Restoration of functioning wet meadows on the Platte River -- experimentation with reseeding, constructed wetlands, and hydrology.

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Summary -- During the last 10 years the Platte River Trust has experimented with techniques for restoring and enhancing wet meadows along the Platte River in central Nebraska. Grassland management techniques used at native sites and various reseeding methods used to restore cropland areas have been fairly successful in re-establishing prairie grasses and some forbs. Plant species diversity and community development, on the other hand, have varied widely, primarily in response to the particular re-seeding and management techniques used. It remains to be seen whether these efforts will in the long-run result in functional wet meadows that emulate the hydrology of native sites and that support the full array of indigenous organisms. An initial vegetation survey indicates that on average, as many as 78% of the wetland species and 73% of the forb species found in native meadows are missing in the newly re-seeded areas. The lack of wetland species suggests that the surface and groundwater hydrology needed to sustain them may be absent. Low forb diversity is most likely due to inadequate seed sources and the limited capacity of many species to self-seed and colonize the sites. Fewer forbs were missing at the Uridil-2 site where a seed mix of over 100 species was used. Over 30 indigenous species that had not been sampled at the managed native sites were actually found here. The roles of landscape position, groundwater pumping, dam and dike construction, land contouring, and management in restoring wet meadows and re-establishing their hydrology are discussed. So far, most attempts at water management have not proved very effective.

INTRODUCTION

Platte River wet meadows provide some of the most important migratory feeding and nesting habitat for wildlife in central Nebraska (Krapu 1981). More than 150 species of birds use wet meadows and their associated wetlands to obtain both plant and animal foods (Currier et al. 1985, Fannes and Lingle *in press*). These organisms include small fish, frogs, egg masses, crayfish, grasshoppers, crickets, beetles, earthworms, insect larvae, invertebrates, roots , seeds, fruits, and tubers (Krapu 1981).

Wet meadows typically consist of grasslands with a series of linear wetlands and elevated sand ridges. Their hydrology is characterized by groundwater and surface water fluctuations driven by changes in river stage, precipitation, and freezing and thawing (Henszey & Wesche 1993, Hurr 1983, Currier unpublished data). Their most salient feature is the presence of groundwater close to the land surface. In areas where the water table intersects the surface, pooling and ponding often occur for extended periods of time. Such high water periods can occur at any time during the year, but they are usually confined to the high precipitation and river discharge period in the spring, and rarely occur during the normal dry season in late summer. A variety of meadow types also exist, ranging from those with a highly dissected drainage of wetland sloughs to more rolling topography punctuated by high sand ridges mixed with lowland sloughs. Some areas resemble pothole wetlands, with a more elliptic than linear wetland drainage, and characterized by heavier, more organic soils.

Over the past 100 years, many wet meadow areas have been drained by ditching and levelling, and converted to cropland. Although topsoils on wet meadow sites are usually shallow and sandy, and have poor water retention capabilities, they can produce excellent crops if irrigation is used to maintain moisture in the soil profile. An estimated 74-80% of the wet meadows in the Platte River Valley have been converted and drained (Sidle et al. 1989). As a result, wet meadows are now one of the most limiting habitat types in the Platte River Valley. If the migratory species that are dependent upon this habitat are to be sustained, wet meadows need protection and enhancement (Currier et al. 1985).

More than 10 years ago, the Platte River Whooping Crane Trust (Trust), began efforts to manage, maintain, and restore wetland meadows in the Big Bend reach of the Platte River as habitat for migratory birds. Our management model has been the mosaic of high quality wetlands at Mormon Island Crane Meadows, located on an island in the river just south of Grand Island. Mormon Island is the largest remaining contiguous grassland/wetland complex in the Big Bend reach of the river, and supports large numbers of migrating cranes, waterfowl, shorebirds, and summer nesting species. At times, 60,000 to 100,000 cranes and waterfowl can be found feeding and loafing on the meadows. Wetlands at Mormon Island are characterized by extensive surface water sloughs and a vegetation dominated by sedges and grasses found principally on lowland sites (e.g., *Carex* spp., big bluestem, blue joint, switchgrass, cordgrass) (Currier 1989).

In 1981, when the Trust acquired Mormon Island, there was intensive, season-long grazing. This management was compatible with the use of the area by spring migrating cranes and waterfowl, but it was clear that some areas were being overgrazed, and that management could be improved to benefit a broader group of migratory species (Lingle and Boner 1981). A management plan was instituted with grazing and haying rotations, prescribed burning, and a reduced stocking rate. Management was aimed at increasing plant production, maintaining a higher stature and diversity of vegetation, and promoting native species (e.g., big bluestem, indiangrass) over introduced species (e.g., bluegrass, smooth brome).

Mormon Island has remained our wet meadow model. With management improvements, however, we are beginning to understand the breadth of plant and animal species that inhabit well managed sites. We are also starting to understand the full habitat needs of a wide variety of migratory birds and the food organisms upon which they depend. This is a continuing learning process in which we test and refine management techniques based on the outcomes and impacts of past management decisions.

Underlying our restoration efforts, is an attempt to replicate the Mormon Island model -- including its species composition and hydrology. In the process though, we recognize that it is an evolving model, and that our knowledge of its sustainable management is limited. The fundamental components of the meadows, the native plant species themselves, however, are generally recognizable after ten years of study. What remains unanswered is a clear understanding of the mix, abundance, and population fluctuations in these native species, and an understanding of ways to replicate the physical setting (i.e., hydrology, soils, and organisms) in which they exist.

