Wetland Vegetation Response to the Restoration of Sheet Flow at Cheyenne Bottoms, Kansas

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Abstract

The restoration of inland salt-affected plant communities, including saltflat mixed prairie and playa lakes wetlands, has received little attention despite the importance of these communities for critical wildlife habitat. The salt-affected communities of Cheyenne Bottoms, located in central Kansas, are a crucial stopover site for migratory waterfowl and shorebirds. In 1998, The Nature Conservancy attempted to restore native plant communities to grazed and former cropland at Cheyenne Bottoms by reestablishing sheet flow across these disturbed areas. We collected vegetation cover data along permanent transects established in rangeland, former cropland, and in a shallow basin 3 years (1996–1998) before the hydrological changes and continued to collect vegetation data for 3 years (1999–2001) after the hydrological changes. Vegetation composition changes in response to the restored hydrology were subtle, but the average wetland index along the transects in the basin and the rangeland significantly declined. Significant decreases occurred in the cover of perennials and graminoids in both spring and fall species assemblages of the rangeland area. Changes in the former cropped areas were mixed, indicating the difficulty of restoring these disturbed plant communities to native plant assemblages within a few years.

Key words: **restoration, salt-affected soils, sheet flow.**

Introduction

Saltflat mixed prairie and playa lakes are temporarily flooded areas that occur in the relatively flat portion of the High Plains landscape in the west-central United States and the Canadian Plains (Faber-Langendoen 2001). The hydrology of these areas is primarily affected by sheet flow as water moves across the surface of a mostly level landscape. The saltflat mixed prairie plant community is characterized by inland *Distichlis spicata* (inland saltgrass), *Hordeum jubatum* (foxtail barley), *Poa arida* (plains bluegrass), and *Sporobolus airoides* (alkali sacaton). Spikerush playa lake plant communities are dominated by *Eleocharis xyridiformes* (spikerush) (Lauver et al. 1999). These communities arise on salt-affected soils that occur on 400,000 ha (1 million acres) of land in Kansas and on over 16 million ha (40 million acres) across the United States (Aschenbach 2000). Most salt-affected areas in Kansas are heavily affected by agricultural activities and grazing. As part of the effort to restore native plant communities and to improve shorebird habitat at the Cheyenne Bottoms Preserve in central Kansas, The Nature Conservancy (TNC) is attempting to convert salt-affected former crop and currently grazed lands to a complex of saltflat mixed prairie and spikerush playa lake by reestablishing sheet flow of surface water across the preserve.

According to the unpublished management plan, the primary objective for TNC's Cheyenne Bottoms Preserve is the expansion of shorebird habitat through the reestablishment of hydrology and the consequent native plant communities on former croplands. Over 320 species of birds have been recorded from Cheyenne Bottoms (Harrington 1984; Hoffman 1987). These surveys have determined that the area is especially important to the 500,000 migratory shorebirds that use the area annually. These shorebirds constitute over 50% of all spring migrating shorebirds and approximately 30% of fall migrating shorebirds east of the Rocky Mountains. Cheyenne Bottoms is designated as a Hemispheric Reserve by the Western Shorebird Reserve Network and was deemed a Wetland in International Importance in 1988 (Ramsar Convention Bureau 1988).

In 1998, TNC installed a drop-log water control structure in a seasonally flooded basin to restore water levels and removed fencerows and low berms to facilitate sheet flow on a portion of crop and rangeland. We monitored the vegetation in this area along permanent transects for 3 years before these hydrological improvements and continued to monitor the vegetation along these same transects for 3 years after the hydrological improvements. We then quantified the effects of the hydrological improvements to determine whether the restoration of sheet flow had (1) increased the saltflat mixed prairie and spikerush playa lake native plant communities, (2) increased wetland

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species cover, (3) increased graminoid and perennial species cover of this perennial grassland vegetation, and (4) increased the cover of species that are dominant or indicative of the desired plant communities, such as inland saltgrass, *Agropyron smithii* (western wheatgrass), *Buchloe dactyloides* (buffalo grass), and spikerush.

