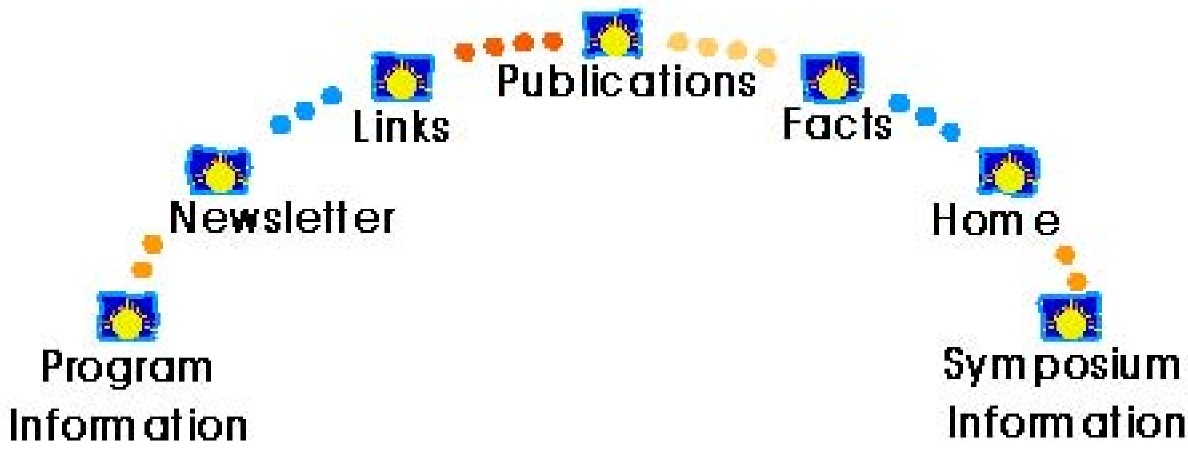

BIOLOGICAL RESPONSES TO HYDROLOGIC FLUCTUATION IN WETLAND SLOUGHS OF THE CENTRAL PLATTE RIVER Matt R. Whiles, Kansas State University, Department of Entomology, Manhattan, KS 66506-4004, and Beth S. Goldowitz, Platte River Whooping Crane Maintenance Trust, Inc., 6611 W Whooping Crane Dr, Wood River, NE 68883.

Abstract

To investigate hydrologic influences on biotic communities of central Platte River wetland habitats, we began a long term study in 1997 which includes monitoring hydrology and aquatic invertebrate, amphibian, and fish communities in five backwater sloughs southwest of Grand Island, Nebraska. Biotic community monitoring at each site consists of monthly benthic sampling of aquatic macroinvertebrates; continuous emergence trapping of adult insects; continuous sampling, during favorable weather conditions, of amphibian populations and migrations using drift fence and pitfall trap arrays; and monthly electroshocking of fish communities.

During the first year of this project, hydrologic regimes of our study sites varied from ephemeral to permanent. A significant positive relationship ($p<0.01$) between river discharge and slough water volume was evident at the permanent site, but this relationship was unclear at the intermittent and ephemeral sites. Invertebrate sampling revealed the presence of a new species of Ironoquia (Trichoptera: Limnephilidae) in one intermittent site, but this caddisfly did not occur in permanent or ephemeral sites. The two dominant amphibian species showed distinctly different breeding habitat preferences: leopard frogs (*Rana blairi*) were most abundant at the permanent site, and chorus frogs (*Pseudacris triseriata*) were most common at intermittent and ephemeral sites. Due to dry conditions during spring and early summer of 1997, only one amphibian species (*R. blairi*) reproduced successfully and only at the permanent site. Among the two sites with fish, species richness was highest at the permanent site, which served multiple functions as a spawning, rearing, seasonal, and year-round habitat for different fish species. The intermittent site was used seasonally as a spawning and nursery area during 1997, though habitat availability for spawning was truncated due to the dry summer.

Preliminary results suggest that wet meadows in the central Platte River support a patchwork of hydrologically diverse slough habitats, and that physical/hydrological diversity may promote biological

diversity on a larger scale. Thus, successful management of this floodplain system may require maintaining and promoting hydrologic diversity of backwater and slough habitats.