Management of an existing wet meadow site, with a full complement of

component species (although maybe not in the desired proportions) is a much easier task than trying to recreate wet meadow communities from scratch on altered and degraded sites. In the process of drainage and conversion to cropland, most elements of the native vegetation are irretrievably lost. Although some seeds, tubers, and other vegetative plant parts can remain dormant in the soil for many years, tillage and physical disturbance of the soil interrupts the growth and reproduction of many native species, while chemical herbicides and pesticides eliminate many others. One has only to survey an abandoned crop field to see that the majority of species present in adjacent grasslands are usually absent. Changes in drainage, depth to groundwater, structure of the soil profile, water percolation, nutrient distribution, and other physical alterations also effect the ability of species to recolonize a site. The ecological structure of native plant and animal communities may have taken thousands of years of co-evolution to achieve. Restoration attempts over the short-term, therefore, may never fully replicate native meadows. Instead, our goal should be to achieve as nearly as possible, wet meadow restorations that in appearance and in function tend to mimic native sites.

The purpose of this paper is to present an initial analysis of our restoration attempts and an assessment of our progress in achieving functional wet meadows. Two native sites at Mormon Island (high quality and very wet) and Shoemaker Island (drier and poorer quality Binfield site) were used as benchmarks for comparison. These two native sites represent a spectrum of species found on native sites, as well as a variety of management scenarios. The native sites were compared with restorations in various stages of development on three former cropland areas and on a floodplain site. The floodplain site had been cleared of trees and woody growth and the subsequent grassland/herbaceous vegetation was allowed to colonize without re-seeding. Two of the cropland sites were re-seeded using conventional drilling techniques in which native grass seed (purchased regionally) was drilled into sorghum stubble. No attempt was made to seed native forbs into these plantings. On the final site, locally collected grass and forb seeds were planted in an attempt to create a high-diversity grassland/wetland restoration.

Emphasis is placed in the following discussion on comparisons between the native sites and the restorations in various stages of development. Less emphasis is placed on comparisons between the various planting techniques. The main purpose in analyzing the restorations at this stage of development is to determine the successional direction they are taking and to evaluate their progress towards functional wet meadows.

STUDY SITES

Six native and restoration sites were compared in the study (Table 1). They were located within an 80-km reach of the Platte River valley extending from Elm Creek to Grand Island, Nebraska. Two of the sites (Mormon Island and Binfield) were native meadows with active grazing and haying operations. Three of the sites (Field-11, Uridil, and Uridil-2) were cropland areas that were re-seeded using a variety of seed mixes and establishment techniques. The last site (Johns) was formerly part of the active river channel, but had developed into a riparian forest over the last 40 years. A majority of the forest was removed and grasses and herbaceous species were allowed to colonize and dominate the site.

Mormon Island

The Mormon Island site (T10N R10W, secs 26,27,34,35) is located near Grand Island, and is the largest of the study areas (more than 800 ha). This site has been left nearly intact since the time of development, except for grazing and haying operations. Disturbances include a few small areas that have been tilled and cropped, and an unsuccessful attempt to ditch and drain a portion of the wettest meadow. The Trust purchased the Mormon Island site in 1981, and shortly thereafter instituted a four-pasture grazing rotation and a haying rotation system. Under this management regime native grassland species have increased in abundance and grassland production has improved greatly. Prescribed burning has also been used to promote native species and to control invasion by willow, false indigo, red cedar, and other woody species. The Mormon Island site is one of the most diverse on the river in terms of its array of flora and fauna. This is in part due to the topographic variation at the site and the variety of hydrologic conditions. These range from very wet to moderately wet, with occasional

Table 1. Description of restoration and native sites, their management, and the restoration techniques used at each location.

Site	Description	Management	Initial Activity	Restoration Techniques
Mormon Island	**Native** - 800-ha wet meadow with existing hydrology and indigenous wet meadow flora and fauna. Includes very wet and moderately wet sites. Wann & Barney soils.	Four pasture grazing rotation and a haying rotation in place. Prescribed burning used to maintain and enhance native grassland species.	1981	Improved grassland management. Began prescribed burning.
Binfield	**Native** - 400-ha wet meadow with existing hydrology and indigenous wet meadow flora and fauna. Moderately wet with a few very wet sites. Wann, Platte, & Barney soils.	Mostly continuous grazing, with some 2-pasture rotation. Intensive grazing in some areas. Red cedar invasion serious in riverbank pasture.	1982	Conservation easement with Platte River Trust to prohibit conversion and prevent drainage. Burning used to control woody invasion.
Field-11	**Re-seeded** - 24-ha area of of Mormon Island that had been in crop and alfalfa production for ~40 years. Moderately dry site with a few poorly drained areas. Wann & Platte soils.	Placed in wildlife habitat program for first 5 years. No grazing or haying. Some areas burned in each of the last 5 years. No hydrological enhancement.	1988	Native grass planting with non-local seed. Forbs allowed to colonize on their own. Burning used to enhance grass & forb development.
Johns	**Re-claimed** - 130-ha floodplain with sparse grass and herbaceous regrowth following cottonwood forest (45+ year old) removal. Moderately dry with surface water impoundments. Loamy alluvial & riverwash soils.	Logging and shredding used to remove floodplain forest. Woody regrowth & noxious weeds controlled with 2,4-D & Banvel. Light to moderate grazing by horses during 1 year.	1983	Floodplain forest removed. Burning & chemical control of regrowth. Natural grassland recolonization. Dams built to enhance wetland hydrology.
Uridil	**Re-seeded** - 25-ha cropland pivot under continuous corn production for ~20 years. Slightly rolling wet meadow topography. Moderately dry to dry site with a small area that is occassionally flooded. Platte soils.	Enrolled in conservation reserve program (CRP) for 10 years. No grazing or haying. Shredded occasionally to control noxious and aggressive weeds. Burned in 1992.	1990	Native grass planting with non-local seed. Wind-mill pump installed to enhance surface ponding. Burning used to control dominance of self-seeded forbs.
Uridil-2	**Re-seeded** - 14 ha flood-irrigated cropland site under continuous corn production for ~20 years. Field was levelled. Moderately wet to wet with some overbank flooding. Wann Volin, and Platte soils.	Part of FWS biodiversity study. Highly diverse planting of 100+ grasses and forbs. Field surface was scrapped to recreate rolling topography and wetlands. No grazing or haying. Flooded 3-4 weeks in 1993 (east end).	1992	Native grass & forb planting with a local high-diversity seed mix. Earth moving was used to restore surface variability and proximity to ground-water table.

