Wet Meadow Literature and Information Review

DRAFT REPORT

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Outline

The present is a summary of literature published on wet meadows and their associated biological and abiotic characteristics. The report is divided into three parts; 1) narrative, 2) annotated bibliography, and 3) supporting documents. Part one is a narrative section summarizing existing literature to present a synthesis of existing knowledge of wet meadow characteristics, descriptions and published parameters. Part 2 is an annotated bibliography where all published literature is presented as a citation and an abstract or comment on the content of each article or report. Part 3 are supporting materials, PDF's of all literature, reports, and data sources presented or discussed in this report

Justification

Wet meadows adjacent the Platte River provide important migratory feeding and nesting habitats for more than 150 species of birds, and other wildlife in central Nebraska (Krapu 1981, Currier 1994). Wet meadows are ephemeral wetlands that commonly occur in poorly drained areas. These wetlands, often surrounded by grasslands, are typically drier than other marshes except during periods of seasonal high water (Mitsch and Gosselink 2000, Library of Congress 2006, US EPA 2006). For most of the year wet meadows are without standing water, though the high water table allows the soil to remain saturated. A variety of hydrophytic grasses, sedges, rushes, and wetland wildflowers proliferate in the highly fertile soil of wet meadows (Library of Congress 2006, US EPA 2006).

Wet meadows are currently considered an endangered system as they are semi-permanent wetlands surrounded by upland grasslands. Often wet meadows occur in areas where farming is prevalent, which has lead to draining and filling of these wetlands for agricultural uses. I.e., The Platte River valley (in the last century) has undergone a dramatic transformation in quantity of agriculture fields. Dams and water diversions have reduced the river's flow and sediment supply substantially. River flows are believed to be the primary influence on water levels in wet meadows adjacent to the river.

Through the 1990's an estimated 74 – 80% of the wet meadows in the Platte River Valley have been drained and converted to cropland and other uses (Sidle et al 1989, Currier 1994). As a result, wet meadows are now one of the most rare habitat types in the Platte River Valley. As a rare and potentially limiting habitat type it is important to determine its significance for migratory species (among them whooping crane and other Platte River Recovery Program Species of Concern, non-target listed species, and non-listed species of concern) that use this habitat.

It would be useful to clearly define and describe a natural wet meadow in order to adequately manage and restore wet them. Therefore, it is urgent that we compile, summarize, analyze, synthesize, and make available existing information on the subject. We need to determine what is known in regards to the relative importance of wet meadows as habitat for wildlife and identify gaps in knowledge that need study. We must understand natural wet meadows in order to define the best conditions, size, management, and restoration of wet meadow habitats to optimize and enhance the interaction between wet meadow potential habitat use by whooping crane and other program Species of Concern, non-target listed species, and non-listed species of concern.

Introduction

The initial process of this information review entailed an exhaustive search for all literature on the subject of wet meadow. For the initial phase of information recovery all sources were collected and compiled which included published articles, reports to government agencies, and other unpublished or unreported data. All literature collected was reviewed and a determination was made as to its inclusion in the annotated bibliography or not based on whether the wet meadows were the subject of study or defined within the document. There are many works which make reference to Mormon Island Crane Meadows, however they do not deal with wet meadows per se but it means that the field work was conducted within the location of Mormon Island Cranes Meadows. We also decided to exclude all unpublished reports and write-ups that where either anonymous, undated, or those that would be difficult to find in the future. The annotated bibliography therefore consists of only works that have been published in scientific journals or have been submitted as official reports to an agency and are readily available.

Wet Meadow Definitions

The term wet meadow has been used in several different ways and has several synonyms with in the literature of the Central Platte River Valley, Nebraska. Within the different agencies, organizations, and personnel working on land along the Central Platte River Valley the concept of wet meadows can have significantly different meanings. This has lead to misunderstanding and at times heated discussions related to what wet meadows are and their importance to biodiversity conservation in the area. The different concepts and understandings of what a wet meadow is may be because of how the concept has been used and described in past publications. Wet meadows, as considered here, have been referenced by other names such as lowland grasslands (Currier 1995, Davis 1991), riparian grasslands (Henszey et al. 2004, Davis et al 2006), mesic grasslands (Jelinski Kim et al 2008), and mesic prairie (Whiles and Goldowitz 1998, Helzer and Jelinski 1999, Pfeiffer 1999, Whiles et al. 1999, Henszey 2004, Kim et al 2008, Meyer et al. 2008a and b). In addition, the term wet meadow has been used extensively to refer native grasslands and prairies in and around the Platte River.

Wet meadow as a recognizable feature in the landscape, land form, or plant association has been described in many ways from broad general categories to more specific and recognizable landscape unit. Wet meadow has been defined in general terms as a temporary wetland (Wheeler and Lewis 1972, Lewis 1977, Frith and Faanes 1982) or native grasslands (Zuerlin 2001). These two different concepts is representative of the misunderstanding as one author sees a wetland while the other sees a grassland. Fortunately, some descriptions are more specific with references to what a wet meadow is and how to identify it. For example, wet meadows have been assigned a geographic limit to areas close to or adjacent to the river, such as to within 0.8 km of the river (Iverson et al 1987); a lowland grassland in the Platte River floodplain (Lingle et al 1984, Armbruster 1990); or as native grassland in and adjacent to the Central Platte (Zuerlin 2001). Other definitions, which may be more useful in identifying a wet meadow describe specific characteristics of what a wet meadow is. For example several authors have described the vegetation (Krapu 1981, Currier 1982, Whiles and Golodwitz 1998, Henszey et al 2004), soil characteristics (Iverson et al 1987), topography (Pfeiffer 1999, Henszey eta l 2004, Renfrew et al 2006), or a combination thereof. The topography of wet meadows is generally described as undulating, with linear wetlands (also referred to as sloughs) and elevated sand ridges (Lingle and Hay 1982, Henszey and Weshe 1993, Hurr 1993, Currier 1995, Pfeiffer 1999, Henszey et al 2004, Meyer et al 2008b). The vegetation associations of wet meadows have been described generally as mixed grass prairies (Reinecke and Krapu 1986), emergent aquatic vegetation (Pfeiffer 1999), and sedge meadows (Currier 1982). Hydrologically, wet meadows are described as intermittent wetlands having highly fluctuating water levels (Henszey and Wesche 1993, Hurr 1983) and high water table or water logged soil (Reinecke and Krapu 1986, Whiles and Goldowitz 1998, Zuerling 2001, Henszey et al 2004, Renfrew et al 2006), at least during a portion of the year.

We propose that wet meadow be described as a grassland with waterlogged soil near the surface but without standing water most of the year (Mitsch and Gosselink 1993). We believe this is an appropriate definition as it is within a wetland classification scheme and encompasses all descriptions previously reported for a wet meadow within the Central Platte River Valley. For example it not only makes references to the intermittent water and moisture characteristics but also to the vegetation associated with, as grassland. While this definition would adequately describe wet meadows within the Central Platter River Valley it may be necessary to expand the definition to include the unique linear qualities and topography of wet meadows in this region.

A reason for why there is discussion and disagreement regarding what a wet meadow is, or is not, is that most previous literature on the subject did not set out to define or describe a wet meadow but rather had objectives to evaluate wetlands and/or grasslands in regards to different elements of biodiversity or hydrological characteristics. For example, most published articles that include wet meadow descriptions or definitions were describing vegetation, invertebrate, and/or vertebrate assemblages in those areas and were not specifically attempting to characterize or define the concept of wet meadow. Therefore, most studies have evaluated wet meadows as a habitat type for different species or groups of species and therefore were defined based on specific objectives of the study to fulfill those objectives. Perhaps the most confusing element of what a wet meadow is, or should be, is related to the landscape where it is located. Under the definition of Mitsch and Gosselink (1993) the surrounding landscape is implicitly a grassland or prairie. However, within management agencies and groups currently working on the Central Platte River Valley, the landscape surrounding a wet meadow can be of critical importance if what we are interested in is wet meadow as habitat for specific species such as cranes, herptiles, or invertebrates. For example cranes are not likely to visit a wet meadow if it is dry or if the vegetation surrounding that wet meadow is forested versus open grassland. While we think that wet meadow as a wetland/grassland category is adequately described in the definition of Mitsch and Gosselink (1993) it may be necessary to have a working definition that encompasses the area or landscape surrounding specific wet meadows within the Central Platte River Valley, in order to accommodate the management and conservation objectives that are in progress in the area. However as with the concept of habitat the area or landscape will have to be species or group specific as, if wet meadows is considered a habitat type it must be specifically reference to a species. Due to the intermittent nature of water presence in wet meadows it is not a stand alone habitat for most organism that use them, as all reported organisms present in wet meadows spend part of their life cycle outside the actual water saturated portion of the wet meadow (see information below). As such, without the inclusion of a landscape surrounding the actual wet meadow in a working definition we will likely not fulfill the habitat needs of most organisms. Possible exceptions would be cases where organisms are there for extremely ephemeral use, such as drinking water or temporarily feeding on organisms present there.

