# Investigations of Fish, Amphibians and Aquatic Invertebrate Species within the Middle Platte River System

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# FINAL REPORT
# INVESTIGATIONS OF FISH, AMPHIBIANS AND AQUATIC INVERTEBRATE SPECIES WITHIN THE MIDDLE PLATTE RIVER SYSTEM

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## SUMMARY

To investigate hydrologic influences on biotic communities of central Platte River wetland habitats, we conducted a study from 1997-98 which included monitoring hydrology and aquatic invertebrate, amphibian, and fish communities in five backwater sloughs southwest of Grand Island, Nebraska. Hydrologic monitoring included daily measurements of wetland size, river discharge, and precipitation. Biotic community monitoring at each site consisted of continuous trapping of emerging aquatic insects, continuous trapping of amphibians using drift fence and pitfall trap arrays, and monthly electroshocking of fish communities.

Hydrologic regimes of the study wetlands varied from ephemeral to permanent (filled with water 15-100% of the time). Generally, there was a significant positive relationship between river discharge and wetland size (wetted surface area and volume). The patterns of habitat use by emerging aquatic insects were consistent: abundance, taxon richness, and biomass production all were highest at intermittent sites. Seasonal patterns of emergence biomass also varied among the sites, depending on the hydrologic regime. The dominant amphibian species showed distinctly different breeding habitat preferences: leopard frogs (*Rana blairi*) were most abundant at the perennial site, chorus frogs (*Pseudacris triseriata*) were most common at intermittent sites, and Woodhouse's toads (*Bufo woodhousii*) used ephemeral habitats almost exclusively. The amphibian species also showed distinct seasonal patterns of activity: chorus frogs were active in early spring and again in late fall, leopard frogs were active from late spring through summer, and Woodhouse's toads only used the study sites in mid-summer. Fish were most abundant, and species richness was highest, at the perennial site; the intermittent site was used seasonally, primarily in the spring as a spawning and nursery area. However, fish species composition at the perennial site changed dramatically over the study period.

Our results indicate that wet meadows in the central Platte River support a mosaic of hydrologically diverse wetland habitats, and that physical/hydrological diversity promotes biological diversity on a larger scale. Thus, successful management of this floodplain system may require managing river flows appropriately and conserving 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 restricted to slough and backwater wetlands in the meadows (e.g., fish and other completely aquatic species), while others are dependent upon the wetlands for at least some period of time (e.g., amphibious and migratory species). Some 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 the feeding activities of insectivorous birds and patterns of 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 play a major role in ecosystem function and are likely an important component of regional biodiversity. This has been suggested for aquatic systems in the Great Plains region in general (Matthews 1988).

Despite their ecological importance, riparian wet meadows and slough wetlands constitute some of the most seriously degraded and diminished habitats in the Platte River valley. After a more than a century 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 studied extensively. Understanding the basic structure and function of these wetlands and their importance on a larger scale—including their effects on surrounding habitats and systems—is essential for effective conservation and 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 understanding Platte River wetlands is to identify the important components of the physical template and elucidate their influence on animal communities and ecosystem processes.

In aquatic systems where flows fluctuate through the year, hydrology is likely to be the single aspect of the physical environment that has the most pervasive influence on resident communities and associated ecosystem processes. Wetlands in the Platte River valley encompass a range from ephemeral pools to perennial aquatic habitats. In addition to varying seasonally within a single year, the water levels in these habitats may change substantially from year to year, as a result of annual variation in river discharge, local precipitation, and evapotranspiration. The effect of this hydrologic variability on aquatic communities and processes is undoubtedly profound. Spring peak (or flood) flows, for example, are considered "elemental" for maintaining the Platte River system, because of their role in maintaining ecological functions in wet meadows, the meadows' usefulness for numerous animal and plant species, and thus biodiversity (US Fish and Wildlife Service 1997). Previous studies have established that groundwater level fluctuations in the meadows are linked to changes in river flow, especially during spring peak flow periods (Wesche et al. 1994). However, there is almost no information about the influence of hydrologic variability in the river on the surface wetlands in wet meadows or their fauna. Hydrologic factors play important roles in structure and function of a variety of other 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, conserving and managing these unique aquatic systems and the species that depend upon them.

Our objective in this study was to examine and quantify the tripartite relationship between river discharge, wetland hydrology, and biotic communities of central Platte River sloughs. Specifically, we examined: (1) hydrologic relationships between slough wetlands, river discharge, and local precipitation; (2) the influence of slough hydrology on aquatic insect emergence patterns and energy transfer to terrestrial habitats; and (3) the influence of slough hydrology on resident amphibian and fish communities. This study incorporated both spatial and temporal components, because our study sites encompassed a wide range of hydroperiods during any given year and annual hydrologic variability, which is high in this sytem, also was examined. Hence, we studied the influence of hydrologic variability on biotic communities in sloughs with both space and time as variables.