grasses. These groups were chosen (in order) as representative of 1) invading species, 2) opportunistic species capable of capitalizing on the availability of new habitat sites in the short-term, 3) lowland species characteristic of wet meadow wetlands, 4) flowering species indicating the state of habitat diversity, and 5) grasses as an indicator of grassland dominance. Species by species comparisons were also made between the sites for each growth form to determine species overlap between the native sites and the restored sites and to determine the percentage of native species present in the restorations. As there was some variation in the flora of the native sites that were sampled, a composite species list for native sites was complied from the Mormon and Binfield sites. This composite may overstate the species diversity of native sites, but it insured that the full complement of native species and habitat heterogeneity was considered in comparison with all the restorations. Finally, dominance diversity curves were developed for the quantitatively sampled sites. These curves illustrate a combination of species richness and species importance within a site, and provide a means of rapidly comparing biodiversity at native and restoration sites. An index of equitability was also calculated for each dominance-diversity curve (Whittaker 1975).

$$E_c = S / (\log n_1 - \log n_s)$$

where, S is the number of species in the sample, n_1 the importance value of the most important species, and n_s the importance value of the least important species. The index of equitability represents the mean number of species per log cycle of a dominance diversity curve, and increases with greater complexity and more even distribution of cover among species at a particular site. The E_c can be used as a rough index of progress towards the diversity and complexity found in native wet meadows.

RESULTS AND DISCUSSION

Comparisons of plant species growth forms based on quantitative cover values is shown in Figure 1. Woodland species were minor in both the native and restoration sites, and averaged less than 1 percent of total cover. Grasses dominated the sites and ranged from 34% to over 50% in cover value. At the Mormon Island site, however,

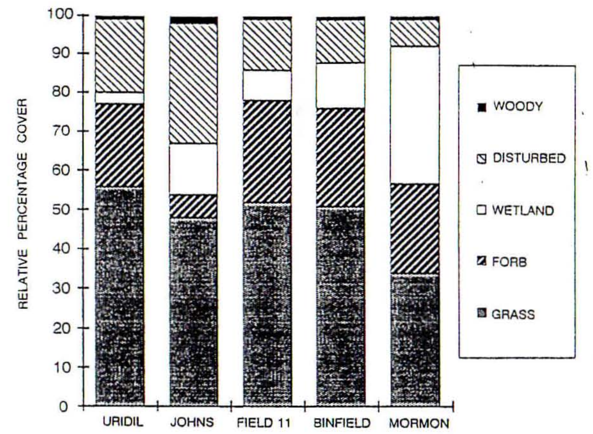

Figure 1. Relative cover of different plant forms in restoration (Uridil, Johns, Field-11) and native sites (Binfield, Mormon Island) in 1993.

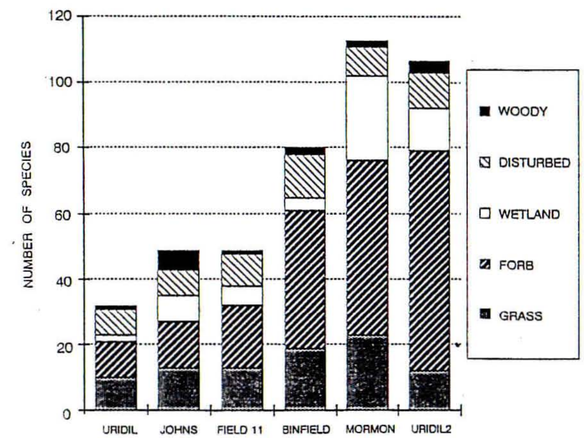

Figure 2. Total number of species, by plant form at restoration (Uridil, Johns, Field-11, Uridil-2) and native sites (Binfield, Mormon Island) in 1993.

wetland and grass species cover was nearly identical. Forbs were also well represented at all the sites (cover values of 22% to 26%) except at Johns, where they comprised only 6% of the cover. This is probably due in part to the use of chemical herbicides at the site (i.e., Banvel and 2,4-D) that control a broad spectrum of broadleaf forbs in addition to the woody species and noxious weeds that were targeted in the spraying. Wetland species cover was substantially less at all of the other sites (1% to 13%) than at Mormon Island (35%). This difference is to a large extent a result of the areal extent of wetland areas at the sites. For instance, wetland species cover at the 2 native sites was considerably different. Mormon Island had nearly 3 times the cover found at Binfield where there are fewer sloughs and swales and the wetland hydrology is more moderate. At the Johns site, where low-elevation dams were constructed to pond water and create shallow-water wetlands, wetland species cover was nearly equivalent to that at Binfield (cover actually exceeded Binfield by 1%). As was expected, however, where enhancements to wetland hydrology on drier sites have either not been very successful (Uridil) or have not been attempted (Field-11), wetland species cover values were lower. Disturbance species cover was greatest at the Uridil and Johns sites. In comparison with Field-11, the Uridil site is a more recent planting (by 2 years) and had its beginnings during a drought period, 2 factors that may have delayed dominance by native species and allowed weedy and other disturbance species to persist. A combination of less fertile floodplain soils and the fact that no seeding was done on the Johns site, has undoubtedly delayed native species development and provided many opportunities for disturbance species to thrive.

