig et al. 1998, Naugle et al. 2001).

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