## STUDY AREAS

We studied five slough and backwater wetlands in the central Platte River. The wetlands are located in a large wet meadow complex southwest of Grand Island in Hall County, Nebraska, on two adjacent islands owned by the Platte River Whooping Crane Maintenance Trust (three sites were on Mormon Island Crane Meadows, and two sites were on on Wild Rose Ranch). All five sites are close 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. Four of the sites are in pastures, and one is in a hay meadow.

Each study area consisted of a 20 m linear reach of slough. The hydrology of our study sites varied from ephemeral to perennial (Table 1). Water depths ranged from 0.25-1.0 m at the deepest points, and water flowed slowly (<5 cm/s) in all the study sloughs. Although some gravel was present at one site, substrates in the sloughs were dominated by sand, silt, and detritus. Aquatic macrophytes (*Potamogeton*, *Typha*, *Scirpus*, *Carex*, *Lemna*, and others) were abundant at all sites except MI3 and WR1, where grasses and other prairie vegetation encroached into the wetlands because of shorter hydroperiods. Filamentous algae also were abundant seasonally at all sites. The sloughs froze over during the winter, except one site which remained open year-round.

## METHODS

### Hydrology

We monitored daily changes in surface area and volume of the study sloughs using fixed staff gauges and depth profile transects in all the wetlands (our methods are described in detail in Whiles and Goldowitz 1998). Data for daily discharge of the Platte River at Grand Island, just downstream of the study area, were collected by and obtained from the US Geological Survey. Data for weather in the area (air temperature and precipitation) were obtained from published records of the National Weather Service. In addition, we monitored water temperature in each slough, air temperature and relative humidity in the center of the study area, and precipitation at each site.

Our empirical measurements of water depths and wetted area were used to calculate wetted surface area and volume of each study slough on a daily basis (Whiles and Goldowitz 1998). We used linear regression to examine the relationships between river flow and wetland size (both surface area and volume).

### Aquatic insect emergence

To quantify their abundance and biomass (i.e., production), adult insects that emerged from the study sloughs were collected continuously (except when sloughs were dry or frozen). We placed three emergence traps in each wetland, at randomly selected locations, from 15 Apr-14 Nov 1997. Each emergence trap consisted of a plastic cylinder (625 $cm^2$ surface area) topped by a fine mesh cone (500 μm Nitex), which tapered and directed insects into a horseshoe-shaped PVC tube that emptied into a 250 ml collection bottle filled with either 50% ethylene glycol or 7% formalin solution.

Traps were suspended at the water surface on fence posts in a manner that allowed vertical adjustment as water levels fluctuated. Emergent vegetation was allowed to grow into traps but was trimmed when it reached the top of the Nitex cone (the entrance into the pipe). At least weekly throughout the study, traps were inspected and routine maintenance was performed. When water levels were changing rapidly, traps were inspected and adjusted daily.

Emerging insects that became trapped were collected monthly at first (April and May) and biweekly thereafter. Trap locations at each site were randomly changed every 1-3 weeks so that oviposition by adults was not inhibited. Whenever the wetted area of sloughs changed significantly, traps were moved in or out from the center of each site. We suspended trapping whenever the substrate surface of the sloughs was completely dry and when the sloughs froze over for the winter.

Aquatic and semi-aquatic insects collected in the traps were identified to genus whenever possible, measured (total body length), sexed, and counted. For each taxon, we measured the average weight per individual on a gender-specific basis. For the common taxa, 4-10 male and female individuals were oven dried for 24-48 hours (60° C) and then weighed on an analytical balance (nearest 0.001 mg) to estimate average dry mass (DM) of an individual from each gender. For Chironomidae (Diptera), gender-specific dry mass estimates were obtained using average dry weights and regressions from Stagliano et al. (1998). For Tipulidae (Diptera), we used a similar regression based on total body length (Stagliano, unpublished). Individuals from exceptionally small taxa were sometimes weighed in groups of 2-4. For some taxa which were very small (e.g., Ceratopogonidae [Diptera]) or collected infrequently (e.g., some Sciomyzidae and Empididae [Diptera]), or when only one sex was collected (e.g., *Psorophora* females [Diptera: Culicidae]), gender-specific DM could not be determined.