Introduction

Wet meadows of the central Platte River are important resources for a variety of flora and fauna, including microbes, plants, invertebrate and vertebrate communities, numerous migratory bird species, and a number of federally protected endangered and threatened species. Some of these are closely tied to slough and backwater wetlands in the meadows (e.g., fish and other completely aquatic species), while others are dependent upon them for at least some period of time (e.g., amphibious and migratory species). Other groups which appear independent of these wetlands may actually rely, directly or indirectly, on species that are closely tied to aquatic systems. For example, Gray (1993) recently demonstrated a strong link between feeding activities of insectivorous birds and aquatic insect emergence. In the Platte, wetlands are essential habitats for migratory birds, particularly sandhill cranes and whooping cranes, because they provide food items that are necessary for successful migration and nesting (US Fish and Wildlife Service 1997).Thus, wetlands in the Platte River valley are likely an important component of regional biodiversity and play a major role in ecosystem function, as has been suggested for aquatic systems in the Great Plains region in general (Matthews 1988).

Despite their ecological importance, wet meadows and slough wetlands constitute some of the most seriously degraded and diminished habitats in the Platte River valley. After a century-long period of regulation and reduction of the Platte's flow, combined with agricultural conversion of land to row crops, the majority of the native meadows in the central Platte have disappeared (Sidle et al. 1989, US Fish and Wildlife Service 1997). Currently, wet meadows comprise less than 5% of the land area in the Platte River valley (US Fish and Wildlife Service 1997).

Notwithstanding the rather obvious importance of these habitats, their limited availability, and their potential linkages with other components of the Platte River ecosystem, backwater and slough wetlands have not been well studied. Understanding the basic structure and function of these wetlands, and their importance on a larger scale, such as their influence on surrounding habitats and systems, is essential for effective management. The influence of the physical template on structure and function of aquatic systems is well documented (e.g., Vannote et al. 1980, Poff and Ward 1990, Townsend and Hildrew 1994). Thus, a key starting point for Platte River wetlands is identifying the important components of the physical template and elucidating their influence on animal communities and ecosystem processes. In particular, hydrology is likely to be the single aspect of the physical environment that has the most pervasive influence on resident communities and associated processes.

Wetlands in the Platte River vary from being ephemeral pools to perennial aquatic habitats. In addition, the hydroperiod in these habitats may change substantially from year to year, as a result of annual variation in local precipitation, river discharge, and evapotranspiration. The influence of this hydrologic variability on aquatic communities and processes is undoubtedly profound. For example, spring peak (or flood) flows are considered "elemental" for maintaining the Platte River system, because of their role in maintaining biodiversity of wet meadows and the meadows' ecological function and usefulness for numerous animal and plant species (US Fish and Wildlife Service 1997). Previous study has established that groundwater level fluctuations in the meadows are linked to river flow, especially during spring peak flow periods (Wesche et al. 1994), but there is almost no information about the influence of hydrologic variability in the river on the surface wetlands in wet meadows. Hydrologic factors play an important role in structure and function of a variety of aquatic systems (Van Der Valk 1981, Moses 1987, Matthews 1988, Resh et al. 1988, Stanley and Fisher 1992, Poff and Allan 1995), and understanding their effects, as well as the factors influencing them, is essential for understanding and managing these unique aquatic systems and the species that depend upon them.

Our objective in this study is to examine and quantify the tripartite relationship between river discharge, wetland hydrology, and biotic communities of central Platte River sloughs. Specifically, we are examining: 1) hydrologic relationships between sloughs, river discharge, and local precipitation; 2) response of aquatic macroinvertebrate communities to hydrologic variability in sloughs; 3) influence of slough hydrology on aquatic insect emergence patterns and energy transfer to terrestrial habitats; and 4) influence of slough hydrology on amphibian and fish communities. This study incorporates both spatial and temporal components: our study sites represent a wide range of hydroperiods during any given year, and annual hydrologic variability also is high in this sytem. Hence, our study is designed to examine the influence of hydrologic variability on biotic communities in sloughs with different hydroperiods, and among years within individual sloughs.