The plant community ecology of inland salt-affected areas has been widely studied by Ortenburger and Bird (1933) in Oklahoma, Ungar (1965, 1967, 1968) in Oklahoma and Kansas, Ungar et al. (1969) in Nebraska, Hanson and Whitman (1937) in North Dakota, and Dodd et al. (1964) in Saskatchewan. However, we do not know of any studies that examine the restoration of these plant communities after hydrology is restored to areas that have been partially drained, grazed, or cropped.

Methods

Site Description

Cheyenne Bottoms is a 165-km^2 (64 mile^2) basin (Bayne 1977) located in the mixed-grass region of the Great Plains (Kuchler 1974) near Great Bend, Kansas (38°29′ N, 98°40′ W) in the Smoky Hills Physiographic Province (Wilson 1978). We conducted this study on The Nature Conservancy's (TNC) Cheyenne Bottoms Preserve at McClain Basin (SW 1/4 Sec. 16, T18S, R13W; see Fig. 1). All soils in the study area are identified as Tabler-Drummond and Drummond silt loams. The Drummond silt loam is slightly or moderately affected by sodium and soluble salts and exhibits salt accumulations at the soil surface (Dodge et al. 1981). The origin of the salt is in the Hutchinson salt member of the Wellington formation that formed during the Permian Age and lies between 10 and 45 m (30 and 140 ft) below the surface (Kulstad 1959). Data from oil well logs indicate that these salt deposits, which persistently add salinity to the soil, are between 250 and 300 ft thick and contain 60–80% salt. They are commercially mined nearby for table and road salt. The climate of Cheyenne Bottoms is characterized by a 27.1° C (80.8° F) mean July temperature, 13.4° C (56.2° F) mean annual temperature, and 650.2 mm (25.6 inches) of annual precipitation, of which 73% falls from April through September (Dodge et al. 1981).

The study site consists of rangeland, former cropland, and a relatively undisturbed, shallow, wet basin. In 1996, the rangeland was dominated by inland saltgrass, *Hordeum pusillum* (little barley), and buffalo grass (Figs. 2 & 3); the former cropland by little barley, *Schedonnardus paniculatus* (tumblegrass), and *Kochia scoparia* (tumbleweed; Fig. 4); and the basin by spikerush (Figs. 5 & 6). The formerly cropped area had been used for alfalfa and wheat production and was last cropped in 1991. All areas in the study experienced light to moderate grazing during the study period.

During the summer of 1998, TNC installed a drop-log water control structure at the east end of the lowest portion of McClain Basin to raise the water level (starting in 1999) by a maximum of 21 inches (50 cm). Additionally, they removed a fencerow and a low berm with a bulldozer to facilitate sheet flow across the range and cropland to the south of the basin.