To calculate emergent numbers and biomass (emergence production) for each sampling interval, data from the three traps at each site were standardized for area and averaged. Data from biweekly collections were combined into monthly intervals for examination of seasonal trends. For total emergence numbers and production at each site, trap catches per unit area were then multiplied by average wetted surface area during sampling intervals. Because we sampled the entire non-freezing period of 1997, we assume our estimates of emergent numbers and biomass reflect annual values. However, some taxa could possibly emerge from these sites during warm periods in winter, so our estimates may be conservative. *Ironoquia* sp., a limnephilid caddisfly that pupates and emerges on land, was abundant at one site (MI 1) but was not present at other study sites. Because emigration of final instar *Ironoquia* larvae from this slough represents a significant emergence event, numbers and biomass of emigrating *Ironoquia* were computed separately and then included in MI 1 emergence abundance and production values (*Ironoquia* production values are detailed in Whiles at al. 1999).

Polynomial regression techniques were used to examine non-linear relationships between hydroperiod and taxonomic richness at each site. A forward stepwise procedure and t-test were used to determine equations most appropriate for fitting relationships (Zar 1996).

### Amphibians

Amphibian migrations to and from each site were monitored continuously with drift fences and pitfall trap arrays (Gibbons and Semlitsch 1981). We installed 20 m long drift fences on both sides of each study area, parallel to the length of the slough and 5-10 m away from the water's edge. The drift fences were constructed of aluminum flashing which was buried ca. 15 cm into the ground and supported with electric fence posts. Pitfall traps consisted of 5 gallon buckets, buried flush with the ground, that were installed at 10 m intervals on both sides of each drift fence. Each pitfall trap was equipped with a sponge to provide moisture for trapped animals, a styrofoam float to prevent drowning, and a dangling burlap 'ladder' to allow small mammals that fell into the traps to escape.

Throughout the spring and autumn, and during favorable weather conditions in the summer, traps were opened during the morning, left open overnight, and checked the following morning (the study period was April-December of each year). Trapped amphibians were identified, sexed (when possible), weighed, measured (snout-vent length), given individual marks (toe clips), and released on the opposite side of the fence. When the traps were not in use, we placed lids on the buckets to prevent incidental catches.

We used polynomial regression techniques to examine non-linear relationships between hydroperiod and amphibian catch at the study sites.

### Fishes

Two of the study sites contained fish communities (MI 1 and WR 2), and these were sampled monthly (except MI 1 when it was dry or frozen). Sampling consisted of electroshocking a single pass through the entire 20 m study reach (Coffelt model Mark-10 electroshocker). Stunned fish were collected with dip nets, identified, measured (standard length), and released at the point of capture. Additional notes on reproductive status (e.g., breeding adults or young-of-year) were recorded for the fish collected on each sampling date.

## RESULTS

### Hydrology

During the study, hydroperiods of our wetland study sites varied from 41-274 days per year (study period April-December=274 d). The two ephemeral sites, those with the shortest hydroperiods, were filled with water less than one-third of the time (range 15-32%; Table 1). They contained water in the early spring, dried by the summer, and filled again in late fall or early winter. Two intermittent sites, with intermediate hydroperiods, were water-filled more than two-thirds of the time (range 65-90%; Table 1). They were filled with water through the spring, dried in the summer, and filled again in early fall. (The ephemeral and the intermittent sites also filled briefly during rainy periods.) One site was perennial, i.e., always filled with water (Table 1).

Discharge of the Platte River was higher than average during almost all of our study (Figure 1). In 1997, flows were at approximately average levels in the spring but were much higher in June and from late summer through the end of the year, though the timing of flow peaks generally followed historic patterns (Figure 1). Flows remained high all winter and also throughout the spring of 1998. In addition, the timing of flow peaks in 1998 differed dramatically from the previous year (Figure 1). Total annual runoff in 1998 was higher than in 1997 (1,989,140 and 1,885,580 acre-feet, respectively; US Geological Survey).

To a lesser extent, total annual precipitation also was higher than average during our study (Figure 2). However, the pattern differed from that for discharge, and precipitation was higher in 1997 than in 1998 (29.11" and 25.99", respectively; National Weather Service). Spring of 1997 was somewhat dry, especially in March; in contrast, late summer and fall were very wet (Figure 2). In 1998, the pattern was reversed: the spring was wet, but the summer and fall were quite dry (Figure 2).

Generally, we found significant positive relationships between size of our study wetlands and river discharge, though these relationships were less consistent in 1997 and much stronger in 1998 (Table 1, Figure 3). In 1997, the relationships were strongest at the sites with the longest hydroperiods (Table 1). The pattern differed in 1998, when the strongest relationships occurred at the ephemeral and intermittent sites (Table 1, Figure 1).