Wet Meadow Status

Grasslands losses on and near the Central Platte River Valley had been reported as high through the 1980's. Krapu (1981), reports 70% loss of native meadow, while Currier (1985) reports a 73% loss of native grasslands and wet meadows within 3.5 of the Platte River. It is not clear what proportion of those losses are specifically referring to wet meadows as both authors referred to meadows and wet meadows in combination with grasslands. Sidle et al. (1989) did specifically quantify the loss of wet meadow as ranging from 23-45% between 1938 and 1982 based on aerial photography. Most wet meadows had been converted to sand and gravel pits, housing, and roads such as the Interstate-80 highway. Conversion to cropland is not believed to be common as usually they would require construction of drainage ditches and land-leveling. Most conversion occurred between 1965 and 1976 when grain prices and farm income were high relative to land and conversion costs. Wetland meadow destruction along the North Platte River since 1938 has been slower (23-33 %), probably because much of the agriculture land in this segment was converted and under gravity irrigation prior to 1938 (Sidle et al 1989).

Hydrological Processes

It is well established that the hydrological regimes and groundwater levels of wet meadows or sloughs are influenced primarily by river stage (Frith 1974, Hurr 1983, Nelson et al. 1988, Henszey and Wesche 1993, Currier and Goldowitz 1995, Whiles and Goldowitz 1998, Wu 2003). After river stage, precipitation and evaporation will influence water level and soil moisture conditions (Henszey and Wesche, 1993, Currier and Goldowitz 1995). Management actions that influence water levels or flow on the river can have rapid and direct effects on ground water levels in wet meadows (Hurr 1983). The response of ground water levels within wet meadows to changes in river stage is rapid; within 24 hours for areas along the river's edge and up to 2,500 feet from the river (Hurr 1983). Precipitation can have a significant influence on water levels but is generally for short periods of time such as when heavy rainfall events occur (Currier and Goldowitz 1995). Coarse sands and gravels and the highly permeable soil allows infiltrated precipitation to quickly pass through to the water table (Henszey et al. 2004). However, Henszey and Wesche (1993) noted temporary elevation in ground water levels from isolated precipitation events, levels that gradually declined over a two week period.

From February through June, river stage is the dominant influence on groundwater regimes in wet meadows followed by precipitation, and evapotranspiration (Hensey and Wesche 1993). Zuerlin et al (2001) summarize the results of a study of wet meadow hidrology as follows; 1) between February and April, mean monthly groundwater levels are at or above the surface 25% to 75% of the time, 2) mean monthly groundwater levels reach their highest level in May and June, 3) mean monthly groundwater depths between February and June are within 0.5 feet of the surface 55% to 80% of the time in wet plant communities but, are never within 0.5 feet of the surface in transitional or dry plant communities, and 4) groundwater levels are relatively constant in February through April and are at or above the surface more often than in May and June. There is a suggestion that between 1 February and 22 March flows of 30 m3/s are adequate to initiate a response in wet meadow vegetation and invertebrate populations (Nelson et al. 1988).

Wet meadow integrity is believed to be directly related to river hydrology, and is therefore threatened, by reduced flows in the Platte River and it is suggested that healthy wet meadows can only be restored by restoring a natural hydrograph (Savidge and Seibert 1992, Davis et al. 2006, Meyer et al. 2008, and others). The changes leading to reduced flows in the

Platte River have had a profound impact on wet meadows by lowering ground-water levels and altering seasonal hydroperiods (Hurr 1983, Currier and Ziewitz 1986, Wesche et al. 1994). Hydroperiods differ among different wet meadows as deeper sloughs tend to have longer hydroperiods (Table 1) and hydroperiods are variable among years even within the same wet meadow.

Vegetation

The plant species composition of wet meadows is extensive and the vegetation communities are complex (Table 2). More than 60 plant species have been identified in wet meadows and different combinations of those species have been grouped to develop unique plant associations (Table 3). The plant species and vegetation communities in and adjacent to wet meadows show a wide range of adaptations from emergent to xeric adapted species (Currier 1985, Henszey et al 2004) as a result of an elevation gradient leading to a moisture gradient present in most wet meadows. Hydrology is the driving ecological factor determining the plant community composition of wet meadows (Currier 1985, Simpson 2001, Henszey et al 2004 and others). Specific plant species presence and distributions are dependent on moisture presence and levels. For example, Currier found that water sedge, smartweed, and cut-grass were good indicators of the wettest conditions, followed by Canada goldenrod, smooth brome, big bluestem, ironweed, and sweet clover were indicators of intermediate moisture sites. Grama grasses and purple poppy mallow were characteristic of xeric sites (Currier 1995). High water-levels are more influential than the mean, median, or low water levels (Henszey etal 2004), as apparently plants respond to periods of physiological stress caused by water saturated soils or flooded conditions (Cronk and Fennessy 2001). Water levels within a wet meadow will vary depending on the location on the slope of the wet meadow.

Wet meadow descriptions in the CPRV generally define a moisture gradient directly associated with the topographical gradient (distance from water table) of wetlands. The moisture level in turn will influence the vegetation association present in each zone. A cross section of a wet meadow or slough would be something similar to a “v” shape with the base of the v being the deepest and closest to ground water. Currier (1995a) described three moisture gradients (wet, mesic, and xeric), while Henszey et al. (2004) describe four (emergent, sedge meadow, mesic prairie, and dry ridge), both defined based on plant species associations (Table 3). Therefore, the lowest or deepest section of the slough (bottom of the "v") is the wettest and may be flooded when water levels are high. The deepest sloughs or wetlands could be permanent and have water most of the year, therefore, supporting emergent vegetation communities characterized by bluejoint (*Calamagrostis inexpansa*), cut grass (*Leersia virginica*), and smartweeds (*Polygonum spp*.) (Currier 1995) and *Sparganium eurycarpum*, *Schoenoplectus fluviatilis*, *Typha spp*. and *Schoenoplectus tabernaemontani* (Heszey et al 2004). The emergent community is characteristic of wetlands which Henszey describes as having water levels up to 20 cm above ground level. The sedge meadow community is next in decreasing moisture gradient (and upward in topography and elevation gradient, with water levels 20 cm above to 30 cm below the surface) and is characterized by *Carex emorya*, *Carex pellita*, and *Symphyotrichum lanceolatum* (Henszey et al. 2004). Mesic prairie covers a wide range of moisture conditions (with water levels from 30 cm to 135 cm below the surface) and is characterized by *Andropogon gerardii*, *Schizachyrium scoparium*, and *Sorghastrum mutans*, *Mecicago lupulina*, *Agrostis stolonifera*, and *Carex crawei*. The dry ridge (with a moisture gradient >135 cm below the surface) is dominated by upland species not affected by moisture levels such *as Carex duriuscula*, *Ambrosia psilostachya*, *Callirhoe involucrate*, *Poa pratensis*, *Dichanthelium oligosanthes*, and *Calamovilfa longifolia*.

The effect of precipitation on plant species cover and composition is believed to be negligible depending on the time of year and the rate of percolation and runoff (Currier 1989). During the non-growing season moisture levels may have little influence on plant cover values (Currier 1989). As described previously, the water levels and moisture gradients of wet meadows is influenced primarily by river stage, but isolated precipitation events may increase water levels that gradually decrease over a period of up to two weeks (heszey and Wesche 1993).