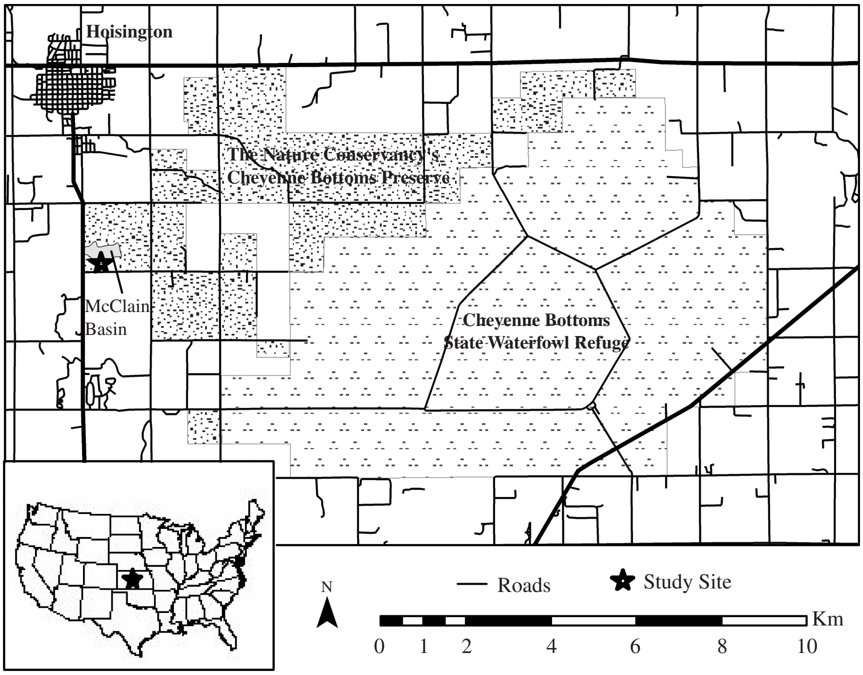

Figure 1. Study area in central Kansas showing McClain Basin on The Nature Conservancy's Cheyenne Bottoms Reserve and the adjacent Cheyenne Bottoms State Waterfowl Refuge.

Figure 2. A field crew sampling meter-square plots at the rangeland transect in the McClain Basin study area, which is dominated by spring vegetation of *Distichlis spicata* (inland saltgrass), *Hordeum pusillum* (little barley), buffalo grass, and *Hordeum jubatum* (foxtail barley).

Figure 3. The rangeland transect within the McClain Basin study area when it was sampled in Fall 1997, after a relatively dry summer with *Distichlis spicata* (inland saltgrass) being the most noticeable grass.

Figure 4. A field crew looking over plots at the cropland transect within the McClain Basin study area in Spring 1997, when *Hordeum jubatum* (foxtail barley) was the most obvious grass species present.

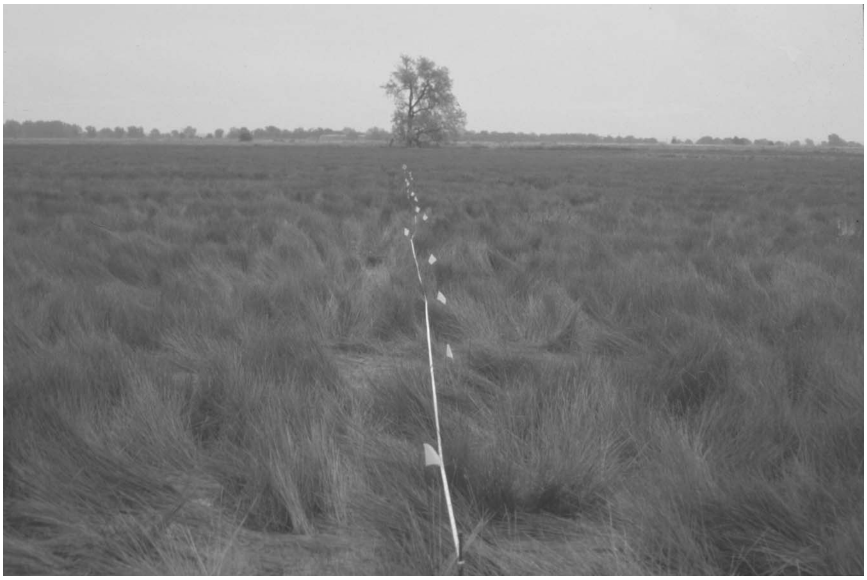

Figure 5. The basin transect in the McClain Basin study area when it was sampled in Spring 1999 after rain and inundation. Vegetation is almost completely dominated by *Eleocharis xyridiformes* (spikerush) with a lone *Populus deltoides* (Plains cottonwood) at the far edge of the basin.