### Aquatic insect emergence

Total number of insects emerging from the study wetlands ranged from a low of 374.9 individuals/m$^2$/yr, at the site with the second lowest hydroperiod, to a high of 24,124.1 individuals/m$^2$/yr at an intermittent site with an intermediate hydroperiod (Figure 4). In general, abundance was highest at sites with intermediate hydroperiods and declined as hydroperiod increased or decreased. Emergence production followed the same trend, with highest annual biomass production at the same intermittent site (5.1 g/m$^2$/yr) and lowest production at the driest site (0.13 g/m$^2$/yr; Figure 5). When emergence production was calculated for the entire wetted surface area during sampling intervals (total emergence production), this trend was still evident (Figure 6). However, differences between the sites were less exaggerated, because calculations for surface area corrected for concentration of insects when sites were shrinking and size differences between sites.

Emergence production varied seasonally at most sites and was generally highest during spring and autumn (Figure 7). The highest production values we observed at each site occurred during the spring at MI 1 (Figure 7A), autumn at MI 2 and MI 3 (Figures 7B and 7C), and spring and autumn at WR 1 (Figure 7D). Only WR 2, the perennial site that displayed a relatively consistent pattern of emergence production throughout the study period, had its highest production values during summer months (Figure 7E).

Members of the Diptera dominated emergence numbers and biomass production in all the wetlands except MI 1, where emigrating final instar *Ironoquia* larvae accounted for 11% of the numerical abundance and more than half of the total emergence production (Table 2). At three of our five study sites (MI 2, MI 3, and WR 2), Chironomidae dominated emergence abundance; chironomids also were the second most important contributor to numbers at the remaining two sites (Table 2). Chironomidae were particularly abundant at the perennial site, where members of this family accounted for 96% of total emergent numbers and 94% of biomass production (Table 2). However, because of their relatively small size, chironomids did not contribute significantly to emergence production at the other four sites. Sciomyzidae, Muscidae, and Tipulidae, which are generally more heavy bodied, were important contributors to emergence production at most sites, particularly those with shorter hydroperiods (Table 2). Culicidae dominated emergence abundance and production at MI 2, accounting for 4.59 g/m$^2$/yr of emergence production there. Culicids were also important, but less dominant, at MI 1, but they did not dominate either abundance or biomass at the other three sites.

Taxonomic composition of emerging insects varied greatly between the sites. Total taxon richness was highest at sites with intermediate hydroperiods, much like abundance and production (Figure 8). There was a significant quadratic relationship between hydroperiod and taxon richness ($p<0.05$; Figure 8), suggesting that hydroperiods of 250-300 days/year support the highest diversity in these wetland systems. A similar relationship was evident between hydroperiod and number of taxa unique to a site ($p<0.10$; Figure 9).

## Amphibians

During 1997-98, three species dominated the amphibian fauna of our study wetlands: plains leopard frog (*Rana blairi*), western chorus frog (*Pseudacris triseriata*), and Woodhouse's toad (*Bufo woodhousii*). Leopard frogs and chorus frogs occurred in large numbers during both years of our study; in contrast, Woodhouse's toads were abundant only during a single brief period in 1998.

The three amphibian species showed distinctly different patterns of seasonality. Chorus frog catches were highest in early spring and late fall, whereas leopard frog catches remained fairly constant from late spring through summer (Figure 10). Woodhouse's toads apparently are explosive, opportunistic breeders, as they were only abundant during and shortly after a rainy period in mid-summer 1998 (Figure 10).

We also observed distinct relationships between amphibian abundance and hydrology of the study wetlands. Chorus frogs were most abundant at the intermittent sites, especially MI 2, a site that lacked fish (Figure 11). Leopard frogs showed a marked preference for the perennial site, WR 2 (Figure 12), regardless of the presence of predatory fishes. Woodhouse's toads were highly variable and only occurred in large numers at an ephemeral site (Figure 13).

## Fishes

Only the two sites with the longest hydroperiods (MI 1 and WR 2) contained fish communities for at least part of the year. Over the course of the study, the intermittent wetland (MI 1) contained 6 species of fish, but only 1-4 species were present at any given time (average 1.5 spp/sampling date; Figure 14). Brassy minnow (*Hybognathus hankinsoni*) dominated the fish community of the intermittent site. They primarily used the slough during the spring, for spawning and rearing of young of the year. During the second year of our study, common carp (*Cyprinus carpio*) also spawned at this site.