Soil and Abiotic Characteristics

Soils of the CPRV are primarily pleistocene sands and gravels (Schreurs and Rainwater 1956), medium to highly permeableand 13 – 43 cm deep (Henszey et al. 2004). Soil characteristics of wet meadows have been described by several authors and are summarized in Table 1. Soil characteristics and parameters follow a similar pattern to the moisture and vegetation gradients described previously with variables either increasing or decreasing as distance to water levels increases. The lower elevations (sloughs) have higher levels of N, organic matter, and clay and lowest sand content while silt did not differ between lower elevation and higher elevations (Simpson 2001, Davis et al 2006). Levels of pH, P, N, organic matter are variable between low, mid, and high elevations and can change in different years (Table 1, Whiles and Goldowitz 2005, Davis et al. 2006).

Wildlife Use

Whooping Crane

Whooping crane use of wet meadows per se is not well quantified in published works to date for the CPRV. Available information for whooping crane use of grasslands and meadows is summarized in Table 4. While there have been some observations of whooping cranes within grassland and prairie habitats, use descriptions do not allow us to confirm if the whooping cranes were in a wet meadow or simply in a broader category habitat type, such as grassland or wetland (ponds for example). Whooping cranes are known to use wetlands for roosting, resting, and feeding during migration (Howe 1987, 1989, Lingle 1987, Armbruster 1990).

Lingle describes diurnal habitat use from 51 whooping cranes sightings. Of a total of 2280 bird-hours of use, 1527 bird-hours (67%) were in known habitat types. Corn stubble received the greatest use (37%) followed by tilled wetlands (18%) and natural wetlands (17%). The majority whooping crane roosts (68%) were recorded in tilled wetlands and natural wetlands. It is not clear if tilled wetlands or natural wetlands could have a subset of observations within wet meadow proper. What is clear from these data is that cranes use wetlands to a considerable extent while in the CPRV and are therefore may use wet meadows if conditions are appropriate. Migrating whooping cranes could use wet meadows for feeding, resting, and roosting if conditions where appropriate. The presence of aquatic and ground organisms could provide a readily available food supply. Surface water could provide drinking water and potential loafing or roosting sites.

Based on physical and structural components of wet meadows, there are some features that would make them less attractive to whooping cranes. For example, deep sloughs with steep slopes and tall prairie and/or wetland vegetation would make it less attractive to whooping cranes. However, managed grasslands that have reduced the vegetative structure via grazing or burning would likely increase the attractiveness of wet meadows to whooping cranes (Johnson

1981). Whooping cranes are well known for responding to burned sites (Lingle 1981, Chavez-Ramirez et al 1996). For roosting, whooping cranes prefer to use wetland sites that are small (<1-4 ha) with open view, shallow water, no emergent vegetation, low vegetative structure, and good horizontal visibility (Johnson and Temple 1980, Ward and Anderson 1987, Armbruster 1990, Howe 1989).

Sandhill Cranes

The use of wet meadows by sandhill cranes is well known and has been documented extensively over several decades (Table 4). Wet meadow use by sandhill cranes is related to loafing (Sparling and Krapu 1994, VerCauteren 1998), drinking water (Tacha et al 1987), feeding on invertebrates (Frith 1974, Krapu 1981, Reinecke and Krapu 1986), and for social interactions (Tacha 1981,).

During the late 1960's and early 1970 aerial surveys showed that 45.5 percent of cranes observed were in wet meadows (Lewis 1974). During the 1990's, Davis (1999) reports that 29% of overall daytime observations were in wet meadow-lowland grassland, with numbers ranging between 17-42% during different weeks of the staging period. There has been a suggestion that roosting cranes select overnight roosts with sufficient wet meadow habitats adjacent to the river (Faanes and LeValley 1993). Crane use of wet meadows has been associated with depth to water table, as VerCauteren (1998) documented that as depth to water table increased, crane use decreased in specific wet meadows. This may reflect the fact that whooping cranes are seeking water to drink and invertebrates for feeding. Greater numbers of soil invertebrates are reported in areas with water tables between 40-80 cm (Davis and Vohs *1993b*, and Nagel and Harding 1987). These water tables provide adequate moisture levels for organisms including earthworms *(Lumbricidae)* and beetle larvae *(Coleoptera)*, which constitute a major proportion of invertebrates consumed by cranes (Reinecke and Krapu 1986, Nagel and Harding 1987, Davis and Vohs 1992*).*

Sandhill cranes spend 36% of their time feeding in wet meadows (Krapu 1981), foraging primarily on invertebrates. As much as 79-99% of food items taking in native grasslands have been invertebrates (Reinecke and Krapu 1986). In a different study, scarab beetle larvae occurred in 58% of the esophagi from collected cranes, and snail shells and vegetation occurred in 50% of the crane esophagi (Davis and Vohs 1992). Other food items consumed from wet meadows have included earthworms, crane fly larvae, ground beetles, crickets and grasshoppers (Reinecke and Krapu 1986, Davis and Vohs 1992). In the Central Platte River Valley cranes fed 36% of the time on native meadows (Krapu 1981). In native grasslands, invertebrates (earthworms, snails, grasshoppers) constitute most of their diet. Cranes consumed earthworms, snails, crickets, grasshoppers, sowbugs, spiders, and adult and larval beetles. Although Invertebrate foods account for a relatively small proportion of the diet, sandhilI cranes spend 42% of their diurnal time budget in the habitat types from which they derive these food Items (27% In grasslands and 15% In alfalfa) (Krapu 1981).

Other Birds

Wet meadows serve as habitat for breeding grassland and wetland birds during the summer months and provide habitat for many other species during the non-breeding period. At least 30 avian species are known to breed in wet meadows or associated grasslands (Table 5) with more than 40 additional species have been identified using wet meadows during the non-breeding season (Table 6). Krapu (1981) originally reported 35 bird species were associated with wet meadows in the CPRV with 27 of those considered as nesting birds. Wet meadows support high densities of nesting birds as Faanes and Lingle (1995) found 20 avian species in wet meadows and report an overall breeding bird density of 110 pairs/km2 (Faanes and Lingle 1995). Helzer (1998) found 13 species of wet meadow breeding birds during two field seasons in 1995 and 1996, while Renfrew et al (2006) recorded 22 bird species in meadows of the CPRV. Twenty one species have been found consistently over a 15 year span in wet meadows which reflect higher average species richness (18.5) than adjacent mesic grasslands (12.5), believed mostly due to the presence of wetland dependent species (Kim et al 2008). When comparing the density of six of seven focal species, there was a significant relationship between avian density and available moisture. Their results suggest that wet conditions decrease densities of ground-nesting grassland birds in wet-meadow habitats, whereas dry conditions increase the density of the avian assemblage. Wet meadows may be particularly important for nesting birds during dry periods as they are believed to serve as local refuge for grassland-nesting birds during local or regional droughts (Kim et al. 2008).

Herptiles

Eighteen herptiles have been recorded in or near wet meadows; 10 anurans, two lizards and six snakes (Table 6), Ballinger 1980, Jones et al. 1981, Whiles and Goldowitz 1998, Franke 2006). Amphibians in particular are associated with wetlands, including wet meadows throughout the CPRV. Some species are known to be very abundant while for others there are very few observations (Table 7). The paucity of data on herptiles may be more related to limited sampling rather than to actual rarity of some species.

Invertebrates

The invertebrate assemblage of wet meadows is rich and varied with at least 75 confirmed taxa consisting of 62 insect and 13 non-insect families (Table 7). This is the most studied animal assemblage within wet meadows in the CPRV and may be why there are so many taxa recorded to date. Dominant taxa varies by location, year, and hydrological conditions (Whiles and Goldowitz 2005, Davis et al 2006, Meyer and Whiles 2008). Earthworms (Oligochaeta), beetles (Coleoptera), and Diptera larvae appear consistently as dominant taxa in abundance and biomass in invertebrate studies of wet meadows (Table 8, Nagle and Hardin 1987, Runge 1998, Davis 1991, Davis and Vohs 1992, Davis et al. 2006). Earthworms and scarab beetles (Scarabaeidae) constituted 93% of the total biomass in one study with the greatest numbers and biomass of each occurring in wet meadow habitats (Davis 1991). In a different study total biomass was primarily composed of earthworms, Scarabaeidae, Isopoda, and Elateridae, with earthworms and Scarabaeidae accounting for >82% (Davis 2006).