Data Collection and Analysis

We established three 120-m transects at the site, one each in the range, crop, and wet basin. The crop and range transects were placed about 50 m apart and were laser surveyed in June 1998 to obtain accurate elevations along each transect. Each transect consisted of 20 1-m^2 plots spaced 4 m apart and was sampled in June and September of each year from 1996 to 2001. Aerial percent cover for each plant species and bare ground were estimated following sampling procedures by Daubenmire (1959). Aerial cover often exceeded 100% per plot due to species overlap. Nomenclature of plant species follows the Flora of the Great Plains (Great Plains Flora Association 1986), and voucher specimens were deposited in the Ronald L. McGregor Herbarium (KANU) at the University of Kansas.

All plant species found were assigned one of the five wetland index classes, defined in the U.S. Army Corps of Engineers Wetland Delineation Manual (Environmental Laboratory 1987) and listed in the National List of Plant Species that Occur in Wetlands (Reed 1988). We assigned obligate species a score of 1.00 and upland species a score of 5.00; facultative wet, facultative, and facultative upland species scored 2.00, 3.00, and 4.00, respectively. We followed the techniques of Atkinson et al. (1993) and Kindscher et al. (1998) and multiplied the wetland scores by the average species cover and averaged all species for each transect to determine whether the cover of the area scored below 3.00, indicating dominance by wetland species, or above 3.00, indicating dominance by upland species.

For each of the transects, we compared the percent cover of all plant species, the average wetland index, and life-history characteristics of the plant community between the years before sheet flow restoration (1996–1998) and years after sheet flow restoration (1999–2001) for each of the transects. Fall cover of indicator species is compared pre- and post-restoration, with the exception of spring-dominant little barley where spring data were used. The plant life-history characteristics compared were percent cover of annual, perennial, forb, and graminoid species. Biennial species cover is reported with annual species cover data. These characteristics were chosen to determine whether native plant community attributes were being realized.

Subtle elevation differences can dramatically influence plant species composition (Mitsch & Gosselink 1993). Some plots were only a few centimeters higher in elevation than others and did not have standing water after precipitation events (personal observation). In addition, elevation on our plots was correlated with wetland index ($p < 0.05$), and we divided the dataset for each transect, separating the 10 lowest from the 10 highest plots. The lower 10 were analyzed separately, because these plots were assumed to have experienced longer periods of inundation and saturated soils. For these plots, we compared 1998 cover data to 2001 cover data to avoid potentially confounding interannual changes in plant community composition before hydrological changes and to give the plant community the maximum response time after restoration.

Statistical analyses were conducted using SPSS (1999). However, the data did not meet parametric assumptions (normality and homoscedasticity) (Sokal & Rohlf 1995), thus comparisons of plant data were made using the Mann–Whitney U test for two independent samples. We used ANOVA to determine any significant differences in rainfall among years. Historical precipitation data were estimated from the Arkansas–Red Basin River forecast center of the National Weather Service.

Figure 6. A *Coreopsis tinctoria* (plains coreopsis) seeking light, emerging from dense Spring 1996 cover of *Eleocharis xyridiformes* (spikerush) at the basin transect of the McClain Basin study area.

Results

After the removal of the berm and fencerow and the insertion of drop-log structure in 1998, the water coverage over the range and cropland increased after rainfall events by about 35% and inundated the lower plots of rangeland and former cropland areas (R. Penner, The Nature Conservancy's preserve manager, personal communication). There was no significant difference in rainfall between those years before and after sheet flow restoration. Survey results indicated that elevation differences along the transects were exceedingly small. The maximum difference in elevation along an individual transect (McClain Range) was 0.36 m (1.17 ft). Nevertheless, elevation was correlated with wetland index ($p < 0.05$).

Dominant Species

There was a significant ($p < 0.001$) increase in the cover of spikerush, an obligate wetland species, along the basin transect, but there was no significant change in the cover of spikerush on either crop or range transect after the restoration of sheet flow. There was no significant change in the cover of other community indicator species, including inland saltgrass, foxtail barley, or plains bluegrass on either the range or the crop transect. Alkali sacaton, however, declined significantly ($p < 0.05$) on the crop transect (Table 1).