The perennial site, WR 2, contained a more diverse assemblage of 16 species and, on any given sampling date, 2-10 species were present in the slough (average 4.6 spp/sampling date; Figure 15). Fish also were more abundant at this site than at MI 1 (average 37 and 9 individuals captured/sample at WR 2 and MI 1, respectively). Species diversity was highest at the perennial site during the first year of our study, when resident species included creek chub (*Semotilus atromaculatus*), plains topminnow (*Fundulus sciadicus*), brook stickleback (*Culaea inconstans*), bluegill (*Lepomis macrochirus*), and Iowa darter (*Etheostoma exile*). Creek chub and plains topminnow remained in the slough through the second year of the study, but Iowa darter were much less abundant, and brook stickleback disappeared altogether. During the last half of 1998, large numbers of western mosquitofish (*Gambusia affinis*) moved into this site.

## DISCUSSION

Our results show distinct relationships between hydrology and biotic diversity in wetlands of the central Platte River. Hydrologic variability had strong effects on each of the three biological communities we examined, although the faunal groups responded differently to water level fluctuations. For example, abundance and production of emerging insects were highest in intermittent habitats; abundance and diversity of fish were highest in the perennial habitat; and individual amphibian species each utilized a different type of wetland for breeding habitat.

The relationship between taxonomic richness of aquatic insects and hydroperiod that we observed during this study follows predictions of the intermediate disturbance hypothesis (Connell 1978). In theory, longer hydroperiods allow for biotic interactions (e.g., competition and predation) which limit diversity, whereas shorter hydroperiods limit the number of species which can persist. Our results suggest that taxonomic richness is highest in these wetland systems when some drying occurs and hydroperiod lengths are 250-300 days/year. Higher insect diversity at some sites likely was linked also to higher biodiversity at other levels. Although they were not measured during this study, macrophyte species richness and productivity both appeared highest at sites with higher insect diversity.

Both emergence abundance and production patterns also followed the pattern we observed for taxon richness, i.e., they were highest at intermediate hydroperiods. This suggests that management and restoration efforts which strive to maximize aquatic insect diversity and productivity in these systems should target intermediate hydrologic regimes. Numerous investigations have documented the importance of emerging aquatic insects to vertebrate groups such as birds (Orians 1964, Street 1977, Sjoberg and Danell 1982, Gray 1993, Cox and Kadlec 1995). Thus, managing for hydroperiods that enhance aquatic insect diversity and productivity should have a positive influence on the vertebrate groups that often are the focal point of management efforts.

On a larger scale, the temporal patterns of aquatic insect emergence production observed during this study indicate that sites with different hydroperiods can produce insect biomass at varying times of the year. Thus, a landscape with a mosaic of sites with different hydroperiods may be more effective at generating insect food resources for predators over a longer period of time. Further, although the number of insect taxa unique to a site was highest at one intermittent slough (MI 2), every site examined during this study harbored at least two taxa not encountered in other sites. Thus, a mosaic of wetlands with different hydrologic regimes also may increase regional insect diversity.

Breeding habitat preferences exhibited by the amphibians in this study also suggest that a mosaic of sites with varied hydrologic regimes supports the greatest species diversity. Each of the species in this study preferred a different hydrologic regime: leopard frogs were most numerous in the perennial site, chorus frogs in the intermittent sites, and Woodhouse's toads in an ephemeral site. Our results are consistent with other observations of these species (Fitch 1958, Whitaker 1971, Skelly 1996), and Skelly (1997) suggests that there are trade-offs associated with breeding site permanence. Feeding rate, growth rate, size at metamorphosis, risk of predation, and other factors that affect fitness vary among frog and toad species which breed in habitats with different hydroperiods (Skelly 1997). In general, smaller species like the chorus frog often are more successful in intermittent habitats where predator populations are reduced, even though the risk of desiccation may be higher (Skelly 1996).

For the fish as well, our results suggest that a mosaic containing temporary wetlands in addition to permanent aquatic habitats promotes biological diversity at a larger scale. Species diversity was highest at the perennial site (WR 2), and that site also contained species, like brook stickleback and Iowa darter, that have very specific habitat requirements and consequently are not common in the Platte River (Clausen et al. 1989). This is consistent with observations that more stable habitats support fish species with more specialized habitat requirements (Poff and Allan 1995). However, our results also indicate that certain fish species preferentially utilize intermittent wetlands as spawning and nursery habitats. In our study, brassy minnow moved into the intermittent slough (MI 1) in spring to spawn, the adults left after spawning, and young of year hatched, grew for 3-4 weeks, and emigrated prior to summer drying. It is interesting that, although we observed large numbers of brassy minnow in the perennial slough, no reproduction was evident at this site. Therefore, fish apparently use permanent and intermittent sloughs for different purposes. It is possible that intermittent wetlands are selected for spawning due to reduced risk of predation for the young or increased growth rates due to higher rates of macroinvertebrate production.