When compared to other vegetation associations or habitat types, wet meadows support greater richness, numbers and biomass of invertebrates than other systems (Davis 1991, Krahulik 2002). Krahulik (2002) compared ground beetles in different habitat types at three study locations beginning in native wet meadows and ending in the cottonwood forest. Wet meadow invertebrate assemblages were the most diverse with 18 species and ecotone habitats were the least diverse with only 11 species. Also wet meadow habitats had the highest number of unique species with 10 and ecotone habitats had the lowest number of unique species with only six.

As with vegetation, several studies highlight the importance of hydrology in shaping macroinvertebrate assemblage richness and productivity (Nagel and Harding 1987, Whiles and Goldowitz 2001, 2005, Davis et al 2006). The relationship between taxonomic richness of aquatic insects and wetland hydrology follows the intermediate disturbance hypothesis; insect richness and productivity is maximized in intermittent sites without fish according to Whiles and Goldowitz (2001). Greater numbers of soil invertebrates are reported in areas with water tables ranging between 40-80 cm deep (Davis 1991, Davis and Vohs *1993*, Nagel and Harding 1987, Davis et al. 2006). These water tables provide adequate moisture levels for organisms including earthworms *(Lumbricidae)* and beetle larvae *(Coleoptera).* In a study by Davis (1991) the greatest earthworm numbers and biomass in the upper 20 cm of the soil strata occurred at sites with water table depths of 55 cm, while the greatest scarab beetle numbers and biomass occurred at sites with water table depths >70 cm. Moisture conditions at sites with water table depths >40 cm appeared more favorable for earthworm and scarab beetle populations than sites with water table depths <40 cm (Davis 1991). In a different study during 1989, nearly all earthworms were found at sites with a water table depth >60 cm, whereas in 1990 earthworms were found at sites with water table depths ≤ 10 cm of the surface; however, the greatest numbers were found on sites where water table depths varied between 50 and 60 cm (Davis and Vohs 1992).

A typical description of wet meadow soil invertebrate communities is summarized by Davis et al. 2006 as follows: We identified 73 invertebrate taxa; 39 were considered soil inhabitants. Differences in river flow and precipitation patterns influenced some soil invertebrates. Earthworms and Scarabaeidae declined dramatically from 1999 (wet year) to 2000 (dry year). The topographic gradient created by the ridge-swale complex affected several soil invertebrate taxa; Scarabaeidae, Diplopoda, and Lepidoptera biomasses were greatest on drier ridges, while Tipulidae and Isopoda biomasses were greatest in wetter sloughs. Responses of earthworm taxa to the topographic gradient were variable, but generally, greater biomasses occurred on ridges and mid-elevations. Water-table depth and soil moisture were the most important variables influencing wet meadow soil invertebrates.

Highest numbers and biomass of macroinvertebrates are present in conditions of intermediate moisture (Whiles and Goldowitz, Davis et al 2006) which are most common in the unique topographical and hydrological conditions of wet meadows (Table 9). The intermediate water level scenario is for both moisture within a site, that is within a wet meadow the region with the intermediate moisture regime at that point in time will support the highest macroinvertebrate richness and biomass (Davis and Vohs *1993,* Nagel and Harding 1987, Davis et al. 2006). At a different scale, within a landscape those wet meadows that experienced intermediate levels of hydroperiods (defined as 296 days wet conditions, Whiles and Goldowitz 2001) are reported to support greater macroinvertebrate richness and productivity than wet meadows with longer or shorter hydroperiods (Whiles and Goldowitz 2001).

A unique element of the wet meadow invertebrate assemblage is the endemic Platter River Caddisfly (*Ironoquia plattensis*) which is known from a handful of intermittent wetlands in the region (Alexander and Whiles 2000, Whiles et al 1999, Whiles and Golodwitz 2005). However, recent information appears to show a broader range and distribution throughout the CPRV. The life history of the Platte River caddissfly is closely tied to the intermittent nature of wet meadows in the CPRV (Whiles and Goldowitz 1998, whiles et al 1999). In those wet meadows where it has been studied very large numbers and productivity have been recorded, suggesting that it may provide an important food source for terrestrial and aquatic secondary consumers (Whiles et al 1999). Concerns have been expressed in regards to the Platte River Caddisfly as it is highly adapted to the previously existing hydrological regime and the fact that wet meadow acreages have decreased significantly.

The regal fritillary butterfly (*Speyeria idalia* Drury), a species of concern, was once an abundant and conspicuous component of the tall-grass prairie. Populations have declined greatly due to agricultural development of the prairie. High density remnant populations are rare but existed in wet meadows along the Platte River Valley through the 1990's (Nagel et al. 1991).

Management Effects

Since wet meadows are generally within a complex of grassland or prairie, they are used extensively as grazing lands or hay fields throughout the CPRV. Therefore, most management activities that occur in wet meadows can be described in relation to the occurrence or not of an activity such as grazing by livestock, prescribed burning, and resting (no management activity during a year or more). Even though water levels in wet meadows are impacted by river stage, this section will not include water management activities related to flows in the river but only to those activities that occur directly on or in the immediate surroundings of a wet meadow. The effect of water level on vegetation and other organisms is summarized in different sections above.

There may be some positive effects of grazing on invertebrate communities. Krahulik (2002) found that grazed sites generally had a higher invertebrate diversity and evenness than ungrazed sites. He found that certain guilds did decrease in abundance and evenness in grazed sites when compared to rested sites.

Prescribed fires are used extensively along the CPRV for management of grasslands and therefore wet meadows in this area get burned periodically. Davis et a. (2006) believes that large abundance of Scaraeidae may be related to increased below ground production as a result of periodic burning (approximately every 4 years).

In relation to the effect of grazing activities on birds Kim et al. (2008) found that for all bird species combined densities were similar between grazed and ungrazed pastures with 28.5 and 32.1 males/10 ha, respectively. Individually however, some species had significantly higher densities in ungrazed plots than in grazed plots (11.5 vs 5.3 males/10 ha for bobolink). Other species (dickcissel, Western meadowlark, and red-winged blackbirds, grasshopper sparrow) did not show any significant effects of grazing.

Restoration of Wet Meadows

Restoration activities have occurred in the CPRV for several decades. Several studies originally describe the techniques used for restorations (Currier 1995, Pfeiffer 1999, Whitney 1999). Later works have attempted to evaluate the success of wet meadow restorations by comparing restoration sites to native wet meadows. Most restoration activities are related to plant reestablishment via plant seeding and land modifications. The measures for comparison and evaluation of restoration success have been vegetation (Currier 1995b, Pfeiffer 1999, Meyer et al. 2008a), soil characteristics (Meyer et al. 2008b), invertebrates (Riggins 2004, Meyer and Whiles 2008), and birds (Renfrew et al 2006, Ramirez et al. In press).

Vegetation

Currier (1995b) reported that a 10 year wetland restoration had 78% of wetland species and 73% forb species missing relative to natural areas. He believed that the groundwater hydrology required to sustain them was missing. In addition inadequate seed sources and limited capacity of many species to self seed could explain their absence. In a study of wet meadow restoration with restoration ranging from 1-7 years old Meyer et al (2008b) found plant species richness and diversity in sloughs showed no change with time suggesting a quick recovery. Percent similarity of plant communities in restoration and natural wetlands increased linearly over time. However, sedges of the Genus *Carex*, one of the most diagnostic species of natural wet meadows in the Platte River Valley (Currier 1998, Henszey et al 2004), were not present in restorations. These are apparently the slowest recovering plant in restorations, assuming that it is a matter of time before they are present in the restored areas. Many wetland species appeared to be missing from the restoration sites evaluated by Currier (1995) and Pfeiffer (1999) found that percent cover of sedges and rushes were in extreme low quantities compared to native areas.

Plant cover shows different degrees of change or recovery in different studies. In wetland margins, mean total percent cover was 44% higher in natural wetlands (107 ± 6) (mean ± SE) than in restored sites (63 ± 7) (p ¼ 0.0006). In sloughs, total percent cover was highly variable in natural sites and average total cover was 45% higher (100 ± 14) than in restored sites (Meyer et al 2008). Currier (1995) found that 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 native sites. Forb cover values were similar in restoration and native sites, although there were far fewer forb species in the restorations, except at a site where a number of these species were intentionally introduced.