Wetland Index

The average wetland indices for the spring survey of range and basin transects significantly declined ($p < 0.001$) after the restoration of sheet flow in 1998. For the range transect, the index fell from 3.46 to 3.40, and for the basin transect, the index fell from 1.12 to 1.00. The average wetland index for the spring survey of the crop transect was significantly higher ($p < 0.001$) after the restoration of

Table 1. Comparison of average wetland index, percent cover of perennial graminoids, and two important indicator species before (1996–1998) and after (1999–2001) hydrological changes at Cheyenne Bottoms Reserve.

	Range		*Cropland*		*Basin*	
	1996–1998	*1999–2002*	*1996–1998*	*1999–2002*	*1996–1998*	*1999–2002*
Wetland index						
Spring data	3.46	3.40***	3.66	3.93***	1.12	1.00***
Fall data	3.84	3.33***	4.02	3.88***	1.03	1.00***
Transect perennials						
Spring (%)	92	83*	29	56	99	99
Fall (%)	113	98*	57	31***	99	99
Transect graminoids						
Spring (%)	98	90*	73	78	99	99
Fall (%)	104	90**	73	65	99	99
Eleocharis xyridiformes	0.001	0.0005	0.001	0.0065	0.960	0.963***
Distichlis spicata	0.285	0.280	0.003	0.0065	NA	NA

Note that the cover of perennials and graminoids may exceed 100% because of species overlap. Data are significantly different at *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

sheet flow, increasing from 3.66 to 3.93. For fall data, the average wetland index for all transects was significantly lower ($p < 0.001$) after the restoration of sheet flow (Table 1).

Species Life-History Characteristics

There was a significant decline ($p < 0.05$) in the spring and fall cover of perennial and graminoid species along the range transect after the restoration of sheet flow. In fact, all species declined along the range transect after sheet flow restoration. For the crop transect, there was a significant decline ($p < 0.001$) in the cover of fall perennial species. There were no significant changes in species life-history characteristics along the basin transect after the hydrological changes were made (Table 1).

Lower-Elevation Plots

The lowest 10 plots on the range transect (those plots experiencing greater inundation and saturated soils) exhibited significantly different spring plant community characteristics after the restoration of sheet flow. Spring bare ground cover increased significantly ($p < 0.04$), along with the percent cover of three annual species: *Aster subulatus* (saltmarsh aster) ($p = 0.001$), *Bromus japonicus* (Japanese brome) ($p = 0.005$), and little barley, which increased dramatically from less than 1 to 19.7%. There were no significant differences in fall cover (Table 2, part A).

The lowest 10 plots on the former crop transect exhibited a significant increase in the spring and fall cover of Japanese brome ($p = 0.031$ and $p = 0.001$, respectively) after the restoration of sheet flow. This weedy, annual grass increased from 32 to 80% cover in the spring and from 7 to 36% in the fall. The spring cover of *Chloris verticillata* (windmill grass) also increased, but not significantly ($p = 0.013$). In contrast, the cover of *Schedennardus paniculatus* (tumble grass) decreased significantly ($p = 0.001$) in both the spring and the fall (Table 2, part B).

After the restoration of sheet flow, the cover of the almost monotypic stands of spikerush in the lowest 10 plots of the basin transect increased from 96% (spring) and 94% (fall) cover to 100% cover in both seasons ($p = 0.001$). Flooding in these plots eliminated all cover of *Coreopsis tinctoria* (plains coreopsis) ($p = 0.005$) as well as the cover of several minor species, including *Ambrosia grayii* (bur ragweed) ($p = 0.005$), *Marselia vestita* (western water clover) ($p = 0.029$), and *Veronica peregrina* (speedwell) ($p = 0.013$). Overall cover substantially increased, and bare ground was also eliminated ($p = 0.001$).