Additional factors, not measured in this study, also may influence fish species composition in these sloughs. The species composition at the perennial site changed rather dramatically over the two years of this study. Initially, the community was dominated by resident species like Iowa darter, brook stickleback, plains topminnow, and bluegill. Other species, like brassy minnow, used the habitat on a more seasonal basis. During the second year of our study, however, brook stickleback and bluegill disappeared from the slough, Iowa darter became much less abundant, and large numbers of mosquitofish moved in. Mosquitofish is an exotic species that has been implicated in the declining abundance of native fish species in Nebraska.

Finally, our results indicate that the hydrology of these slough habitats is significantly influenced by river discharge. In general, the study wetlands increased in size when instream flows in the river were higher. Because the relationships were not always consistent, the degree of influence exerted by river flow may by modified by additional factors, like local precipitation and evapotranspiration. In addition, there may be threshold levels of river discharge that cause specific types of responses in slough hydrology. Future analyses that incorporate river discharge, local precipitation, evapotranspiration estimates, and antecedent conditions will allow us to identify the factors governing hydrology of individual sloughs more completely.

This study indicates that hydrologic diversity among these wetland habitats is related to flow of the Platte River and has a positive influence on biological diversity in these habitats. Conserving biodiversity and ecosystem integrity in the Platte River should include managing both instream flows and habitat conservation/restoration efforts for the hydrologic heterogeneity that maintains a mosaic of temporary and permanent wetland habitats.

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Table 1. Hydroperiods of the study wetlands and results from linear regressions of wetland size against discharge of the Platte River. Hydroperiod is calculated as the number of water-filled days from April-December (274 days total) at each site. Coefficients of determination ($r^2$) and probability levels (p) result from linear regressions of wetted surface area and wetland volume vs. river discharge (n=245 for 1997, and n=215 for 1998). "n.s." indicates that no significant relationship was detected ($p>0.05$). No regressions were performed of surface area vs. discharge at WR2; because of the channel morphology at that site, there is no variation in wetted surface area.

| Site | Hydroperiod | | Regressions of wetland size against Platte River discharge | | | |
|---|---|---|---|---|---|---|
| | # of days | % of days | volume | | surface area | |
| | | | $r^2$ | p | $r^2$ | p |
| 1997 | | | | | | |
| MI 1 | 237 | 86% | 0.01 | n.s. | 0.07 | <0.001 |
| MI 2 | 201 | 73% | 0.01 | n.s. | 0.03 | <0.01 |
| MI 3 | 72 | 26% | 0.01 | n.s. | 0.005 | n.s. |
| WR 1 | 87 | 32% | 0.03 | <0.01 | 0.02 | <0.05 |
| WR 2 | 274 | 100% | 0.30 | <0.001 | --- | --- |
| 1998 | | | | | | |
| MI 1 | 225 | 82% | .67 | <0.001 | .77 | <0.001 |
| MI 2 | 186 | 68% | .84 | <0.001 | .72 | <0.001 |
| MI 3 | 41 | 15% | .66 | <0.001 | .62 | <0.001 |
| WR 1 | 67 | 24% | .76 | <0.001 | .71 | <0.001 |
| WR 2 | 274 | 100% | .03 | <0.01 | --- | --- |

Table 2. Insect emergence at the five wetland sites in this study. Top half of the table shows the four families contributing the greatest numerical abundance to annual emergence (number/$m^2$/yr); bottom half shows the four families contributing the most biomass to annual emergence production (mg DM/$m^2$/yr). Table entries contain emergence abundance, emergence biomass, and annual total for each site. Numbers in parentheses show the percent contribution of each family to the annual total at that site. Values represent pooled totals of all collections over the 1997-98 study period. The study sites are arranged, from left to right, in order of increasing hydroperiod.