In terms of overall species richness, the native sites at Binfield and Mormon and the high-diversity seeding at Uridil-2 had the greatest numbers of species (80 to 113 species at each location)(Figure 2). On average, the restorations at Uridil, Johns, and Field-11 only had about half of the species found at Mormon Island, Binfield, and Uridil-2. There were 6 to 13 more species of grass at the native sites than in other locations, but the major differences in numbers were among the wetland and forb species. Forbs were 2 to 4 times more numerous in the native sites than in the Uridil, Johns, and Field-11 restorations. The highest forb numbers actually occurred at Uridil-2,

where 75 or more forb species had been included in the seeding mix. Wetland species diversity also varied substantially at the sites. The 26 wetland species found at Mormon Island for instance, was twice the number in the high-diversity seeding at Uridil-2, while the remaining restorations had only a few wetland species (2 to 8 species, depending upon the location). The native Binfield site had only 4 wetland species, fewer even than at the Johns and Uridil-2 restoration sites.

Dominance-diversity curves were used to visually examine the dominance and diversity of species at the various sites (Figure 3). In the Figure, the importance value represents the log of the percentage cover value for each species. The species sequence is simply the rank order listing of the species from the most important (left) to the least important (right). The five curves in the diagram have been offset on the species sequence axis so that they would all fit on the same graph. The total length of the species sequence is what is important -- not where the sequence stops and starts. For instance, the Johns curve begins at point 25 and ends at point 74, representing 49 species (74-25=49), while the curve for Mormon Island begins at point 125 and ends at point 238, and represents 116 species at that site (238-125=113).

The shapes of the dominance-diversity curves represent differences in the distribution of cover among the species at the different sites. The least structurally complex and diverse Uridil site had a simple geometrically shaped straight-line curve, while the more complex Binfield and Mormon Island sites had more sigmoid-shaped curves. The Johns and Field-11 sites had intermediate shapes. A way to mathematically compare the curves is to calculate an index of equitability or E_c, which measures the equitable distribution of cover among species. The Uridil restoration site had the lowest E_c of 11.4, while the native Binfield and Mormon Island sites had values of 39.5 and 42.6, respectively. The Johns site with an E_c of 13.6, was only slightly higher than the Uridil site, while Field-11 had a moderate index of 24.8, indicating considerable development towards a diverse flora.

A comparison of cover values and species richness, indicates several general trends: 1) Grasses in the restorations were the dominant species, and had cover values equal to or exceeding those at native sites, although they had fewer species than at

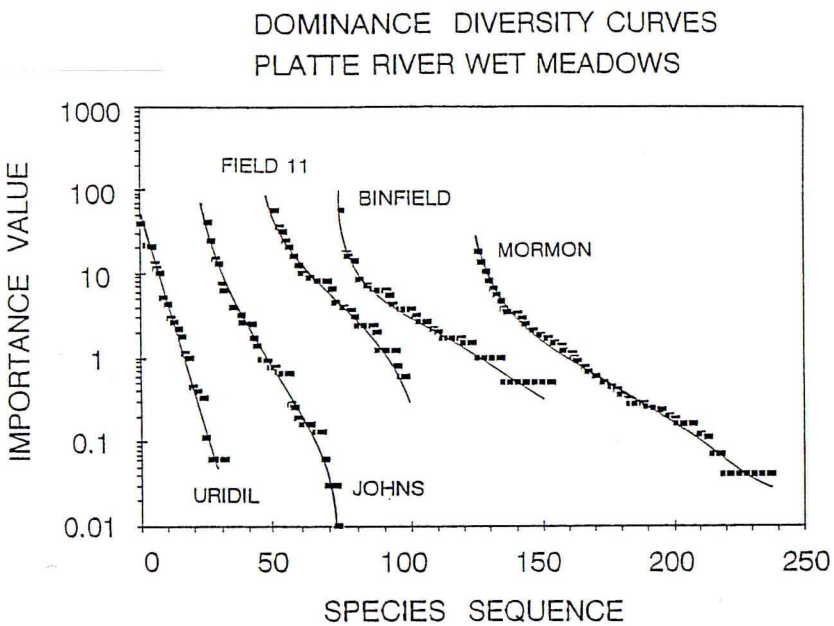

Figure 3. Dominance-Diversity curves for restoration and native sites. Equitability, expressed by an E_c index, increases from left to right in the diagram and is greatest in native wet meadows (represented by Binfield and Mormon Island), where the plant community is more diverse and more complex.

native sites. 2) Many wetland species appeared to be missing from the restoration sites as well as the native Binfield site. 3) Although forb cover values were similar in restoration and native sites (excepting the herbicide-treated Johns site), there were far fewer forb species in the restorations, except at Uridil-2 where a number of these species were intentionally introduced. 4) Dominance-diversity and equitability calculations indicate that the restorations have not yet reached a stage of development that rivals the complexity and diversity of native wet meadow sites.

Table 2. Comparison of grasses in native and restoration sites as of 1993.

