Wet Meadow Literature and Information Review

A REPORT

By

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Executive Summary

The present is a summary of literature published on wet meadows and their associated biological and abiotic characteristics with a focus on the central Platte River. The report is divided into three parts; 1) narrative, 2) annotated bibliography, and 3) supporting documents. Wet meadows adjacent to 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, most 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, -not in Lit Cited, US EPA 2006-not in Lit Cited).

The initial process of this information review entailed an exhaustive search for all literature available on the subject of wet meadows. 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all sources were collected and compiled which included published articles, reports to government agencies, and other unpublished or unreported data.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, as a habitat type for example, but rather it means that the field work was conducted within the geographical location of Mormon Island Crane 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 We also decided to exclude all unpublished reports and write-ups that where either anonymous, undated, or those that would be difficult to find in the future.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.

The term “wet meadow” has been used in several different ways and has several synonyms within the literature of the Central Platte River Valley, Nebraska (CPRV). 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 1998, 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 to 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 units. 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). 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 et al 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, Zuerlin 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 2000). We believe this is an appropriate definition as it is within an existing/recognized wetland classification scheme and encompasses all descriptions previously reported for a wet meadow within the CPRV. For example it not only makes references to the intermittent water regime and moisture characteristics but also to the vegetation associated with it as a 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 preliminary working definition is proposed.

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).

The plant species composition of wet meadows is extensive and the vegetation communities are complex. 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. 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).

Wet meadows are highly variable in regards to moisture regime, and presence and abundance of invertebrate and vertebrate organisms in space and time. Most information available on associated organisms is on invertebrates and the use of wet meadows by sandhill cranes for which they are important for resting, feeding, drinking water, and interactions. The use of wet meadows by whooping cranes is not well quantified and the data available does not specifically document its presence or what use they make of this habitat type. The information on herptiles, mammals, and other species of concern to the program are very limited and some information sources are only available as raw data.

Natural and restored wet meadows have been characterized and compared in regards to soil characteristics, plant species, and assemblages and invertebrates. In general most restorations, while tending to significant biomass and cover, are generally lower and vary in plant species richness and normally missing sedges which are considered a distinctive element of natural wet meadows. Restored wet meadows can have high invertebrate biomass and productivity but may also differ in species richness and composition. Natural wet meadows have the most richness and have often unique species not encountered in restorations.

Overall restoration of wet meadows is believed to be more influenced by hydroperiod than any other factor (Davis et al. 2006, Meyer et al. 2008). 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 (age since restoration) in shaping the wetland macroinvertebrate communities (Meyer et al. 2008). While some directional changes towards something more similar to a natural wet meadow 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 (Meyer et al 2008). 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.

Management activities can also influence wet meadow restoration efforts. 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.

It is clear, based on the literature available and the summaries presented here, that there is a great deal of difference in the amount of information available on different groups associated with wet meadows. For example, there is very little published information on the herptiles, even though there are some unpublished sources of information. However, since they are not analyzed and are unpublished, those sources of information are of limited value at present. Other groups have received more attention, such as invertebrates, and some topics have much more information available such as the use of wet meadows by sandhill cranes.

Wet meadows are complex, highly dynamic open systems and as such, are difficult to quantify and measure. While some data and information has been gathered over the last several decades, most of that information is totally descriptive and static. For example, we will get a good idea of what organisms have been observed in wet meadows, however, in most cases we do not know the relationship between different variables with the wet meadow or associated biotic and abiotic factors. There are some studies that show relationships between water levels and vegetation and invertebrate presence and abundance, but most studies have been conducted over a relatively short period of time. A better understanding of how the different components of wet meadow are related to each other may help us better understand their natural functioning and will help us better plan and develop restoration projects to emulate the natural wet meadow system. As an open system, many elements of the surrounding landscape will influence what happens in a wet meadow and therefore an understanding of the surrounding landscape and conditions is necessary for a more thorough understanding of wet meadow characteristics and functioning. There are no system level studies in which wet meadows are studied from a holistic perspective. Because of the complexities and variability of wet meadows in the CPRV, system level ecological models and studies could provide for better planning and implementation of research and restoration activities of wet meadows in this area.

Report Outline

The present is a review and summary of literature published on wet meadows and their associated biological and abiotic characteristics with a focus on the central Platte River Valley Region. The report is divided into three parts; 1) narrative, 2) annotated bibliography, and 3) supporting documents. Part 1 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 is 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, 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 (US EPA 2006).