Discussion

Dominant Species and Species Life-History Characteristics

Three years after the restoration of sheet flow across the study site, the cover of community-dominant species (inland saltgrass, western wheatgrass, buffalo grass, and spikerush) had not significantly increased along the range or crop transects. However, when the lowest 10 plots were considered, we found that after 3 years of restored hydrology the greatest plant community shift was an increase in annual species. The increase in the cover of annuals may be the result of a corresponding increase in bare ground. Two of the annuals exhibiting significant increases in cover, Japanese brome and saltmarsh aster, are particularly adapted to take advantage of the altered conditions. Japanese brome, a non-native winter annual, avoids inundation by maturing and senescing before the wettest month, June. Saltmarsh aster is very tolerant of flooding. Some of the minor annual species, including *Eriochloa contracta* (cupgrass) and little barley, were no longer present in the sample plots at the end of the study period, and we expect this decline to allow for an increase in the cover of flood-tolerant perennial species over time.

Alkali sacaton decreased in cover across the former cropland areas within 3 years of hydrological change, and the fall cover of perennial species declined significantly (Table 1). This was not what we expected, because we thought that the additional time beyond the last cropping event (over 3 years) would have led to an increase in both perennial cover and the cover of this salt-affected soil dominant plant.

The basin area was close to being a monotypic stand of spikerush (95% cover) before reestablishment of sheet flow and subsequent greater hydrology (Table 2). After the water control structure was put in place, standing water increased substantially in both the spring and the fall, and standing water or moist soil was common throughout the growing season. This resulted in a more solid stand of spikerush in the existing basin and greater cover, eliminating less flood-tolerant species.

Wetland Index

With the exception of the spring crop transect, the wetland index for each area declined after sheet flow was reestablished in the fall of 1998 (Table 1). This indicated that wetland species were increasing as a percentage of the total cover. Although the indices for the range and crop transects are above 3.00, and therefore indicate that species cover is composed of more upland species than wetland species, the trend toward a lower wetland index is encouraging.

The recovery of the saltflat mixed prairie community is very slow. Our data show only some minor trends toward recovery. For example, the wetland index scores indicate an increase in wetland species in most of the areas studied and an increase in some key important plants, such as saltmarsh aster. However, the dominant change was an increase in annual species, which may indicate that the recent flooding events and subsequent dry periods are creating disturbance mostly suitable for annuals. In

Table 2. Comparisons of vegetation between the lowest elevation sampled plots before (1998) and after (2001) hydrological changes in spring and fall sampled rangeland transects.