Species	Common Name	Native	Field-11	Johns	Uridil	Uridil-2
Agropyron caninum	slender wheatgrass	x				x
Agropyron intermedium	intermed. wheatgrass	x				
Agropyron repens	quackgrass	x	x			
Agropyron smithii	western wheatgrass	x				
Agrostis stolonifera	redtop	x	x			
Andropogon gerardii	big blue stem	x	x		x	x
Andropogon scoparius	little blue stem	x			x	x
Bouteloua curtipendula	side-oats grama	x				x
Bromus inermis	smooth brome	x			x	
Bromus japonicus	japanese brome	x	x	x	x	
Calamagrostis inexpansa	reedgrass	x		x		
Dactylis glomerata	orchardgrass	x				
Distichlis spicata	saltgrass	x				
Elymus canadensis	Canada wild rye	x		x	x	x
Eragrostis pectinacea	Carolina lovegrass	x				
Festuca pratensis	meadow fescue	x				
Hordeum jubatum	foxtail barley	x				
Muhlenbergia asperifolia	muhly	x				
Panicum lanuginosa	little panicum	x				
Panicum oligosanthes	Scribner's panicum	x	x	x		
Panicum virgatum	switchgrass	x	x	x	x	x
Paspalum setaceum	paspalum	x	x			
Phalaris arundinacea	reed canary grass	x	x	x	x	
Poa pratensis	Kentucky bluegrass	x	x	x	x	
Setaria spp.	foxtail	x		x	x	
Sorghastrum avenaceum	indiangrass	x	x	x	x	x
Spartina pectinata	cordgrass	x	x	x		x
Sphenopholis obtusata	wedgegrassnip	x	x			x
Sporobolus asper	rough dropseed	x		x		x
Additional Species						
Bromus tectorum	downy brome		x			
Phragmites australis	common reed			x		
Elymus virginicus	virginia wild rye			x		
Alopecurus aequalis	short awn foxtail					x
Eragrostis trichodes	sand lovegrass					x

SPECIES TOTALS	Native	Field-11	Johns	Uridil	Uridil-2	SUMMARY AVERAGES
Common with natives	29	12	11	10	10	37% of natives present
Missing species	0	17	18	19	19	63% of natives missing
Additional species	0	1	2	0	2	1-2 additional species

Table 4. Comparison of forbs in native and restoration sites as of 1993.

Species	Common Name	Native	Field-11	Johns	Uridil	Uridil-2
Abutilon theophrasti	indian mallow	x				
Allium texensis	wild onion	x				
Apocynum sibiricum	dogbane	x	x		x	x
Artemisia ludoviciana	white sage	x				
Asclepias speciosa	showy milkweed	x				x
Asclepias syriaca	common milkweed	x	x	x	x	
Asclepias verticillata	whorled milkweed	x				
Aster ericoides	white aster	x	x		x	x
Aster praealtus	willowleaf aster	x				x
Aster simplex	panicled aster	x	x	x	x	x
Bidens comosa	beggar-ticks	x				
Callirhoe involucrata	purple poppy mallow	x				x
Callirhoe alaecoides	pink poppy mallow	x				x
Chrysanthemum leucanthemum	chrysanthemum	x				
Convolvulus spp.	bindweed	x				
Cuscuta glomerata	dodder	x	x			
Desmanthus illinoensis	bundle flower	x	x	x	x	x
Equisetum arvense	field horsetail	x		x		
Equisetum laevigatum	scouring rush	x	x			
Erigeron strigosus	daisy fleabane	x				x
Eustoma grandiflorum	prairie gentian	x				
Gaura parviflora	velvety gaura	x	x			x
Glycyrrhiza lepidota	wild licorice	x	x			x
Helenium autumnale	sneezeweed	x		x		x
Helianthus grosseratus	sawtooth sunflower	x	x			
Helianthus maximillianii	maximillian sunflower	x	x		x	x
Helianthus petiolaris	plains sunflower	x	x	x	x	
Lactuca serriola	prickly lettuce	x				x
Liatris pycnostachya	big-spike gay-feather	x				x
Liatris aspera	little gay-feather	x				x
Lithospermum incisum	puccoon	x				
Lobelia siphilitica	blue lobelia	x				
Lobelia spicata	low-spike lobelia	x				
Lycopus americanus	American bugleweed	x				x
Lycopus asper	rough bugleweed	x				x
Lysimachia ciliata	fringed loosestrife	x				
Lythrum alatum	winged loosestrife	x				x
Medicago lupulina	black medic	x	x			
Medicago sativa	alfalfa	x				
Mentha arvensis	field mint	x				x
Oenothera biennis	evening primrose	x		x	x	x
Penthorum sedoides	stonecrop	x				
Petalostemon candidus	white prairie-clover	x				x
Petalostemon purpureus	purple prairie-clover	x				x
Physalis virginiana	ground-cherry	x	x		x	
Plantago eriopoda	alkali plantain	x				
Plantago patagonica	wooly plantain	x				x
Prunella vulgaris	heal-all	x				
Pynanthemum virginianum	mountain mint	x				x
Ratibida columnifera	prairie coneflower	x				x
Ratibida pinnata	grayhead coneflower	x	x			
Rhus toxicodendron	poison ivy	x				
Rudbeckia hirta	black-eyed susan	x	x			x
Scutellaria galericulata	marsh scullcap	x				
Scutellaria lateriflora	blue skullcap	x				
Solidago rigida	stiff goldenrod	x			x	x
Solidago canadensis	canada goldenrod	x	x	x	x	x
Strophostyles leiosperma	slick-seed wild bean	x		x		
Taraxacum officinale	dandelion	x				
Teucrim canadense	American germander	x				

Table 3. Comparison of wetland species in native and restoration sites as of 1993.