Wet meadows are currently considered an endangered system (Currier 1995) 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. 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 (Frith 1974, Hurr 1983, Nelson et al. 1988, Henszey and Wesche 1993, Currier and Goldowitz 1995, Whiles and Goldowitz 1998, Wu 2003).

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 the endangered whooping crane (a PRRIP target species) and other PRRIP "species of concern, non-target listed species, and non-listed species of concern" that use this habitat type.

It would be useful to clearly define and describe a wet meadow in order to adequately manage and restore them. Therefore, it is important that we compile, summarize, analyze, synthesize, and make available existing information on the subject. The PRRIP needs to determine what is known in regards to the relative importance of wet meadows as habitat for wildlife and identify gaps in knowledge that may need study. We need to understand wet meadows in order to define and understand the conditions, size, management, and restoration of central Platte River Valley wet meadow habitats to optimize and enhance the interaction between wet meadow habitat and whooping cranes 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 whether to include it in the annotated bibliography based on whether 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, as a habitat type for example, rather it means that the field work was conducted within the geographical location of Mormon Island Cranes Meadows. These articles were not included in the annotated bibliography. 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 within 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 misunderstandings 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 1988, 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 to 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 units. 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 are 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 et al 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, Zuerlin 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 regime and moisture characteristics but also to the vegetation associated with it 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. If wet meadows are considered a habitat type, it must be specifically referenced 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 (wetland) 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.

Proposed Working Definition

Within the context of the objectives of the Platte River Recovery Implementation Program a proposed wet meadow working definition could be the following. A wet meadow is a wetland within a grassland landscape adjacent to, and influenced, by Platte River. Wetland components are generally in linear configuration and deep enough to be influenced by river water stage levels. Water levels can fluctuate based on river flows, precipitation, and evaporation and may be dry during portions of the year. The vegetation of a natural wet meadow will consist of emergent vegetation communities characterized by bluejoint (*Calamagrostis inexpansa*), cut grass (*Leersia virginica*), smartweeds (*Polygonum spp*.) and broadfruit bur-reed

(*Sparganium eurycarpum)*, river bulrush (*Schoenoplectus fluviatilis)*, cattail (*Typha spp*.), and sofstem bulrush (*Schoenoplectus tabernaemontani*). Other characteristic plant species present will include sedges of the genus *Carex.* The landscape surrounding the wetland portion of the wet meadow must encompass a minimum of 100 mts of native grassland in all directions in order to accommodate potential use by cranes. Management actions (prescribed burns, grazing or haying) will be necessary to maintain vegetation characteristics appropriate for some species, such as cranes, which prefer short vegetation.

Wet Meadow Status

Grasslands losses on and near the Central Platte River Valley had been reported as high through the 1980's (Currier 1995). Krapu (1981), reports 70% loss of native meadow, while Currier (1985) reports a 73% loss of native grasslands and wet meadows within 3.5 miles of the Central 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 in segments of the North Platte River and Platte River. Some 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 (in Nebraska) since 1938 has been slower (23-33 %), probably because much of the agricultural land in this reach was already 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 the most (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 occurs (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 in the lower 250 miles of the Platte River 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 affected, by reduced flows in the Platte River and it is suggested that healthy wet meadows can 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 diversity of wet meadows is extensive and the vegetation communities are complex (Table 2). Plant species richness recorded in wet meadows so far is greater than 60 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 elevation. For example, Currier found that water sedge, smartweed, and cut-grass were good indicators of the wettest conditions, followed by Canada goldenrod (*Solidago canadensis*), smooth brome, (*Bromus inermis*), big bluestem (*Andropogon gerardii*), ironweed (*Vernonia fasciculata*), and sweet clover (*Melilotus albus*) as 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 et al. 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 and 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 gradients (emergent, sedge meadow, mesic prairie, and dry ridge), both of which defined their categories 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 broadfruit bur sdeed (*Sparganium eurycarpum)*, river bulrush (*Schoenoplectus fluviatilis)*, cattail(*Typha spp*.) and softsstem bulrush (*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 effect of precipitation on plant species cover and composition is believed to be for brief periods 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 are influenced primarily by river stage, but isolated precipitation events may increase water levels that gradually decrease over a period of up to two weeks (Henszey and Wesche 1993).