Study Areas

We studied five slough and backwater wetlands in the central Platte River southwest of Grand Island in Hall County, Nebraska. Three sites are located on Mormon Island Crane Meadows (MI1, MI2, and MI3), and two sites are on the adjacent island at Wild Rose Ranch (WR1 and WR2). All five sites are in close proximity to each other and to the main channel of the Platte River. Habitat surrounding all sites is a mosaic of wet and mesic prairie. In the Platte River, these grasslands (often called wet meadows) have groundwater levels which are high for much of the year, and the vegetation is dominated by grasses, sedges, and forbs typical of tall grass prairie.

Each study site is a 20 m linear reach of slough. Sloughs flow into and are connected to the main channels of the river when water levels are high, but some may become disconnected from the river during dry periods. The study sites vary from ephemeral to perennial (Table 1), with water depths ranging from 0.25-1.0 m at the deepest points. Water flows at slow velocities (<5 cm/s) in all the study sloughs. Although some gravel is present at one site, substrates in the sloughs are dominated by sand, silt, and detritus. Aquatic macrophytes (*Potamogeton, Typha, Scirpus, Carex, Lemna, and others*) are abundant at all sites except MI3 and WR1, where grasses and other prairie vegetation encroach because of shorter hydroperiods. Filamentous algae are also abundant seasonally at all sites. The sloughs freeze over during the winter, except one site which remains open year-round.

Methods

Hydrology monitoring

In spring 1997, we installed staff gauges at all the sites and read them daily thereafter (except when sloughs were dry or frozen). At approximately weekly intervals, depth profiles and wetted surface area of each site were measured. We obtained depth profiles of each site by measuring water depth at 1 m intervals across the width of the slough along three fixed transects that were 10 m apart (0 m, 10 m, 20 m). From depth profiles and wetted area measurements, we calculated slough volume and surface area, then regressed these against staff gauge readings from the same dates. In all cases but one, significant relationships were obtained ($p < 0.01$ for all). No significant relationship was detected with the surface area at WR2 because channel morphology is such that surface area changes very little. Regression equations were then used to predict daily volume and surface area from staff gauge readings taken on days when depth profiles and wetted area were not measured. Because WR2 wetted surface area changed very little throughout our first study year, we used a seasonal average of wetted area values for this site instead of a regression equation.

In conjunction with the hydrologic measurements, we also installed data loggers to continuously monitor water temperature in all the sloughs and air temperature and relative humidity in the general study area. Precipitation at all sites was monitored with rain gauges which were read daily.

Macroinvertebrate communities

Benthic macroinvertebrate communities were sampled monthly (except when sloughs were dry or extensively frozen). On each sampling date, three samples were taken with a 20 cm diameter coring device at random locations in each site. The coring device was driven into the substrate, and all material (substrates, vegetation, water, etc.) was removed by hand and cup down to ca 10 cm into the substrate and placed in a 5 gallon bucket. Samples were then elutriated and poured through a 250 µm sieve, rinsed, preserved in 7-8% formalin solution with phloxine B stain (to facilitate sorting), and transported to the laboratory.

Adult insects that emerged from the sloughs were collected continuously (except when sloughs were dry or frozen) from three emergence traps placed at each site. Each trap sampled a 550 cm2 surface area of the slough. Traps consisted of a plastic cylinder that was suspended on electric fence posts and placed ca. 3 cm into the water of the slough. They were placed at random locations in each site and mounted in a manner which allowed adjusting for fluctuating water levels. Each trap was topped with a fine mesh cap (250 µm mesh), which directed insects into a plastic pipe connected to a bottle filled with a dilute solution of ethylene glycol. Emerging insects that became trapped in the bottles were collected ca. every 2-4 weeks. During drying periods when slough surface areas were shrinking, traps were often moved into deeper water to allow for continuous sampling.