Species	Common Name	Native	Field-11	Johns	Uridil	Uridil-2
Alisma plantago-aquatica	water plantain	x				x
Alisma subcordatum	water plantain	x				
Ammania coccinea	tooth cup	x				
Asclepias incarnata	swamp milkweed	x	x			x
Carex aquatilis	water sedge	x	x	x	x	x
Carex gravida	heavy sedge	x				
Carex tenera	sedge	x	x			x
Carex vulpinodea	fox sedge	x				
Cyperus spp.	nutsedges	x	x			
Eleocharis acicularis	little spikerush	x				x
Eleocharis macrostachya	spikerush	x		x		
Fimbristylis puberula	fimbristylis	x				
Juncus bufonis	toad rush	x				x
Juncus balticus	baltic rush	x				
Juncus dudleyi	Dudley rush	x		x		
Juncus torreyi	Torrey's rush	x		x	x	x
Leersia oryzoides	rice cut-grass	x				
Lysimachia thyrsiflora	tufted loosestrife	x				
Mimulus glabratus	monkeyflower	x				
Phyla lanceolata	fog fruit	x		x		x
Polygonum hydropiper	water pepper	x				
Polygonum lapathifolium	pale smartweed	x				x
Polygonum amphibium	water smartweed	x	x			x
Polygonum persicaria	lady's thumb	x				
Sagittaria latifolia	arrowhead	x				
Scirpus americanus	three-square	x		x		x
Scirpus atrovirens	green bulrush	x				
Sium sauve	water parsnip	x				
Triglochin maritima	arrowgrass	x				
Additional Species						
Scirpus validus	softstem bulrush			x		x
Scirpus fluviatilis	big river bulrush			x		
Cicuta maculata	water hemlock		x			

SPECIES TOTALS	Native	Field-11	Johns	Uridil	Uridil-2	SUMMARY AVERAGES
Common with natives	29	5	6	2	12	22% of natives present
Missing species	0	24	23	27	17	78% of natives missing
Additional species	0	1	2	0	1	1-2 additional species

Table 4 (continued).

Species	Common Name	Native	Field-11	Johns	Uridil	Uridil-2
Trifolium hybridum	alsike clover	x				
Trifolium pratense	red clover	x				
Trifolium repens	white clover	x		x		
Verbena hastata	blue vervain	x		x		x
Verbena stricta	wooly vervain	x	x			x
Vernonia fasciculata	ironweed	x	x			x
Viola pratincola	prairie violet	x				
Additional Species						
Achillea millefolium	yarrow					x
Amorpha canescens	leadplant					x
Anemone cylindrica	candle anemone					x
Aster novae-angliae	New England Aster					x
Astragulus crassicarpus	ground-plum					x
Astragulus canadensis	Canada milkvetch					x
Calylophus serrulatus	yellow primrose					x
Crepis runcinata	hawk's beard					x
Dalea leporina	foxtail dalea					x
Desmodium canadense	Canada tickclover					x
Desmodium illinoense	Illinois tickclover					x
Desmodium paniculatum	panicled tickclover					x
Eupatorium perfoliatum	boneset					x
Froelichia floridana	snake-cotton					x
Geum canadense	white avens					x
Helianthus laetiflorus	stiff sunflower					x
Lespedeza capitata	bush clover					x
Liatris glabrata	gay-feather					x
Liatris punctata	dotted gay-feather					x
Lotus purshianus	prairie trefoil					x
Monarda fistulosa	wild bergamot					x
Nepeta cataria	catnip			x		
Penstemon grandiflorus	large penstemon					x
Penstemon gracilis	slender penstemon					x
Penstemon digitalis	smooth penstemon					x
Potentilla paradoxa	bushy cinquefoil					x
Salvia pitcheri	pitcher sage					x
Schrankia nuttallii	sensitive briar					x
Senecio plattensis	prairie ragwort					x
Silphium speciosum	rosin-weed					x
Sisyrinchium montanum	blue-eyed grass					x
Solidago missouriensis	prairie goldenrod					x
Thalictrum dasycarpum	meadow rue					x
Verbascum thapsus	common mullein			x		
Verbena urticifolia	nettle-leaf vervain					x
Vernonia baldwinii	western ironweed					x

SPECIES TOTALS	Native	Field-11	Johns	Uridil	Uridil-2	SUMMARY AVERAGE
Common with natives	67	19	11	11	32	27% of natives prese
Missing species	0	48	56	56	35	73% of natives missir
Additional species	0	0	2	0	34	2-34 additional specie

A species by species comparison between native and restoration sites provides additional insight into the structural differences at the sites (Tables 2, 3, and 4). Overall, the restoration sites contained 68% of the grass species found at native sites, and 5 additional species not recorded at the native sites. On a site by site basis, however, only 37% of the native grass species were present on average (Table 2).

Only half of the wetland species found at native sites were present in the restorations overall, but on a site-by-site comparison 78% of the wetland species on average were missing (Table 3). Although 3 additional wetland species were found in the restorations, all 3 species commonly occur on native Platte River sites, but were missed in the survey of native sites at Mormon Island and Binfield.

The greatest variation between native and restoration sites occurred among the forb species (Table 4). Excluding the high-diversity seeding at Uridil-2, there was only 38% overlap of forbs in restoration and native sites. On a site-by-site basis only 27% of the native species were present. The Uridil-2 site, in contrast, had 32 forb species (50% of the native species) in common with the native sites, as well as having an additional 34 species not found at the native sites. All of the additional species are known in the Platte River Valley, although bush clover (*Lespedeza capitata*), pitcher sage (*Salvia pitcheri*), and other species are not very common elements of the Platte River flora. Most of these additional species were included in the seed mix for the Uridil-2 site. Some of these species, however, were not intentionally introduced and have either colonized the site from local seed sources, or were introduced as impurities in our native seed mix.

MANAGEMENT IMPLICATIONS

Caution needs to be taken in interpreting the data presented here. After all, the restorations described are experimental, and have been allowed to run their course for only a few short years. In addition, although development has been allowed to occur over a 10 year period at the Johns site, no "introduced" seeding has been undertaken there at all. It is therefore not surprising that the structure and complexity of the restoration areas is far less than that in the native Binfield and Mormon Island sites where the flora has developed over perhaps hundreds of years. The real impact of our management techniques and restoration attempts will probably not be known for decades. The preliminary results of our restoration attempts are valuable in understanding the kinds of habitat we are creating, the value of the habitat to migratory birds, and whether we have created habitat that resembles and ecologically functions similar to native sites.