Soil and Abiotic Characteristics

Soils of the CPRV are primarily pleistocene sands and gravels, medium to highly permeable and 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 have higher levels of nitrogen, organic matter, and clay and lowest sand content, while silt did not differ between lower and higher elevations (Simpson 2001, Davis et al 2006). Levels of pH, phosphorus, nitrogen, and 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 (1987) describes diurnal habitat use from 51 whooping cranes sightings. From 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 habitat type. What is clear from these data is that whooping cranes use wetlands to a considerable extent while in the CPRV and therefore may use wet meadows if conditions are appropriate. Migrating whooping cranes could use wet meadows for feeding, resting, and roosting if conditions where adequate. The presence of vertebrate and macroinvertebrate 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. 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 recently 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 an 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 CPRV 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 sandhill cranes observed in the central Platte River Valley were in wet meadows (Lewis 1974). During the 1990's, Davis (1999) reports that 29% of overall daytime observations of sandhill cranes 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 sandhill 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 sandhill cranes are seeking water to drink and invertebrates for feeding. Greater numbers of soil invertebrates have been reported in areas with water tables between 40-80 cm (Davis and Vohs *1993b,* and Nagel and Harding 1987). These water tables provided 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 taken 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 sandhill 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, sandhill 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 CPRV wet meadows or associated grasslands (Table 5) with more than 40 additional species 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 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/km^2 (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 important for nesting birds during dry periods as they are believed to serve as a 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 abundant while for others there are 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 the reason 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 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 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 (within a specific wet meadow), the zone with the intermediate moisture regime at a particular 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 Platte 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 caddisfly is 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 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 may be 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). Current status of this species in the area is not reported in any recent literature.

Management Effects

Since wet meadows lie within a complex of grassland or prairie, they can be used 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 can be impacted by river stage, this section of the report will not address 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 on wet meadows or grasslands. Krahulik (2002) found that grazed sites generally had a higher invertebrate diversity and evenness than ungrazed sites. He found that certain guilds decreased 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 some wet meadows in this area get burned periodically. Davis et al. (2006) believes that an abundance of Scaraeidae may be related to increased below ground production as a result of periodic burning (approximately every 4 years).

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 suchas dickcissel (*Spiza americana*), Western meadowlark (*Sturnella neglecta*), red-winged blackbirds (*Agelaius phoeniceus*), and grasshopper sparrow (*Ammodramus savannarum*)) 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. 2011).

<u>Vegetation</u>

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 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 CPRV wet meadow restoration with restoration age 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 is not occurring. 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 plants 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 wet meadows in the CPRV while maintaining species diversity.

Invertebrates

Management of native grasslandsand associated wet meadows 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 along the CPRV. 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 compared to natural systems, within 10 years. Root biomass and carbon and nitrogen 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 sloughs than in 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 his 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. 2011). 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. 2011).

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 age 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.

Wet Meadow Knowledge Gaps

Based on the literature available and the summaries presented above, there is a great deal of difference in the amount of information available on different groups associated with wet meadows. For example, there is very little published information on herptiles, even though there are some unpublished sources of information. However, since they are not analyzed and are unpublished, those sources of information are of limited value at present. Other groups have received more attention, such as invertebrates, and some topics have much more information available such as the use of wet meadows by sandhill cranes. However, not all invertebrates have received equal attention, for example for the regal frittalery and the Platte River Caddisfly there is little recent information available, although for the caddisfly, data gathering is underway. Following is a summary of what are considered to be significant gaps in information or knowledge regarding wet meadows and their associated organisms.

Physical characteristics

While the connection between river stage and wet meadow water levels is generally established, the precise influence of specific water levels in the river to specific wet meadows or specific wet meadow conditions is not yet clearly defined, particularly given the significant variability in various reaches of the central Platte River (i.e., gaining and loosing reaches). While it is clear that more water in the river may improve wet meadow conditions overall, the exact effect and the predictability of wet meadow conditions to river stage needs more in depth analysis. As distance to ground water is an important variable influencing both plants and invertebrate animal presence and abundance, defining the depth at which intermediate hydrological regimes can be attained based on the water available in the river would be important to determine. This may allow for the creation or restoration of future wet meadows to be created to a depth that would provide the most productive water levels and hydroperiods based on expected river stage flows.