Because one site (MI1) contained larvae of Ironoquia (a genus of caddisfly in which final instar larvae migrate onto land to pupate and metamorphose into adults), we placed three additional emergence traps over the meadow at this site, adjacent to the slough in areas where pupae were evident. These traps were used to quantify adult *Ironoquia* emergence. Because larval production of *Ironoquia* occurs in the water, *Ironoquia* values will be added to estimates from traps positioned over the water to obtain total emergence production of insects from this site.

Amphibian communities

Amphibian movements into and out of each site were monitored continuously during favorable weather conditions with drift fences and pitfall trap arrays (Gibbons and Semlitsch 1981). The length of each slough was bordered, on both sides, by 20 m drift fences constructed of aluminum flashing which was buried ca. 15 cm into the ground and supported with electric fence posts (ca. 0.5 m height above ground). Drift fences were oriented parallel to each slough, and were 5-10 m away from water's edge during wet periods. Pitfall traps (5 gallon buckets buried flush with the ground) were placed at 10 m intervals on each side of each drift fence (drain holes were drilled in each pitfall bucket prior to installation). During use, each pitfall bucket was equipped with a sponge to keep trapped animals moist and a styrofoam float to prevent drowning. Additionally, we suspended a strip of burlap from the adjacent meadow into each bucket to facilitate the escape of small mammals that fell into the traps.

During favorable conditions (spring, autumn, and rainy periods during the summer), traps were opened before dark and checked the following morning. Trapped amphibians were identified, sexed (when possible), weighed, measured (snout-vent length), marked by clipping toes, and released on the opposite side of the fence. When not in use, lids were placed on traps to prevent incidental catches.

While performing routine hydrologic measurements and monthly sampling, all study sites were searched for the presence of amphibian egg masses and larvae. Presence or absence was noted, and egg masses and larvae were identified when possible. Occasional estimates of larval densities were made using a frame sampler.

Fish communities

Two of the study sites (MI1 and WR2) contained fish communities, and they were sampled monthly (except at MI1 when it was dry or frozen). Sampling at each site consisted of single-pass electroshocking of the entire 20 m study reach (using a Coffelt model Mark-10 backpack electroshocker). Stunned fish were collected with dip nets, identified, measured (standard length), and released. Additionally, notes on reproductive status (e.g., presence of breeding adults or young-of-the-year) were recorded on each date.

Results and Discussion

Hydrology

During the 274-day study period in 1997, slough hydroperiods ranged from 72-274 days with water (Table 1). The two ephemeral sites had the shortest hydroperiods (MI3 and WR1) and were wet in spring (dry by late April), dry during the summer, and re-filled with water in late November. These ephemeral sites also filled temporarily during rainy periods in the summer. Two intermittent sites had intermediate hydroperiods (MI1 and MI2); they were wet from spring into early summer (dried in late June), occasionally filled during rainy periods in the summer, and re-filled in mid-September.

Although total annual precipitation during 1997 was slightly above average for the region, much of that precipitation, especially during spring months, was concentrated into a few days. For example, March 1997 ranked as the tenth driest March in the long-term record (National Weather Service, 1997 data for Grand Island). Furthermore, all the precipitation in May and June was almost completely concentrated into 4 and 2 days, respectively. Only during the period of August-October was precipitation significantly above average. Thus, any influence that local precipitation has on hydrology of these sloughs, particularly in spring and early summer, may have been reduced during our first study year, and hydroperiods may vary under different climatic conditions.

Discharge of the Platte River also was higher than average during 1997, though the timing of flow peaks was somewhat unusual. On average, June and then March rank as the highest-flow months in the central Platte (US Geological Survey, statistics for water years 1942-1997). During 1997, June was indeed the highest-flow month of the year, but the next highest flows occurred from October-December (flows were double to triple the average levels).

Preliminary analysis of slough hydrology data revealed some relationships with river discharge. In particular, we detected a highly significant relationship ($p < 0.001$) between slough volume and river discharge at the perennial site, WR2 (Table 1). This positive relationship was apparent throughout most of year, with the exception of a period in November when water volume rapidly declined for no apparent reason (Figure 1). The other sites showed a pattern of decreasing correlations between slough volume and surface area with river discharge as slough hydroperiods decreased, with the exception of WR1 volume (Table 1). Thus, hydrology of sloughs with longer hydroperiods is apparently more closely linked with river discharge. Future analysis incorporating river discharge, local precipitation, evapotranspiration estimates, and antecedent conditions will allow us to identify the factors governing hydrology of individual sloughs more completely.