Meyer et al. (2008) suggest that differences in management activities in different sites may have driven changes in plant community structure and overriding measurable recovery following restorations. Renfrew et al. (2006) suggest that periodic burning and grazing may help restore planted meadows in the CPRV while maintaining species diversity.

Invertebrates

Management of native grasslands should be focused on maintaining abundant and available populations of earthworms and scarab beetles in the upper soil strata in spring. This can be accomplished by maintaining moderate water table depths (40-80 cm) in the lowland grassland habitat (Davis 1991).

Soil

Soil variables have also been evaluated in different age restorations. Meyer et al. (2008b) suggests that soil organic matter (SOM) may be an easily measured indicator of restored systems after measuring several soil parameters (Table 1). He found that soil texture did not change with different age restorations and total above ground biomass increased with age of restoration and compared to natural systems within 10 years. Root biomass and C and N storage in roots increased linearly with years restored in margins and sloughs. Natural sites had higher mean CEC (cation exchange capacity) than restored sites. Mean pH was significantly higher in restored margins and slough than natural margins and sloughs. Bulk density decreased in upper soil surface of slough due to recovery of roots and increases in SOM. Soil organic matter generally increases following restorations. The lack of SOM in younger sites in our study may be related to lack of hydrologic recovery. Drier sites have been shown to accumulate less organic matter than wetter sites.

Birds

Bird species and assemblages have been used to evaluate the success of restoration of wet meadows and grasslands throughout the CPRV (Renfrew et al. 2006, Ramirez et al. in press). In general natural meadows supported higher densities of upland species, where restored meadows supported generalists species associated with moisture conditions and shrubby vegetation (Renfrew et al. 2006). Overall avian species richness was lower in natural (22) vs restored meadows (29) (Renfrew et al 2006). Breeding territory density of Bobolink and grasshopper sparrow where significantly greater in native vs restored sites (Ramirez et al. in press).

Overall restoration of wet meadows is believed by many authors to be more influenced by hydroperiod than any other factor (Davis et al. 2006, Meyer et al. 2008). Flow management should focus on regaining the former hydrograph through properly timed flows. Restoring and maintaining the natural hydrological regime should be a central focus of restoration and management of these wetlands (Davis et al 2006, Meyer et al. 2008a). Hydroperiod may be more important than restoration status in shaping the wetland macroinvertebrate communities

(Meyer et al. 2008). While some directional changes have been observed in plant species compositions in different age restorations it seems that hydroperiod may be more important than age since restoration. Some indicator species of natural wet meadows have been noted to be absent in restorations up to 10 years old. It is unlikely that restorations will be successful without recreating or replicating the wet meadow hydrological conditions. Hydrological conditions appear to be important not only for plants and invertebrates but may also be significant in creating soil conditions more similar to natural wet meadows.

Table 1. Effects of site elevation, hydroperiod and WM restoration on soil characteristics of wet meadows along the Platte River in south-central Nebraska, 1999 –2000 (sources: Whiles and Goldowitz 2005, Davis et al 2006, Meyer et al 2008)

	Hydroperiod[1]			Topography[2]				WM Restoration[3]			
	97-1998			99-2000				2003 - 2004			
Physical Characteristics	158 d	296d	331d	365d	High	Mid	Low	Natural	Restored	Natural	Restored
Site age in 2003 (y)											
Maximum depth (cm)	21	54	68	43				41.53	45.48	45.63	26.75
Maximum wetted area (m2)	262	300	386	43				202.2	188.9	205	153.93
Average area (m2)								158.03	154.95	144.27	137.96
Maximum volume (m3)	19	149	151	17				49.13	54.78	62.73	29.55
Annual hydroperiod (days)	158	296	331	365				4,4,12 mo	2,3,4,12mo	3,3,12mo	1,4,12mo
Organic matter					3.4	4.48	5.33				
% gravel	0	0	0	8	8.7*	14.8*	17.6*	1.67	2.75		
% sand	33	24	24	53	68.3	56.6	56.2	28.33	46.5		
% silt	67	76	76	39	23	28.5	26.2	79	50.75		
pH					7.22	7.77	7.55	7.13	7.35		
DO (mg/L)								9.37	6.93		
Conductivity (lS/cm)								1222	985		
Potassium (ppm)					226	193	150	24.92a	15.15a		
Phosphorus (%)					6.69	6	7.135	4.01a	1.07a		
Nitrogen (%)					0.18	0.27	0.35				
Organic matter (%)					3.4	4.48	5.33				

(*) % clay, (a) Dates of Potassium and Phosphorus in g/m2

Table 2: List of plant species observed in a Wet Meadow Habitat in the Central Platte River (sources: Nagel and Kolstad 1987, Currier 1989, Henszey et al. 2004)

Scientific name	Common name
Agrostis stolonifera	Redtop
Ambrosia artemisiifolia	Common ragweed
Ambrosia psilostachya	Western ragweed
Andropogon gerardii	Big bluestem
Apocynum cannabinum	Hemp dogbane
Asclepias speciosa	Showy milkweed
Bromus inermis	Smooth brome
Calamagrostis stricta	Northern reedgrass
Calamovilfa longifolia	Prairie sandreed
Callirhoe alcaeoide	Pink poppy mallow
Callirhoe involucrata	Purple poppy mallow
Carex crawei	Crawe's sedge
Carex duriuscula	Needleleaf sedge
Carex emoryi	Emory's sedge
Carex pellita	Woolly sedge
Carex praegracilis	Clustered-field sedge
Carex tetanica	Rigid sedge
Cirsium flodmanii	Prairie thistle
Dalea purpurea Vent.	Purple prairie clover
Desmanthus illinoensis	Bundleflower
Dichanthelium oligosanthes	Small panicgrass
Dichanthelium wilcoxianum	Wilcox' panicgrass
Eleocharis elliptica	Slender spikerush
Eleocharis palustris	Marsh spike-rush
Elymus trachycaulus	sSender wheatgrass
Equisetum arvense	Field horsetail
Equisetum laevigatum	Smooth horsetail
Erigeron strigosus	Daisy fleabane
Glycyrrhiza lepidota	Wild licorice
Helianthus maximiliani	Maximillian sunflower
Hordeum jubatum	Foxtail barley
Hypoxis hirsuta	Yellow stargrass
Leersia oryzoides	Rice cutgrass
Lithospermum incisum	Narrow-leaved puccoon
Lycopus americanus	American bugleweed
Lycopus asper	Rough bugle weed
Lysimachia thyrsiflora	Tufted loosestrife

Maianthemum stellatum	False Solomon's seal
Medicago lupulina	Black medick
Muhlenbergia asperifolia	Scratchgrass
Oxalis stricta	Common Yellow Woodsorrel
Panicum virgatum	Switchgrass
Phyla lanceolata	Lanceleaf fogfruit
Poa pratensis	Kentucky bluegrass
Polygonum amphibium	Swamp smarrweed
Prunella vulgaris	Selfheal
Ratibida columnifera	Prairie coneflower
Rosa woodsii	Western wild rose
Rudbeckia hirta	Black-eyed susan
Schizachyrium scoparium	Little bluestem
Schoenoplectus pungens	Sharp Club-rush
Solidago canadensis	Canada goldenrod
Solidago gigantea	Late goldenrod
Sorghastrum nutans	Indian-grass
Spartina pectinata	Prairie cordgrass
Sporobolus compositus	Meadow Dropseed
Symphyotrichum ericoides	White Heath Aster
Symphyotrichum lanceolatum	Panicled White Aster
Taraxacum officinale	Dandelion
Trifolium pratense	Red clover
Verbena stricta	Hoary vervain
Vernonia fasciculata	Ironweed
Viola nephrophylla	Northern bog violet

Table 3: Change in the wet meadow vegetation assemblage as a function of the groundwater level (Sources: Currier 1989, Henszey et al 2004).