Whooping Cranes

Whooping crane use of wet meadows is highly contested but actual use of the wet meadow as defined here is not well documented. In order to properly document wet meadow use by whooping cranes it is necessary to better establish the exact location where cranes may be standing when observed within a grassland landscape near the river. For example, when describing cranes use of wet meadows most literature references do not clarify whether the cranes were in the grassland or the wetland portion of the area under view. If a crane is observed from the ground in a grassland it may be extremely difficult to determine exact substrate it is standing in. Therefore, the most exact determination of where a crane is present is likely to come from observations of cranes from the air or from elevated observation locations.

If the crane is indeed within the actual wet meadow, the level at which the crane is present must be determined as we know the invertebrate organisms are influenced by soil moisture and water levels. It is important to determine what the water level is at the time the crane observations were made. Whether there is standing water and what level it might be could be important in regards to the availability of aquatic organisms such as amphibians and fish. Potential resources present in the elevation/level where the cranes are present must be quantified as most productivity studies have determined that most abundant invertebrate resources are too small to serve as food items for whooping cranes. However, some are not (beetles, earthworms etc) and are known to be consumed by sandhill cranes while in wet meadows.

A more standardized system of habitat use data gathering should be created with actual descriptions of habitat types clearly defined. For example, current information while referencing the location as a wet meadow, could be referring to grassland or a pond. There is not sufficient detail to determine in most cases whether whooping cranes were using the actual wet meadow or the surrounding grassland. The activity of cranes while in wet meadows should be clearly evaluated and documented to actually determine the importance of that habitat type to whooping cranes. The cranes presence in a wet meadow is only a measure of use. Further detail is required to define whether wet meadows are used for feeding, resting, or other activities. For example, there is information quantifying the importance of wet meadows for sandhill cranes in regards to many different activities (see above).

While the list of food items for migrating whooping cranes is extensive there are little direct observations of what if any potential food items might be taken by whooping cranes in wet meadows in the CPRV. There are many potential food sources present in wet meadows, however, most studies of invertebrate and vertebrate organisms in wet meadows have been conducted during time periods during which whooping cranes are not present. Specific studies should evaluate potential wet meadow conditions including food sources during the time frame that whooping are likely to be present in the area. For species that may be actual or potential food sources for cranes, an evaluation of biomass, energetic content of different prey items, and energy available at different wet meadow or under variable conditions should be conducted as previous studies report high variability among sites and within a site at different time periods.

Other species of Concern

There is a paucity of data in regards to some of the other species of concern, for example for the Regal fritillary butterfly and the western prairie fringed orchid there are no recently published studies

Herptiles

In general, most herptile information available is primarily unpublished information collected at the Crane Trust by staff or collaborators. Most data available presents information on presence, as most of the projects were intended to record and document the species occurrence (Table 6). However, we consider this information as preliminary as many of those projects where short term in duration and no detailed studies exist on the potential habitat type associations, habitat selection or any other more detailed analysis of the importance of wet meadow for any individual herptile species. For amphibians, while unpublished, several years of data are available on their presence and abundance in different years and in different time periods within a year. No in depth analysis of this information has been conducted and may be useful to attempt. This data set could be used to correlate other elements such as river stage and precipitation patterns effects on trapping and collection efforts.

Mammals

There is a complete lack of information in regards to this vertebrate group and their presence or association to wet meadows. Ongoing projects may document the presence of small mammals associated with grasslands and prairies with wet meadows but not the actual presence of small mammals within the wet meadow wetland proper. While there are few species of mammals considered of concerns that may associated with wet meadows it would be of interest to gather information on mammals associated with wet meadows. It is possible that wet meadows may serve as refuge areas for some species during drought periods or at other times as happens with birds.

Invertebrates

Invertebrates are the most studied element of wet meadows in the CPRV. The summary of studies suggests high productivity overall of invertebrates with high variability in space and time. Some of the productivity has been associated to moisture gradients and location. Perhaps a better understanding of how to create more natural invertebrate assemblages in restorations would be a knowledge gap in regards to invertebrates. While invertebrate abundance and productivity has been shown to resemble natural wet meadows species richness and composition are very different between restored and natural systems.