	Mean Percent Cover		
	1998	*2001*	*Significance*
A. Rangeland transect			
Spring			
Bare ground	**7.00 ± 3.60**	**14.40 ± 2.71**	**0.040**
Agropyron smithii	25.60 ± 11.51	26.30 ± 10.11	0.870
Aster subulatus	**0.15 ± 0.10**	**7.61 ± 6.17**	**0.001**
Bromus japonicus	**0.40 ± 0.020**	**19.71 ± 10.10**	**0.005**
Buchloe dactyloides	43.50 ± 12.4	9.81 ± 6.54	0.109
Distichlis spicata	23.00 ± 8.88	17.30 ± 5.67	1.00
Hordeum pusillum	**1.45 ± 0.55**	**5.41 ± 2.03**	**0.035**
Lepidium densiflorum	0.60 ± 0.29	7.33 ± 4.07	0.600
Fall			
Bare ground	1.90 ± 0.42	13.5 ± 5.98	0.190
Agropyron smithii	24.40 ± 12.10	28.2 ± 11/15	0.760
Ambrosia psilostachya	6.25 ± 5.45	3.50 ± 1.35	0.5600
Bromus japonicus	0.10 ± 0.010	10.7 ± 9.64	0.466
Buchloe dactyloides	46.8 ± 13.0	14.20 ± 9.26	0.093
Distichlis spicata	24.3 ± 9.61	33.8 ± 11.90	0.640
Polygonum ramosissimum	6.50 ± 2.36	6.60 ± 2.65	0.70
Schedennardus panniculatus	0.85 ± 0.43	0.00 ± 0.00	0.029
B. Former cropland transect			
Spring			
Bare ground	11.40 ± 4.14	8.27 ± 4.87	0.733
Ambrosia psilostachya	0.05 ± 0.05	6.40 ± 5.96	0.214
Aristida oligantha	1.10 ± 0.76	5.33 ± 4.53	0.520
Bromus japonicus	**32.40 ± 12.30**	**80.20 ± 7.03**	**0.031**
Buchloe dactyloides	9.30 ± 9.30	2.60 ± 1.79	0.627
Chloris verticillata	**0.00 ± 0.00**	**2.00 ± 0.78**	**0.013**
Schedennardus panniculatus	20.80 ± 5.40	5.10 ± 1.35	0.001
Fall			
Bare ground	2.00 ± 8.63	24.60 ± 12.40	1.000
Aristida oligantha	23.20 ± 11.80	28.90 ± 10.60	0.443
Bromus japonicus	**7.32 ± 3.25**	**36.72 ± 9.45**	**0.001**
Buchloe dactyloides	8.80 ± 8.80	3.80 ± 3.48	0.627
Haplopappus ciliatus	7.00 ± 3.71	12.42 ± 5.81	0.761
Medicago sativa	7.45 ± 5.19	0.50 ± 0.50	0.256
Polygonum ramosissimum	10.10 ± 6.15	0.92 ± 0.70	0.579
Schedennardus panniculatus	**21.50 ± 5.76**	**0.41 ± 0.22**	**0.001**
C. Basin transect			
Spring			
Bare ground	**3.50 ± 0.40**	**0.00 ± 0.00**	**0.000**
Coreopsis tinctoria	**2.30 ± 0.49**	**0.00 ± 0.00**	**0.005**
Eleocharis xyridformis	**95.80 ± 0.55**	**100.00 ± 0.00**	**0.000**
Fall			
Bare ground	**5.80 ± 0.49**	**0.00 ± 0.00**	**0.000**
Eleocharis xyridformis	**94.20 ± 0.49**	**100.00 ± 0.00**	**0.000**

The table lists those species with greater than 2% cover; cover values are based on a mean percent cover of 10 sample plots followed by the standard error. Significance is determined by using a two-tailed Mann–Whitney *U* test. Significant species are in bold.

another study, we found that salinity varied markedly from plot to plot and has a complex relationship with the vegetation (Aschenbach 2000).

An important result of the increase in sheet flow, standing water, and saturated soil was the observation that shorebirds (greater yellowlegs and American avocets), waterfowl (blue-winged teal), and ibis, egrets, and herons showed an increased use of this site after the drop-log structure was in place (R. Penner, preserve manager, personal communication). It appeared that the longer water-holding capacity of the wetland areas allowed for aquatic invertebrates to develop and at times explode, thus bringing in bird species that eat these invertebrates. It is likely that snails and birds are responding much more quickly than the vegetation to these hydrological changes.

It was encouraging to note that spikerush cover was increasing in the formerly cropped areas with the greatest hydrology, but it is still unclear whether passive restoration of hydrology will allow for a natural return of the previously dominant saltflat mixed prairie plant community to these formerly cropped areas. In addition, although increased sheet flow and subsequent saturated soils do slightly increase the cover of wetland species of the rangeland area of saltflat mixed prairie, it is unclear whether these changes are long-lasting because most of the change in the vegetation composition of these areas occurred among annual species. With complex interactions between salts, hydrology, seed banks, and other human activities, restoration of the vegetation of these communities is difficult to achieve.

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