	Ground water level (cm)			
	50 to 20	20 to -30	-30 to -135	-135 to -200
Wet Meadow Vegetation	Emergents	Sedge Meadow	Mesic Prairie	Dry Ridge
Agrostis stolonifera		x	x	
Ambrosia artemisiifolia		x		
Ambrosia psilostachya			x	x
Andropogon gerardii		x	x	x
Apocynum cannabinum		x	x	
Asclepias speciosa		x	x	
Bromus inermis		x	x	x
Calamagrostis stricta		x		
Calamovilfa longifolia			x	x
Callirhoe alcaeoide			x	
Callirhoe involucrata			x	x
Carex crawei		x	x	
Carex duriuscula			x	x
Carex emoryi	x	x		
Carex pellita	x	x		
Carex praegracilis		x		
Carex tetanica		x		
Cirsium flodmanii		x		
Dalea purpurea Vent.		x	x	
Desmanthus illinoensis		x	x	
Dichanthelium oligosanthes		x	x	x
Dichanthelium wilcoxianum		x	x	
Eleocharis elliptica	x	x	x	
Eleocharis palustris	x	x		
Elymus trachycaulus		x	x	
Equisetum arvense		x	x	
Equisetum laevigatum		x	x	x
Erigeron strigosus		x	x	
Glycyrrhiza lepidota		x	x	
Helianthus maximiliani		x		
Hordeum jubatum		x		
Hypoxis hirsuta		x	x	
Leersia oryzoides	x			
Lithospermum incisum			x	x

Lycopus americanus	x	x		
Lycopus asper		x		
Lysimachia thyrsiflora		x		
Maianthemum stellatum		x		
Medicago lupulina		x	x	x
Muhlenbergia asperifolia	x	x	x	x
Oxalis stricta			x	
Panicum virgatum		x	x	
Phyla lanceolata		x		
Poa pratensis		x	x	x
Polygonum amphibium	x	x		
Prunella vulgaris		x	x	
Ratibida columnifera			x	
Rosa woodsii			x	
Rudbeckia hirta		x	x	
Schizachyrium scoparium		x	x	x
Schoenoplectus pungens	x	x		
Solidago canadensis		x	x	
Solidago gigantea		x		
Sorghastrum nutans		x	x	x
Spartina pectinata		x		
Sporobolus compositus			x	x
Symphyotrichum ericoides		x	x	
Symphyotrichum lanceolatum		x	x	
Taraxacum		x	x	
Trifolium pratense		x	x	
Verbena stricta			x	x
Vernonia fasciculata		x		
Viola nephrophylla		x	x	

Table 4: Wet Meadow habitat use by endangered, threatened, and other species on concern

Endangered & Threatened species	year	mean	Abundance	t use	Alert	Courtship	Feeding	Preening	Resting	Period	Location	Ref.
Whooping Crane	1926		5				5			sp	near house	1
	1977		2				2			fa	SM	1
	1978		1				1			fa	SM	1
	1983		8 ($)							fa		2
	1986		3							apr	0.5m W, 0.5m S Maxwell	5
	1987		2							apr	MI	5
	1987		51	35% , 1208 bhu			33%* (40% spr 62%)Fa **			sp,fa		3
	1996		1							apr	2m N, 3m W Doniphan	5
	1997		3							fa	RS	5
	1999		7								FKL area	6
	2008		120(^)	57% (30h)	7^(6%)	1(1%)	76^(63%)	22^(18%)	12^(10%)	sp		4
	2010		2				2				FKL area	7
Regal Fritillary	1990		1400				5.2% nec 67% mw			Su	RS	18
Smooth Green Snake	84, 94		< 5								WM, Seg7	21,22

Others sp of concern												
Sandhill Cranes	69-71		45,308				45% Δ			sp	WM in MI	8
	71						1000's			sp	Sh,MI,Ki,Ffi	9
	78-80		500000	36%			27% ¤			sp		1,10
												11
	78,79		20	28%			36%*			Feb-Apr	Native grass	12
	79-80		67500				7.1%*			sp		13
	1981	13731	31,420	45311 0 CUD			50% *§			sp	WM in MI	14,20
	1990	7500	15000							sp	MICM	14
	79-89		560/km							sp	PR++	15
	96-97		9800/65ha (x)									16
	96-97		1700/65ha (ρ)									16
	98	5900	93669 (42%)	19%						sp		17
	99			35%			35% *			Mar-Apr		6

Ref.= references. 1. Krapu 1981, 2. Lingle 1984, 3. Lingle 1987, 4. Lingle 2008, 5. URS Breiner Woodward Clyde Federal Services 1999, 6. Crane Trust unpublished data, 7. Gil 2010 comm pers, 8. . Lewis 1974, 9. Frith 1974, 10. Reinecke & Krapu 1979, 11. Sparling & Krapu 1994, 12. Krapu 1984, 13 Iverson et al 1987

sp=spring, su=summer, fa=fall, wi=winter, yr= year. t use= time use. * = % of time, Δ = % of individuals. **= time feeding in spring vs fall. bhu= # bird hours use. CUD= crane use days. N= abundance . al = alert, b=breeding, Cs= courtship, P=preening, R=resting, uk= unknown.

¤ = 3% of the diet are invertebrates that collected in wet meadows (cranes fed earthworms, snails (25%), spiders, grasshoppers, crickets, beetles (click, ground, roves, and scarab), and cutworms). § cranes possible ate invertebrates. nec= nectaring, mw=Milkweeds

cpr=Central Platte River, ctp= Central Table Playas, Ffi= Fort Farm Islands area, FKL= Funk Lagoon, Ki=Killgore area, MI= Mormon Island,MICM= Mormon Island-Crane Meadows, Sh= Shoemaker area, wrb= western rainwater basin. SM= Subirrigated meadow. WM=Wet meadow. RS= Rowe Sanctuary. seg7= segment 7 - Buffalo County

^ = counts of instant points, activity in emergents habitat. ($)WM in cleared area of woody vegetation over the past 20 yrs. (x) = in grazed fields. (ρ)= in hayed fields. PR++ in pristine reaches of Platte River associated with adjacent wet meadows complex. Prroost= Platte River roosting

Table 5: Avian species observed on Wet Meadows habitat. At least 30 avian species are known to breed in wet meadows or associated grasslands with more than 40 additional species present during the non-breeding season.

Birds	year observed	N	mean territory	Density in wet prairies (Pairs/Km2)	% patches WM occupied	Period	observations	Reference
breeding in WM						(mar-apr)		
Wood duck	80,81-96	5	0.5			su	MI,WM	1,3
Mallard	81-96	20000 2	16			su	MI,WM	1,3,4
Northern Pintail	78-88, 80,81,84	20000 1		16		sp,fa,wi		1,5
Blue-winged Teal	78-88, 80,81,84	105 1	19.3	39.5		sp,su,fa	MI,WM	1,3,10
Ring-Necked Pheasant	79,80, 81-96	16,500 8	1		3% 6%	sp,su,fa,wi	MI,WM	1,3,6,7,8
Northern Bobwhite	81-96		1.5			su	MI,WM	1,3
Sora	80, 95,96	7 1		10.5	4%	su	MI,WM	1,5,7,8
Least Bittern	81-96		1.5			su	MI,WM	3
Virginia Rail	81-96		1			su	MI,WM	3,10
Killdeer	80,81-96	98	24.5			sp,su,fa	MI,WM	1,3,4,9,10
Upland Sandpiper	79,80 81-96	31500 115	135.25	9.1	22% 22%	su	MI,WM	2,3,4,5,6,7,8,10
Long-billed Curlew	79,80			1		sp,su,fa		5
Wilson’s Snipe	80,81-96	6	2.5			sp,fa	MI,WM	1,3
Wilson's Phalarope	79-80, 83 81- 96	22 1	30	10.1		sp,su	MI,WM	1,2,3,9