Restorations

Evaluations of restoration effortes show that plant and invertebrate species composition in restored wet meadows are significantly different from natural restorations. Methods to accelerate wetland recovery from a plant and invertebrate composition may require some experimentation and application of new and different techniques. For example, can new restorations be “inoculated” via soil and organisms from a natural wet meadow? Or can organism be produced in captivity to reintroduce to new restorations? If hydroperiod is the primary driving force in plant and invertebrate presence, abundance, and productivity then finding ways (such as the appropriate depth) to replicate natural or intermediate hydrological conditions may be something to attempt in future restorations. The complete absence of some sedgesfrom restorations, which are characteristic of natural wet meadows needs to be investigated. For example, are the conditions not suitable for germination and establishment of these species or is seed dispersal to restorations not occurring under the current restoration conditions? Are the physical characteristics of the restored wet meadow not appropriate and it’s a matter of time or is the hydrological regime present in restorations not adequate to sustain sedges? More detail needs to be collected in restorations present to date to determine what natural physical and or biological characteristics are not being recreated.

There seems to be some disagreement in regards to how soon after restoration should management activities, such as grazing and burning, be applied. This is clearly an area that requires further study and very likely some experimentation in the future. There has been a lack of controlled experiments regarding restorations throughout the CPRV to date. So while one approach is to study existing restorations and attempt to understand what differences are present among the different age restorations and natural wet meadows it may also be necessary to design and implement experimental restorations moving forward where specific variables are deliberately tested in more controlled conditions, such as soil inoculations, or time to first management actions, etc.

Overall

Wet meadows are complex, highly dynamic open systems and as such are difficult to quantify and measure. While some data and information has been gathered over the last several decades most of that information is totally descriptive and static. For example, by looking at the tables presented here we will get a good idea of what organisms have been observed in wet meadows, however, in most cases we do not know the relationship between different variables with the wet meadow or associated biotic and abiotic factors. There are some studies that show relationships between water levels and vegetation and invertebrate presence and abundance, but most studies have been conducted over a relatively short period of time. A better understanding of how the different components of wet meadow are related to each other may help us better understand its natural functioning and will help us better plan and develop restoration projects to emulate the natural wet meadow system. As an open system, many elements of the surrounding landscape will influence what happens in a wet meadow and therefore understanding of the surrounding landscape and conditions, are necessary for a more thorough understanding of wet meadow characteristics and functioning. There are no system level studies in which wet meadows are studied from a holistic perspective. Because of the complexities and variability of wet meadows in the CPRV, system level ecological models and studies could provide for better planning and implementation of research and restoration activities of wet meadows in this area.

For some topics, such as restorations, there may be significantly more information than has been reported but it is not summarized or has not been published and therefore it is very difficult to access. One way to update our knowledge of wet meadows would be to collect, analyze, and report on existing data bases that currently exist as raw data. At least we need to determine whether the data sets are useful or whether they are not likely to increase our knowledge of wet meadow ecology in the CPRV. The Crane Trust currently has data sets on hydrology, herptiles, and fish that have not been analyzed and in some cases have never been reported outside the organization.

One other element of learning about wet meadows could include monitoring restorations on a regular basis to determine how they are changing and how external variables such as weather and river stage influence these. A more thorough documentation of starting conditions of wet meadow restoration could help us better understand current development paths for specific sites. This would be more complex than just evaluating existing data sets but could set the stage for significantly learning into the future.

Table 1. Effects of site elevation, hydroperiod and wet meadow (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	Sender 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 spp 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	453110 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, 14 Hay & Lingle 1981, 15 Faanes and LeValley 1992, 16 Ver Cauteren 1998, 17 Davis 1999, 18 Nagel et al 1991, 19 Lingle 1994, 20 Lingle 1981, 21 Lynch 1985,1994, 22 Lingle 1994
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 Meadow (WM) 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-	22 1	30	10.1		sp,su	MI,WM	1,2,3,9

	96							
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	1968				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	4300034	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	92420	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	32511	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	1225	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

References: 1. Ballinger 1980, 2. Jones et al. 1981, 3. The Crane Trust 2007, 4. Franke 2006
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-ground macroinvertebrate assemblage and wet 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/m^2)								
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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APPENDIX

Reviewer Questions and Concerns and Author Responses

Comment : The report did a good job of summarizing many published reports and served as a good review and summary. However, it did not have the level of synthesis as detailed in the RFP. "Minimum habitat criteria" was not developed for whooping cranes either in the wet meadow definition or in the form of a working definition. There was some expectation of developing a working definition that includes criteria such as: a) size, b) wetland/upland composition, c) target depth to groundwater (hinted to a number of times in report but not formally recommended), d) target hydroperiod, e) target buffer size and structure (e.g. sediment and vegetative buffers), and f) distance from river. This report summarized other studies findings but did not provide practical application that could be used in development of a working definition.