The vegetation differences identified in this study are a result of management, differences in seed mixes, differences in planting techniques and tending, and differences in hydrologic conditions at the various sites. In some instances, the restoration efforts have been very encouraging. Grasses have successfully been established at the restoration sites. Grasses have also self-seeded into the Johns site. The lower diversity of grasses and forbs in the plantings is, in large part, directly related to the lack of diversity in the seed mixes. At the Uridil-2 site, for instance, with only a year of growth (and flooding disturbance), a broadly diverse flora has initially become established following seeding with over 100 species. Such diverse seed mixes are not commercially available, and require hundreds of hours of hand and machine harvesting. With such labor intensive collecting, the size of high-diversity restorations is also necessarily limited by seed availability.

Although many of the seed mixes containing just 4-5 species of grasses have been fairly successful, and look similar in composition and structure to native wet meadows (particularly Field-11), it is clear that many elements of the native flora are missing. It was hoped that with time the planted warm-season grasses would dominate the restorations and out-compete introduced smooth brome and bluegrass. We also envisioned that other grasses and forbs would immigrate to the sites, filling openings in the newly established prairies, and establishing diverse communities not unlike native sites. Aggressive, dominating species such as Blackwell Switchgrass were specifically avoided in the seed mixes to reduce single-species dominance and allow for the successful introduction of additional species. The data presented here indicates that immigration of additional species or the development of residual seedbanks at the sites, is most likely a painfully slow process. Herbicide spraying to control noxious species

(Johns site) has also probably set-back floral diversity.

The handful of grasses missing from the restorations will probably eventually establish at the sites, as these species are generally common elements of native meadows. Introductions of a more diverse forb flora will, on the other hand, probably require additional seeding. Overseeding established areas with forbs has been tried on a few sites, but we do not yet have any conclusive results. Based on the results of the Uridil-2 planting, it appears that the earlier forbs are introduced, the more success there will be in developing a diverse planting. Early development of tall prairie grasses can suppress the development of subsequently introduced species as a result of over-shadowing and resource competition. While a diverse mix of grasses and forbs often occur on native sites where resources have efficiently been partitioned, such a division may not occur where a few species are allowed to dominate early in successional development. Mowing, haying, grazing, burning, or other techniques that reduce the dominance of well-established native species (primarily grasses), need to be examined as methods of augmenting species diversity in restorations.

Management can also be a determinant of the direction of plant development and diversity. Since 1981, the Mormon Island site has been managed with rotation grazing, haying, and prescribed burning to promote native species and greater structural and species diversity. Over the years, grazing and haying intensity have gradually been reduced, resulting in nearly a two-fold increase in plant production, and a widespread increase in forb abundance (Currier, unpublished data). Grazing exclosures at the site also suggest that even moderate grazing in standing water sloughs can entirely eliminate some sensitive species. Likewise, the more intensive grazing regime and higher stocking rates at the Binfield site are probably responsible for much of the reduction in wetland and forb species there.

The lack of wetland species at the restoration sites, however, can not be a consequence of grazing management, because none of the sites have been grazed (minor grazing was allowed at the Johns site about 5 years ago). It seems apparent that the major factor responsible for the lack of wetland species is a lack of the necessary ground and surface water hydrology to sustain them. Attempts to enhance wetland hydrology have produced with mixed results. Windmill pumping at the Uridil site was not very effective in creating widespread surface water wetlands, or in enhancing the wetland flora. The development of low-elevation dams at Johns, and recontoured sloughs at Uridil-2 were moderately more successful in creating temporary wetlands, but these sites still don't rival the native Mormon Island site in the number of wetland species.

One of the central features of wet meadows is their high soil saturation near the ground surface for at least a portion of the year. At Mormon Island this seems to be accomplished with a combination of poorly drained soils, a naturally high groundwater table (highest usually in spring), periodic precipitation, and relatively high river stages at some point in the year (normally spring and early summer)(Henszey and Wesche 1993). As water development and drainage has occurred on the Platte over the past 100 years, groundwater levels have undoubtedly declined, leaving many former wet meadow sites (potential restoration sites) at considerably higher elevations relative to the groundwater table than they were historically (see O'Brien and Currier 1987). The fact that crops were grown on all the restoration sites except Johns, intuitively suggests that either groundwater levels have dropped or that these sites were artificially drained to permit tillage and cropping.

Attempts to increase surface water hydrology with windmills were probably unsuccessful because a large enough volume of water could not be pumped to saturate the relatively dry soils at the Uridil site. With a higher water table, windmill pumping might have been more successful. Re-contouring sloughs at the Uridil-2 site was an attempt to retard drainage and to effectively lower surface elevations in relation to the current groundwater level. In the limited areas where scraping was done, the local hydrology was enhanced and additional wetland species were found. Earth moving, however, is expensive, making widespread use of this technique impractical in wetland creation.

In meeting wet meadow hydrologic criteria, the most successful technique, (and most expensive) was to attempt a restoration on a portion of the river floodplain at the Johns site. The floodplain sits in a landscape position that is probably similar in elevation and proximity to the water table as many historic wet meadows. In fact, such

floodplain sites lie adjacent to the active channel, where most wet meadows were historically found. Although surface water sloughs and a high water table is present at Johns, characteristic wet meadow soils are lacking. Instead of silt and organic loam, the soils are primarily coarse riverwash and sand with a few areas of heavier soils on poorly drained sloughs. Construction of low-head dams at Johns has resulted in more wetland surface area, but water retention is relatively poor, owing to the sandy soils. The dams have gradually begun to seal, however, as silt and organic matter has accumulated in the wetlands behind them.