Short-eared Owl	1979	1					MI,WM	5
Mourning Dove	80, 81-96	65	22.25			su	MI,WM	1,2,3
Common Flicker	80,81	196 8				sp,su		1
Sedge Wren	1984 81-96	100	15	5% 5%		su	MI,WM	2,3,5,7,8,10
Yellow Warbler	79-80			0.7			MI,WM	5
Common Yellowthroat	81-96		1.5			su	MI,WM	3
Grasshopper Sparrow	80,81-96	2	165	14.7	54% 53%	su	MI,WM	1,2,3,4,7,8,9,10
Savanna Sparrow	79-80					sp,su		
Swamp Sparrow	81-96		2		2%	su	MI,WM	3
Dickcissel	79-80, 81-96	27	193.3	19.2	49% 60%	su	MI,WM	1,2,3,4,7,8,9,10
Lark Bunting	79-80			1				5
Bobolink	79,80, 81-96	43000 34	501.5	9.2	29% 40%	su	MI,WM	1,2,3,4,5,6,7,8,9,10
Red-winged Blackbird	79-80, 81-96	924 20	384.8	13.5	27% 47%	sp,su	MI,WM	1,2,3,4,5,6,7,8,9,10
Eastern Meadowlark	79- 80, 81-96	325 11	8.5	1.5	2%	sp,su	MI,WM	1,3,5,7,8,
Western Meadowlark	79,80, 81-96	302000	132.5	17.7	68 % 71%	su	MI,WM	1,2,3,4,5,6,7,8,9,10
Yellow-headed Blackbird	80,81-96	122 5	2			sp,su	MI,WM	1,3
Great-tailed Grackle	1988	250 pairs				sp,su	MI,WM	5
Brown-headed Cowbird	79 -80, 81-96	170	207.5	14.1		su	MI,WM	1,2,3,4,5,9,10

Non breeding								
Greater Prairie chicken	79, 81	40	35			sp,fa,wi		1,6
American Kestrel	80,81	82	16			sp,su,fa,wi		1,6
Canada Goose	81	135,000				sp, wi		1
White Fronted Goose	81	80,000				sp,fa,wi		1
Snow Goose	81	117				sp,wi		1
Mallard	80,81	20,000				sp		1
Green-winged Teal	80,81	106				sp,fa		1
Northern Shoveler	80,81	10		3		sp,su,fa		1
Gadwall	79,80			6.4		sp,fa	MI,WM	5
American Wigeon	79,80			3.2		wi,sp	MI,WM	5
Northern Harrier	80,81	99				sp,fa,wi	MI,WM	1,5
Red-tailed Hawk	80,81	61				fa,wi	MI,WM	1,5
Rough-legged Hawk	80,81	66				fa,wi		1
Ferruginous Hawk	81	1				fa		1
Golden Eagle	81	1				sp		1
Bald eagle	81	146				sp,wi		1
Prairie Falcon	81	4				sp,fa,wi		1
Bobwhite	80,81	753				sp,su,fa,wi		1
Solitary sandpiper	81	1				sp		1
Skimo curlew	1987	1				sp	MI,WM	11
Lesser Yellowlegs	80,81	154				sp		1
Willet	81	10				sp		1
Spotted Sandpiper	79,80			6.2		sp,su		5
Pectoral Sandpiper	80,81	11				sp		1
White-rumped sandpiper	80,81	66				sp		1
Baird Sandpiper	80,81	106				sp		1
Least Sandpiper	80,81	52				sp,su		1
Stilt Sandpiper	80,81	10				sp,su		1

Marbled Godwit	80	1				sp		1
Henslow's Sparrow	95,96				2% 7%	su		7,8
Lark Sparrow	95,96				2%	su		7,8
Vesper Sparrow	80,81	115				sp,fa		1
American Coot	80,81	4				sp		1
Common Flicker	80,81	196				sp,su,fa,wi		1
Easter Kingbird	80,81	67				sp,su		1
Western Kingbird	80,81	3				sp,su		1
Horned Lark	80,81	16				fa,wi		1
Blue Jay	80,81	216				sp,su,fa		1
Common Crow	80,81	100				sp,su,fa,wi		1
American Robin	80,81	51				sp,su,fa		1
European Starling	80,81	1248				sp,su,fa,wi		1
American Goldfinch	80,81	1000				sp,su,fa,wi		1

References: 1. Hay and Lingle 1981, 2. Lingle1995, 3. Lingle 2005, 4. Lingle and Bedell 1990 , 5.Faanes and Lingle 1995 , 6. Krapu 1981, 7. Helzer 1996, 8. Helzer 1999, 9. Lingle et al 1994 , 10. Lingle and Whitney 1991, 11. Faanes 1990.

N= abundance

sp=spring, su=summer, fa=fall, wi=winter, yr= year. wm=Wet meadow, MI= Mormon Island, WR= Wild Rose Ranch, UR= Uridil restoration, JC= John clearing, JR= John restoration, NC1= NC1 restoration, NCR= Nature Center restoration, CM= Crane Meadows

Table 6: Amphibian and reptiles species observed on wet meadows adjacent to Central Platte River

	year	N	Period	observations	Reference
Amphibians					
Wood house's toad	80, 97-2003	Abundant 247	Apr-Dec	WM(MI,WR,NC1,NCR,UR,JR,JC)	1,2,3
Chorus frog	80, 97-2003	Abundant 265	Apr-Dec	WM(MI,WR,NC1,NCR,UR,JR,JC)	1,2,3
Plains Leopard Frog	80, 97-2003	Abundant 742	Apr-Dec	WM(MI,WR,NC1,NCR,UR,JR,JC)	1,2,3
Bullfrog	97-2003	28	Apr-Dec	WM(MI,WR,NC1,NCR,UR,JR,JC)	3
Northern Leopard Frog	97-2003	2	Apr-Dec	WM(MI,WR,NC1,NCR,UR,JR,JC)	3
Plains Spadefoot	97-2003	1	Apr-Dec	WM(MI,WR,NC1,NCR,UR,JR,JC)	3
Great Plains Leopard Frog	2006	29	Jun-July	Slough, side channels transects	4
Wood house's toad	2006	x	Jun-July	CM pond & office parking lot	4
Bullfrog	2006	4	Jun-July	CM pond & office parking lot	4
Great Plains Toad	2006	1	Jun-July	Road	4
Lizards					
North Prairie Skink	80, 2006	Common	Apr-Sept	MI, Big slough, north meadow	1,2,4
Six-lined Racerunner	1980	Abundant	Apr-Sept	MI	2,4
Snakes					
Red-sided Garter Snake	2006	2	Jun-July	MI	4
Great Plains Garter Snake	80, 2006	Abundant	su	MI	1,2,3,4
Common Garter Snake	1980	Common	Jun-July	MI	1,4
Smooth Green Snake	2006	1	Jun-July	in prescribed burn near NCR	4
Lined Snake	2006	2	Jun-July	In big slough field	4
Ring-necked snake	2006	1	Jun-July	reported In pitfalls	4

sp=spring, su=summer, fa=fall, wi=winter, yr= year. wm=Wet meadow, MI= Mormon Island, WR= Wild Rose Ranch, UR= Uridil restoration, JC= John clearing, JR= John restoration, NC1= NC1 restoration, NCR= Nature Center restoration, CM= Crane Meadows

Table 7: List of aboveground and belowground invertebrates on wet meadows adjacents to the Platte River

Above-Ground Invertebrates		Native	Restored
Class/Order	Family/Genus		
Acarina		x	x
Araneida		x	x
Blattodea	Blattidae	0	x
Chilapoda		x	0
Coleoptera	Anobiidae	x	0
	Anthicidae	x	x
	Bruchidae	x	0
	Buprestidae	x	0
	Cantharidae	x	x
	Carabidae	x	x
	Cerambycidae	x	0
	Chrysomelidae	x	x
	Cicindellidae	x	x
	Clambidae	x	0
	Cleridae	0	x
	Coccinellidae	x	x
	Colydiidae	0	x
	Cryptophagidae	0	x
	Cucujidae	x	0
	Curculionidae	x	x
	Dytiscidae	x	x
	Elateridae	x	x
	Eucinetidae	x	0
	Helodidae	x	0
	Histeridae	0	x
	Hydraenidae	x	x
	Hydrophilidae	x	x
	Lampyridae	x	x
	Leiodidae	x	0
	Lyctidae	0	x
	Melandryidae	0	x
	Meloidae	x	x
	Melyridae	x	x
	Mordellidae	x	x
	Mycetophagidae	0	x
	Nitidulidae	x	x
	Pedilidae	x	x