Response: There is almost no information on whooping crane use of wet meadows therefore a synthesis is impossible at this time with the data available for this summary.

Comment 1: Minimum habitat criteria" was not developed for whooping cranes
Response: Minimum habitat criteria can be summarized based on all information gathered for whooping cranes throughout their entire migration corridor, but that information will show stopover habitat as something very different than wet meadow. Without specific infromation it is impossible to say what is the minimum habitat for a whooping crane if we don't know exactly what the "mean level of energy requirements" for a migrating WC. Without the information about the " potential nutritional and energetic content of the optimal resources that exist (in WM located 3000 ft to the Platte River Channel).

Comment 2: About **Wet meadow definition or a working definition.**

Response: Working definition can and should be made by TAC or other PRRIP group based on information presented in the documents summarized here and any other management or administrative needs. Not sure that it should be us, or any other external group, who comes up with a working definition as working definition implies. If TAC or other PRRIP group want to consider a broader criteria than presented in scientific literature, need to consider a working definition of optimal habitat as "the Platte River landscape" (for example, where wet meadow is included). There is insufficient data on habitat use of Whooping Cranes, and other species of concern, compared with other habitats, and food consumed by these organism to consider quality criteria at this point.

Comment 3: The report did not attempt to incorporate USFWS' whooping crane database of historic sightings. The USFWS' records have not been officially compiled and published.

Response: USFWS data needs to be processed and published in some way to fulfill the criteria considered for inclusion in this project. The whooping crane database could be a very good resource, but it was beyond the scope of this project to summarize and get it into publishable form for use here. However habitat type definitions are not as explicitly defined as one would hope. We did conduct a review of the database and looked at all references that mentioned wet meadow (see annex tables below). As can be observed the data available in the data base at present are lacking detail and do not allow a determination of what the a relation between whooping crane and wet meadows adjacent to Platte River is.
Austin and Richert [2001] conducted a preliminary analysis of this data set but included only the first day of each sighting of Whooping Crane reported, the rest of the information is still not processed.

Annex 1: Whooping crane sightings in Platte River Area (data from Austin and Richert, 2001)

Site_id	Year	Season	Feeding Habitat	Adjacent Habitat	Observed food
1980101104	1980	Spring	wet meadow	wet meadow	-----
1995102102	1995	Spring	wet meadow	corn stubble, river, seasonal basin, woodland	-----
1996102101	1996	Spring	wet meadow	corn stubble, river, woodland	-----
1996102201	1996	Spring	wet meadow	corn stubble, river, woodland	-----
1989200501	1989	Fall	river	wet meadow	mollusks
1989200502	1989	Fall	river	wet meadow	-----
1989201801	1989	Fall	river	wet meadow	-----
1989201802	1989	Fall	river	wet meadow	-----
1990100401	1990	Spring	river	wet meadow	-----
1993100204	1993	Spring	corn stubble	wet meadow	-----
1995102103	1995	Spring	marsh	wet meadow	-----

Annex 2: Sightings of Whooping Cranes observed feeding (Austin and Richert 2001)

Site_id	Year	Area Name	Season	Feeding Habitat	Observed food
1988102103	1988	Other NE	SPRING	seasonal basin	invertebrates, others
1989102201	1989	Other NE	SPRING	river	snake
1989200501	1989	Platte River	FALL	river	mollusks
1997101103	1997	Other NE	SPRING	corn stubble	seed and plant
1997101104	1997	Other NE	SPRING	disked corn stubble	seed and plant
1997101106	1997	Other NE	SPRING	corn stubble	seed and plant
1997101301	1997	Other NE	SPRING	corn stubble	seed and plant