Although the hydrology at the Johns site may more closely replicate that at historic wetland meadow sites, the soils and existing vegetation are not very conducive for wet meadow plant development. The highly permeable sandy soils are not ideal for germination and development of species characteristic of mesic meadows. Although no attempt has been made to re-seed the Johns site, the lack of typical lowland soils would most likely limit its success. In addition, because numerous stumps remain after forest clearing, there are difficulties in using a drill or other machinery to seed the site. Seeding by air is a possibility, but this would limit the mix to seeds that are heavy enough to be carried to the ground (fluffy seeds such as big bluestem and indiangrass would blow away unless they were attached to some type of carrier material).

An additional drawback to wet meadow development on the floodplain is that for the most part they are covered with a heavy mantle of forest vegetation (most 10-50 years of age)(see Sidle et al. 1989). Clearing such forests and inhibiting regrowth is expensive. The Johns site cost nearly $700 per acre ($300,000) to initially clear and maintain as a non-woody site. Estimated clearing costs for other sites have ranged from $1400-$1900 per acre (U.S. Bureau of Reclamation 1990). In any case, these costs are quite expensive, considering the marginal wet meadow habitat that we have been able to create to date.

Wherever wet meadow sites are created, it appears that fluctuating river flows that simulate or mimic the historic high spring peaks are probably essential to recharge and maintain the wetland hydrology needed to sustain them (U.S. Fish & Wildlife Service 1993). Attempts to manipulate the local hydrology at restoration sites have so far been relatively ineffective. In addition, hydrologic enhancements will have little impact unless base groundwater levels are maintained as a result of river flow management.

CONCLUSIONS

The data analyzed in this study reviews the progress in wet meadow restorations undertaken by the Platte River Trust during the past 10 years. A variety of management, seeding, and hydrologic techniques have been attempted. The model for the restorations has been the native Mormon Island site, the largest remaining wet meadow in the Big Bend reach of the Platte. It is clear from the data presented here, that we are a long way from the goal of re-creating wet meadows that function hydrologically and support the assemblage of flora and fauna present at Mormon Island. The inherent hydrology of native wet meadows and their component wetland vegetation is generally lacking in our restorations. Techniques to manipulate ground water and surface water have been only marginally successful, and in many areas the soils and species characteristic of wetland sloughs and swales have not developed very readily.

The successful seeding of grass species on most of the restorations has resulted in new habitat that has filled a niche in the Platte River ecosystem. The Field-11 site, for instance, has provided some of the most structurally diverse habitat along the Platte, and some of the highest densities of breeding birds anywhere in the valley (Savidge & Siebert 1992 and personal communication). This response is a combination of the re-seeding effort and subsequent management with prescribed burning but no grazing or haying. Even though such areas play an important role in maintaining the habitat for some migratory birds, they have not been able to replace the thousands of acres of native wet meadow habitat that has been lost. The Uridil-2 site, although not very long in development, has shown great promise as a way to restore a highly diverse flora. But such restorations also raise questions about the level of diversity in historic meadows, and the role of high-diversity plantings in enhancing avian habitat. It is possible that the species mix being introduced at this site is far more diverse and uniform than the native wet meadow mosaic. Over time, species may sort themselves into more clumped

distributions, and in the process out-compete and eliminate other species. In any case, few native sites on the Platte can rival the diversity found in this one small planting at this point in its succession.

The results presented here should be considered and weighed as we continue with attempts to restore wet meadow habitat along the Platte. One step that seems clear, however, is that before we can be successful in re-establishing wet meadow plant and animal communities, we must first be successful in restoring hydrologic conditions at the sites. Not only is the appropriate hydrology necessary to allow colonization and expansion of wet meadow plants; it is also necessary to sustain invertebrates and other aquatic organisms that serve as an important food base for cranes, waterfowl, and a wide array of other migratory birds. Only then will we be capable of fine-tuning vegetation succession and development and begin to restore truly functional wet meadows as an integral part of the Platte River ecosystem.

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WET MEADOWS — NATURE'S UTILITY PLAYER

Few habitats on the Platte have the diversity of life found in the unassuming complex of wetland swales and rolling grasslands found on wet meadows. Although dominated by prairie grasses (Big bluestem, Indiangrass, switchgrass), sedges, and marsh emergents (bulrushes, cattail, burreeds), wet meadows also support a variety of flowers and other plants including mints, smartweeds, asters, sunflowers, prairie clovers, spikerushes, rushes, and minor grasses. Woody species are rare, except at meadow perimeters, but red cedar, Russian olive, false indigo, and buffalo berry can become invasive. ■ The variety of plants and micro-habitats in the meadows provide habitat for a wide diversity of organisms from birds to amphibians, to small mammals and insects. Although a primary territory for feeding and resting cranes and waterfowl, many other migratory birds also use the meadows. Northern harriers, red-tailed hawks, eagles, and other raptors soar over the meadows in search of mice, snakes, frogs, and other prey. Bobolinks, sedge wrens, dickcissels, grasshopper sparrows, and other nesting species also call the meadows home. Coyotes, skunks, deer, badgers, and other animals use the meadows as well, for travel corridors, and as burrowing, feeding, and resting areas. ■ The seeds, tubers, insects, snails, ground beetles, spiders, insect larvae, caterpillars, cutworms, and other smaller organisms found in wet meadows form the bulk of the production at the base of the food chain. A succession of food items becomes available as each of these organisms in turn complete their life and reproductive cycles. As mid-summer advances, insects, beetles, and insect larvae predominate, while grasses and flowers begin to mature and produce fruits and seeds by summer's end. Such a storehouse of diverse plants and animals provides a food base that is the mainstay for many organisms living in the shadow of the Platte.