| **STUDY SITE** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **MI 3** | | **WR 1** | | **MI 2** | | **MI 1** | | **WR 2** | |
| **ABUNDANCE** | | | | | | | | | |
| Family (% of total) | number | Family (% of total) | number | Family (% of total) | number | Family (% of total) | number | Family (% of total) | number |
| Chironomidae (33%) | 152.1 | Tipulidae (28%) | 103.2 | Culicidae (95%) | 23021.1 | Chironomidae (32%) | 635.7 | Chironomidae (96%) | 1553.9 |
| Sciaridae (27%) | 125.0 | Chironomidae (19%) | 70.6 | Chironomidae (1%) | 331.4 | Culicidae (19%) | 364.0 | Ceratopogonidae (1%) | 21.7 |
| Sciomyzidae (8%) | 38.0 | Sciaridae (17%) | 65.2 | Ceratopogonidae (1%) | 211.9 | Limnephilidae (11%) | 219.0 | Sciaridae (1%) | 16.3 |
| Dolichopodidae (8%) | 38.0 | Muscidae (16%) | 59.8 | Muscidae (1%) | 146.7 | Ceratopogonidae (7%) | 141.3 | Tipulidae (1%) | 10.9 |
| Total | 456.4 | Total | 374.9 | Total | 24124.1 | Total | 1957.7 | Total | 1619.1 |
| **BIOMASS** | | | | | | | | | |
| Family (% of total) | DM | Family (% of total) | DM | Family (% of total) | DM | Family (% of total) | DM | Family (% of total) | DM |
| Sciomyzidae (45%) | 60.6 | Muscidae (41%) | 64.7 | Culicidae (90%) | 4590.4 | Limnephilidae (57%) | 560.0 | Chironomidae (94%) | 239.8 |
| Muscidae (20%) | 27.6 | Sciomyzidae (29%) | 45.9 | Muscidae (3%) | 171.9 | Culicidae (14%) | 137.9 | Ephydridae (3%) | 7.0 |
| Sciaridae (12%) | 16.0 | Tipulidae (14%) | 22.3 | Sciomyzidae (2%) | 80.5 | Sciomyzidae (11%) | 112.6 | Tipulidae (2%) | 4.7 |
| Tipulidae (10%) | 13.9 | Chironomidae (8%) | 12.6 | Baetidae (1%) | 55.4 | Leptoceridae (5%) | 50.3 | Sciaridae (1%) | 2.1 |
| Total | 134.7 | Total | 157.4 | Total | 5099.4 | Total | 982.3 | Total | 255.7 |

Figure 1. Mean daily discharge of the Platte River at Grand Island (cfs). The graph shows the long term average flow for each month compared with flows during each year of this study. Data from US Geological Survey.

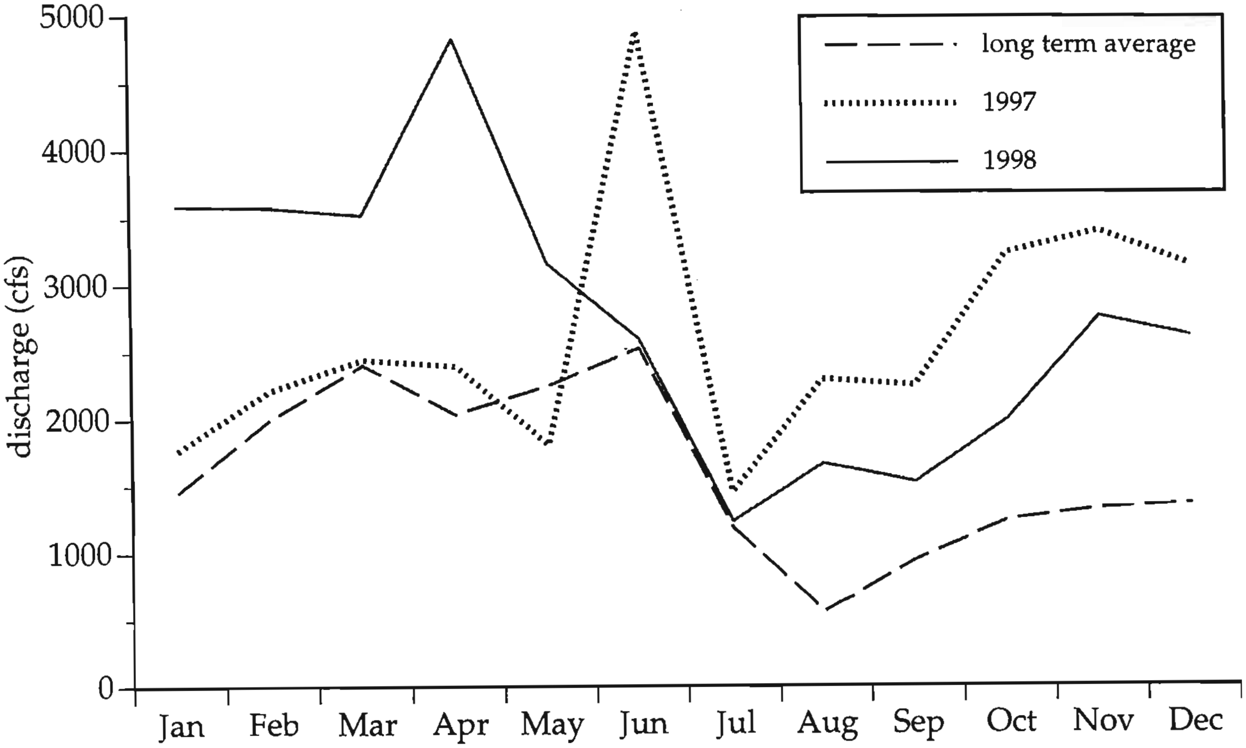

Figure 2. Monthly precipitation at Grand Island, Nebraska (inches). Bars show the long term average precipitation for each month compared with monthly totals during each year of this study. Annual totals are 24.90 inches (average), 29.11 inches (1997), and 25.99 inches (1998). Data from NOAA-National Weather Service.