	Phalacridae	x	0
	Ptilodactylidae	x	0
	Scaphidiidae	0	x
	Scarabaeidae	x	x
	Silphidae	x	x
	Staphylinidae	x	x
	Tenebrionidae	x	x
Collembola	Entomobryidae	x	x
	Sminthuridae	0	x
Diplopoda		x	x
Diptera	Asilidae	x	x
	Bibionidae	x	0
	Calliphoridae	x	x
	Culicidae	x	x
	Dolichopodidae	x	0
	Limnephilidae	x	0
	Muscidae	x	x
	Otitidae	x	x
	Sciomyzidae	x	0
	Syrphidae	0	x
	Tachinidae	x	x
	Therevidae	x	0
	Tipulidae	0	x
Gastropoda		x	x
	Lymnaeidae	0	x
	Viviparidae	x	x
Hemiptera	Berytidae	0	x
	Corimelaenidae	x	x
	Cydnidae	x	0
	Delphacidae	x	x
	Gelastocoridae	0	x
	Lygaeidae	x	x
	Miridae	x	x
	Nabidae	x	x
	Pentatornidae	x	x
	Podopidae	x	x
	Reduviidae	x	x
	Rhopalidae	x	x
	Saldidae	x	x
	Scutelleridae	0	x
Homoptera	Aphididae	x	x

	Cercopidae	x	x
	Cicadellidae	x	x
	Dictyopharidae	x	x
	Fulgoridae	x	0
Hymenoptera	Apidae	0	x
	Braconidae	x	x
	Chalcidae	x	x
	Eupelmidae	x	0
	Formicidae	x	x
	Halictidae	x	x
	Ichneumonidae	x	x
	Mutilidae	x	x
	Pornpilidae	x	x
	Sphecidae	x	x
	Vespidae	x	0
Isopoda		x	x
Lepidoptera	Arctiidae	0	x
	Pieridae	x	x
	Pyralidae	x	x
	Noctuiidae	x	x
	Nymphalidae	x	x
Neuroptera	Myrmeliontidae	0	x
Oligochaeta	Diplocardia	x	0
Opiliones	Trogulidae	x	x
Orthoptera	Acrididae	x	x
	Gryllacrididae	x	x
	Gryllidae	x	x
	Tetrigidae	x	x
	Tettigoniidae	x	x
	Tridactylidae	x	x
Phalangida		x	x
BELOW-GROUND INVERTEBRATES			
	Araneida	x	x
Coleoptera	Cantheridae	x	x
	Carabidae	x	x
	Chrysomelidae	x	x
	Cicindelidae	x	x
	Cucujidae	x	0
	Curculionidae	x	x
	Dermestidae	x	0
	Elateridae	x	x

	Heteroceridae	x	x
	Lampyridae	x	x
	Lycidae	0	x
	Meloidae	x	x
	Orthoperidae	x	0
	Scarabaeidae	x	x
	Silphidae	x	x
	Staphylinidae	x	x
	Tenebrionidae	x	x
Diptera	Tipulidae	0	x
Gastropoda	Haplotrematidae	x	0
Haplotaxida	Aporrectodea	x	x
Hemiptera	Coreidae	0	x
	Miridae	x	x
Homoptera	Aphidae	0	x
	Cicadelidae	0	x
	Cicadidae	0	x
	Membracidae	x	0
Hymenoptera	Formicidae	x	x
	Halictidae	x	x
	Isopoda	x	x
Lepidoptera	Geometridae	x	x
	Gracilariidae	0	x
	Hesperidae	x	0
	Noctuidae	x	x
	Nymphalidae	x	x
	Pyralidae	x	x
	Lithobiomorpha	x	0
Neuroptera	Mynneliontidae	x	0
Opisthopora	Diplocardia	x	x
Hemiptera	Nabidae	0	x
	Pentatomidae	x	x
	Diplopoda	0	x

(Sources: Nagel and Harding 1987, Davis 1991, Davis and Vohs 1992, Runge 1998, Nebraska Environmental Trust Fund 2001, Whiles and Goldowitz 1998, Whiles and Goldowitz 2001, Whiles and Goldowitz 2005, Riggins 2004, Davis et al 2006, Riggings et al 2009.

Table 8 Changes of the below-groud macroinvertebrate assemblage and meadows functional groups of soil macroinvertebrates in response of hydroperiod and natural and restored conditions of wet meadows. (sources: Meyer et al 2008, Whiles & Goldowitz 2001, 2005, Riggins 2004, Riggins et al 2009)

			Hydroperiod (1997-1998)			2003 -	2004	
Assemblage and Guild Characteristics	158 d	296d	331d	365d	Natural	Restored	Natural	Restored
Abundance (no./m2)	26989.3	66595	57070.8	152741.1	12,870.60	16,119.70	21,561.90	13,953.90
Collector-filters	1%	10%	11%	3%	41%	17%	8%	8%
Collector-gatherers	88%	65%	69%	92%	55%	70%	88%	84%
Predators	11%	16%	17%	3%	<1%	4%	1%	3%
Scrapers	<1%	9%	2%	1%	3%	1%	1%	3%
Shredders	0	1%	1%	1%	<1%	<1%	1%	<1%
Herbivore-piercers	-	-	-	-	<1%	<1%	<1%	<1%
Biomass (mg DM/m2)	127.2	4364.3	2449.2	9472.2	988.5	1772.2	2476.2	1530.6
Collector-filters	1%	2%	4%	7%	10%	2%	2%	1%
Collector-gatherers	62%	14%	26%	59%	45%	40%	48%	43%
Predators	6%	35%	19%	12%	19%	38%	21%	11%
Scrapers	31%	49%	38%	19%	22%	18%	19%	42%
Shredders	0	<1%	14%	3%	2%	<1%	7%	2%
Herbivore-piercers	-	-	-	-	<0.1%	<0.1%	0.20%	<0.1%
Average taxon richness	7.3	34.3	32.7	20.3	13.5	14.2	15.7	13.8
Total taxon richness	10	55	54	34	34.3	33.5	37	27.5
Shannon diversity (H')	1.1	2.1	1.7	1.4	1.3	1.5	1.3	1.3
Unique taxa	2	14	12	7	12	21	13	11
Invertebrate taxa's abundance (No/m²)								
Tricladida	0	1.3	0	86.2	17.7	14.5	7.9	65.9
Nematoda	2840	9897.3	9454.2	3707.3	54.4	1239.6	33.3	106.9
Annelida	5061.3	20798.2	19175.7	64345.7	1556.7	6724.1	4734.1	3914
Oligochaeta	5061.3	20771.5	19149.3	64163.5	1555.6	6724.1	4729.7	3914
Hirudinea	0	26.7	26.4	182.2	1.2	0	4.4	0

Crustacea	17797.3	29260.8	25361.8	17015.1	7347	5452.3	8540.5	4435.6
Branchiopoda	--	--	--	--	5058.3	2705.5	1471.5	1091.6
Cladocera	0	6203.5	5097.5	0	--	--	--	--
Ostracoda	0	878.7	1141.3	256	1769.3	1804.9	5882.7	617.9
Copepoda	17797.3	21793.3	19069.6	14171.1	434.4	932.7	1009.8	2719.1
Amphipoda	0	385.3	53.3	2588	85	9.2	176.5	7.1
Hydrachnidia	0	25.3	11.9	0	1.7	10.2	59.9	18.9
Insecta	1248	2365.3	2168.9	60735.7	3409.2	2496.1	7671.4	5142.3
Collembola	0	88	72.3	52.5	0.5	118.1	0.8	20.6
Odonata	21.3	36	126.8	103.4	5.6	94.1	7.5	53.5
Ephemeroptera	0	98.7	41.5	38.6	0	10.7	2.1	6.5
Hemiptera	0	60	9.5	13.1	10.6	22.3	1	4
Coleoptera	0	128	21.3	73	49.5	63.8	111.3	34.6
Trichoptera	0	0	629.3	0	22.2	0	221.5	4.8
Lepidoptera	--	--	--	--	0	0	0.7	,0.1
Diptera	1226.7	1954.7	1268.1	60455.1	3320.5	2187	7325.5	5017.6
Molluska	42.7	4246.7	898.4	6851.3	483	183	514.7	270.4
Hydrobiidae	0	53.3	19	0	--	--	--	--
Lymnaeidae	42.7	1728	219.3	0	140	124.4	71.6	128.3
Physidae	0	2321.3	155.3	1938.7	42	43.2	173.5	141.7
Planorbidae	0	144	502.5	0	145.3	14	62.8	0.3
Sphaeriidae	0	0	2.4	4912.6	155.6	1.5	206.9	0.1

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