Annex 3: **Locations where potential food where observed**

Site id	Year	Area Name	Season	Feeding Habitat	Potential food
1977203403	1977	Other, NE	FALL	wet meadow	invertebrates, seeds and plants
1984101111	1984	Rainwater basin	SPRING	marsh	invertebrates, seeds and plants
1985101201	1985	Other, NE	SPRING		invertebrates, seeds and plants
1986100504	1986	Other, NE	SPRING	wet meadow	invertebrates, frogs
1986100505	1986	Other, NE	SPRING	alfalfa	invertebrates, seeds and plants
1987201601	1987	Other, NE	FALL	river	invertebrates, seeds and plants
1987202001	1987	Other, NE	FALL	marsh	invertebrates, frogs
1988102102	1988	Other, NE	SPRING	seasonal basin	seeds and plants
1988102103	1988	Other, NE	SPRING	seasonal basin	seeds and plants
1988102104	1988	Other, NE	SPRING	pasture	seeds and plants
1989100102	1989	Other, NE	SPRING	corn stubble	seeds and plants
1989101901	1989	Other, NE	SPRING	marsh	seeds and plants
1989101902	1989	Other, NE	SPRING	alfalfa	invertebrates
1989102001	1989	Other, NE	SPRING	marsh	invertebrates, seeds and plants
1989102201	1989	Other, NE	SPRING	river	invertebrates
1990100402	1990	Other, NE	SPRING	corn stubble	invertebrates
1992100601	1992	Other, NE	SPRING	river	invertebrates, seeds and plants
1992101301	1992	Other, NE	SPRING	river	invertebrates,tubers
1992102001	1992	Quivira NWR,KS	SPRING	wet meadow	invertebrates, seeds and plants
1992202301	1992	Quivira NWR,KS	FALL	wet meadow	invertebrates, seeds and plants
1992202401	1992	Quivira NWR,KS	FALL	wet meadow	invertebrates, seeds and plants

Comment 4: Identify any literature addressing program other species of concern- River otters and western prairie fringed orchid were absent all together. They were specifically pointed out in RFP. The report simply mentioned that there was no recent information on WPFO in CPRV.

Response: This is a literature report, if there is no literature on the subject (did not find peer reviewed articles, thesis, or governmental) we cannot report on it. It is likely that some unpublished data has been collected but it was not available to us during this review

Comment 5: Species were not categorized by use of upland, wetland, or interface.

Response: This work only presents what is in the literature. If there is nothing related to a specific topic there is no possibility of summarizing it. Specific information gaps or questions are elements that are used to design future studies. Most of the information available in the literature lacks detail to accomplish this, except for macroinvertebrates (which are summarized in the tables of the report).

Comment 6: End note? Or other searchable database for the annotated bibliography? This wasn't present. Current annotated bibliography is in Adobe acrobat. Is there another database out there or was this obligation not addressed?
Response: The EndNote searchable database was submitted in a DVD to Chad Smith in three EndNote files: 1. the Annotated bibliography of WM, 2. The annotated unpublished data, and 3. Annex documents.

Comment 7: Significant gaps section does not point toward any characteristics that would help us decide where to acquire or restore properties into wet meadows.

***Response*:** Without a working definition decided upon by the PRRIP (or clear quality variables defined for particular species) there is no way to define specific geographical areas that would fit non-existing criteria. With the level of information that we have for Wet Meadows near the Platte River Channel, the only possible alternative is to consider similar examples from other geographical areas.

Comment 8: Most of the entire synthesis section of the RFP is not present in this report . …"proposed working definition of a "high-quality wet meadow.

Response: This reports provide variables and parameters that have been evaluated and reported in the literature. That information should be used to come up with a working definition for the PRRIP. Any definition presented here would have to be general as it is not looking at specific specie's habitat requirements, for example. While a working group of the Platte River recovery Implementation Program should be the one to address this, we believe the most appropriate way to address quality wet meadow is to assume that the most natural ones evaluated to date are of the highest quality. However this will not address the issue of characteristics that may be needed or preferred by species of interest as the species have in some cases contrasting requirements.

Items from the PRWCTs' proposal that were not addressed, partially addresses, or inadequate:

Comment 9: Project schedule- The TAC, AMWG was never contacted for input or given an update on the schedule. The final report originally proposed to be completed in November is well behind schedule.

Response: We thought this was the input period. The Draft report was submitted in the first week of November, in agreement with Chad Smith from PRRIP. The final report was supposed to be submitted after the input period (including the workshop). We received the input from of the reviewers after January 15^{th}.

Comment 10: The trust indicated in their proposal that they would "develop a comprehensive summary, analysis and synthesis of the existing written knowledge of wet meadows along the Platter River Valley, including all research reports available to date". The Services' whooping crane database has not been compiled into research reports but is written knowledge of whooping crane use that was not addressed in their search and summary. At a minimum they went on to say that they "will provide a summary of data sources available that may not be published but may be useful to our better understanding of wet meadows". The Services database would definitely fit this category.

Response: This information was submitted in the DVD as Aggregated data file in the EndNote database.