Macroinvertebrate communities

Processing and identification of the benthic core and emergence trap samples has just begun; however, initial macroinvertebrate sampling has revealed the presence of a previously unidentified caddisfly of the genus *Ironoquia*, which we are currently in the process of describing. The discovery of this new species in our MI1 study site extends the known range of *Ironoquia* in North America westward by a significant amount (Wiggins 1996). As has been observed in other members of this genus (Williams and Williams 1975), final instar larvae migrated from MI1 before the site dried in early summer, aestivated and pupated in grass litter on land through the remainder of the summer, and emerged as adults in late September. This life history demonstrates an adaptation to intermittent aquatic habitats and may explain why this caddisfly is not present in our study sites that have different hydroperiods (i.e., intensive sampling in nearby drier [WR1, MI2, MI3] and wetter [WR2] sites has failed to produce specimens of *Ironoquia* elsewhere). Thus, it appears that there may be hydrologic thresholds governing the distribution of this new species in Platte River sloughs.

Amphibian communities

During 1997, our study sloughs contained a total of four species of anuran amphibians. They included plains leopard frog (*Rana blairi*), bullfrog (*Rana catesbeiana*), western chorus frog (Pseudacris triseriata), and Woodhouse's toad (*Bufo woodhousii*). However, only leopard frogs and chorus frogs occurred in large numbers. Although generally abundant in our area, plains spadefoot toad (S*pea bombifrons*) was not collected during our first study year. This is presumably a result of weather patterns, as this species is an explosive, opportunistic breeder (Wells 1977) that emerges from the ground and breeds during warm rainy periods in late spring and summer (Collins 1993). These weather conditions scarcely occurred in the study area during 1997.

Chorus frog catches were highest in spring and fall, whereas leopard frog catches remained fairly constant throughout the study period (Figure 2). Eggs and larvae of both species were observed in several sloughs by April, and larvae of both species were present shortly thereafter (Figure 2). However, emerging metamorphs of *R. blairi* only were collected during the summer. This is likely a result of different breeding habitat preferences of the two species and the weather patterns during 1997. *R. blairi* showed a distinct preference for the perennial site, WR2 (Figure 3A), regardless of the presence of predatory fishes. Successful recruitment of this species was documented only at WR2. In contrast, *P. triseriata* preferred intermittent and fishless sites (Figure 3B), but these sites dried early in the year during 1997. As a result, although breeding adults were abundant in spring, we were unable to document successful recruitment by *P. triseriata* at our sites during 1997.

Breeding habitat preferences exhibited by leopard frogs and chorus frogs at our study sites are consistent with other observations of these species (Fitch 1958, Whitaker 1971, Johnson 1992, Skelly 1996), and recent investigations suggest that adult breeding site choice is only one of many factors which may influence distribution of anuran larvae across hydrologically variable habitats. Skelly (1997) suggests that there are trade-offs associated with breeding site permanence, and that feeding rates, growth rates, size at metamorphosis, risk of predation, and other factors affecting fitness vary among anuran species which breed in habitats with different hydroperiods. In general, smaller species such as *P. triseriata* are often more successful in intermittent habitats where predator populations are reduced but risk of desiccation may be higher (Skelly 1996). Presumably, we will be able to document successful recruitment of P. triseriata at our intermittent sites in years when weather patterns and river flow differ and hydroperiods in our intermittent sites are longer.

Fish communities

The two sites with the longest hydroperiods, MI1 and WR2, contained fish communities for at least part of the year. The perennial site, WR2, contained a more diverse assemblage of 13 species, while the more intermittent site, MI1, contained only three species (Figure 4). Brassy minnow (*Hybognathus hankinson*i) dominated the community in the intermittent site, MI1. We observed spawning adults in early April and young-of-the-year in late June (Figure 5), suggesting that MI1 is used seasonally as a spawning habitat by this species. In early June, prior to the appearance of young-of-the-year brassy minnows, no fish were present in MI1, and this site dried shortly after our 28-June sample was collected (Figure 5). Although reproduction of brassy minnow is not well documented (Lee et al. 1980), our data indicate that, in the Platte River, this species moves into intermittent sloughs in spring to spawn, adults leave after spawning, and young hatch prior to summer drying. Interestingly, large numbers of adult brassy minnows appeared in the perennial site (WR2) in mid-summer (Figure 6), but no reproduction was evident at this site, suggesting that fish may use permanent and intermittent sloughs for different purposes.

In the perennial site, WR2, composition of the fish community varied throughout the year. A few species were present on most sampling dates and appeared to be year-round residents (Figure 6), e.g., brook stickleback (*Culaea inconstans*) and Iowa darter (*Etheostoma exile*). Both are species of special concern in Nebraska (Clausen et al. 1989), and neither occupied the more intermittent site. Some other species moved into this slough and used it during a single season only: brassy minnow and fathead minnow (*Pimephales promelas*) occupied WR2 during the summer only, while largemouth bass (*Micropterus salmoides*) moved in during the autumn. These varied patterns suggest that perennial wetlands may serve multiple functions for the different fish species in the Platte.

Conclusions and future considerations

This paper presents the results from only the first year of a long-term endeavor, and portions of the data have not been analyzed yet; however, our initial results indicate that there is a relationship between hydrology and biotic diversity in central Platte River wetlands. Preferences for hydrologic regimes among species in each of the three biological communities we are examining are evident. For example, *Ironoquia* is present only at one intermittent site (MI1); the two dominant anurans show distinctly different preferences for breeding habitats; and, although many fish species utilize only in the perennial site (WR2), at least one species selects intermittent wetlands for spawning.

Initial results also indicate that the hydrology of these slough habitats, at least those with longer hydroperiods, is significantly influenced by river discharge. Therefore, temporal variation in factors influencing wetland hydrology may be crucial to reproductive success of their inhabitant species. For example, breeding adult chorus frogs were quite abundant at several of our sites during 1997, indicating past reproductive success. However, factors influencing slough hydroperiod inhibited their successful recruitment in 1997. Identifying these factors, and the extent to which human activities are influencing them, will provide a basis for successful future management of the Platte River basin ecosystem.

Thus, our results to date indicate that hydrologic diversity among the wetlands is related to flows of the Platte River and has a positive influence on biological diversity in those habitats. This suggests that maintaining biodiversity, and thus ecosystem integrity, in the Platte River basin should include managing for hydrologic heterogeneity (i.e., a mosaic) of backwater and slough wetland habitats.

Additional investigation, encompassing years with different climatic and river discharge patterns, will allow us to elucidate more completely the role of individual factors that govern the hydrology of Platte River wetlands and to quantify their influence on biotic diversity, amphibian and fish reproductive success, and processes such as energy transfer between aquatic and terrestrial habitats. We also anticipate that future work will allow us to identify specific hydrologic thresholds governing distribution of a variety of species which depend on these wetland habitats. In addition to furthering understanding of the Platte River ecosystem, this information about the function of these wetland habitats should be a useful reference for measuring the success of current wetland restoration efforts.

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Table 1. Slough hydroperiods (April-December, 1997), with correlation coefficients and p values from linear regressions performed on slough volume and surface area vs. discharge of the Platte River (n=245 for all regressions). "n.s." indicates that no significant relationship was detected (p > 0.05). No regression was performed of surface area vs. discharge at WR2; because of the channel morphology at that site, there is essentially no variation in wetland surface area.

Site	Number of days with water	Regressions of wetland size against Platte River discharge			
		volume vs. discharge		surface area vs. discharge	
		r	p	r	p

MI 1	237	0.11	n.s.	0.27	<0.001
MI 2	201	0.10	n.s.	0.18	<0.01
MI 3	72	0.09	n.s.	0.07	n.s.
WR 1	87	0.18	<0.01	0.15	<0.05
WR 2	274	0.55	<0.001	---	---

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