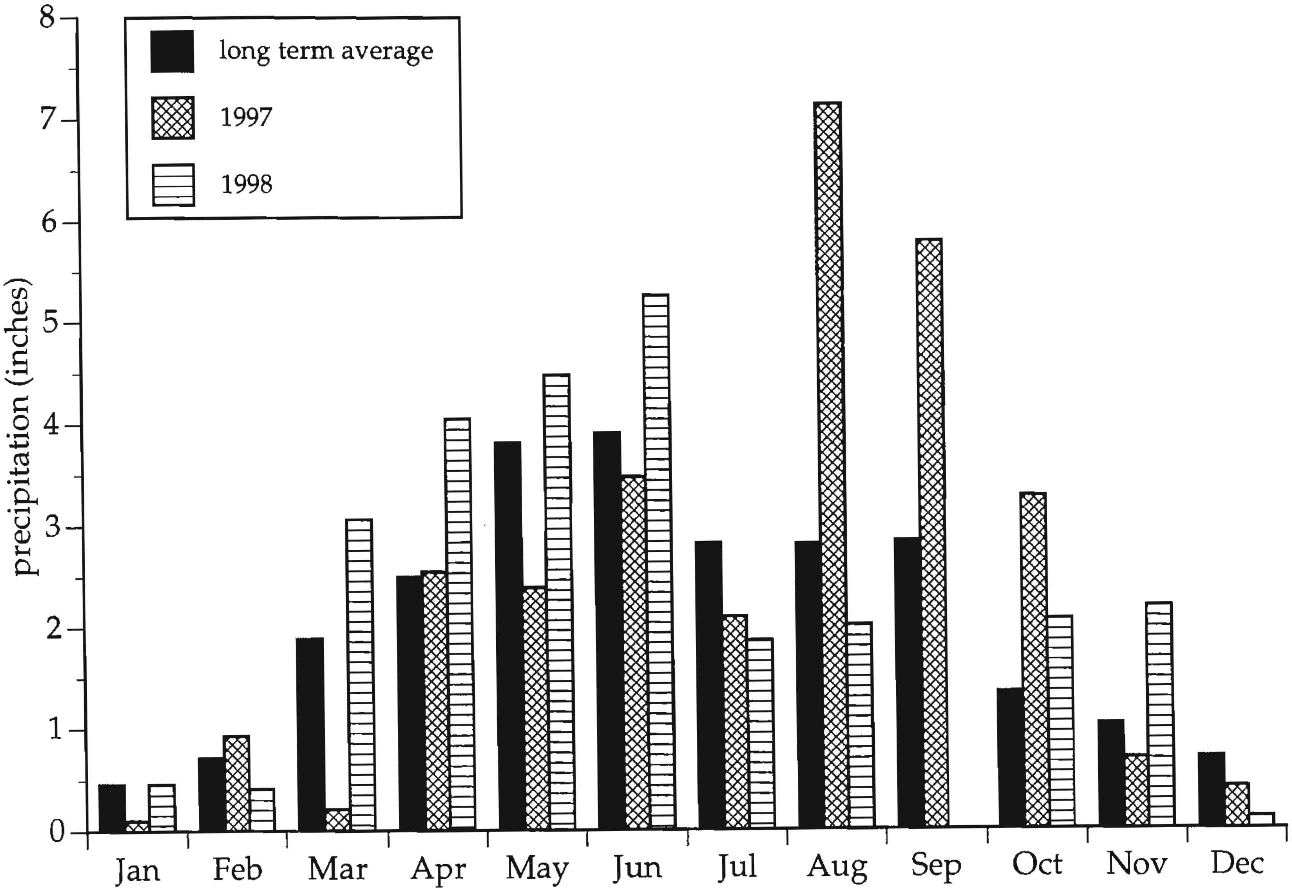

Figure 3. Relationship between river flow and wetted surface area at an intermittent wetland, Mormon Island 1. Thick line shows daily mean discharge of the Platte River at Grand Island (cfs), and thin line shows wetted surface area ($m^2$), from April-December in (a) 1997 (top) and (b) 1998 (bottom). Wetted surface area and river discharge were significantly correlated in both years ($p<0.001$). Gaps represent periods when surface area was not measured.

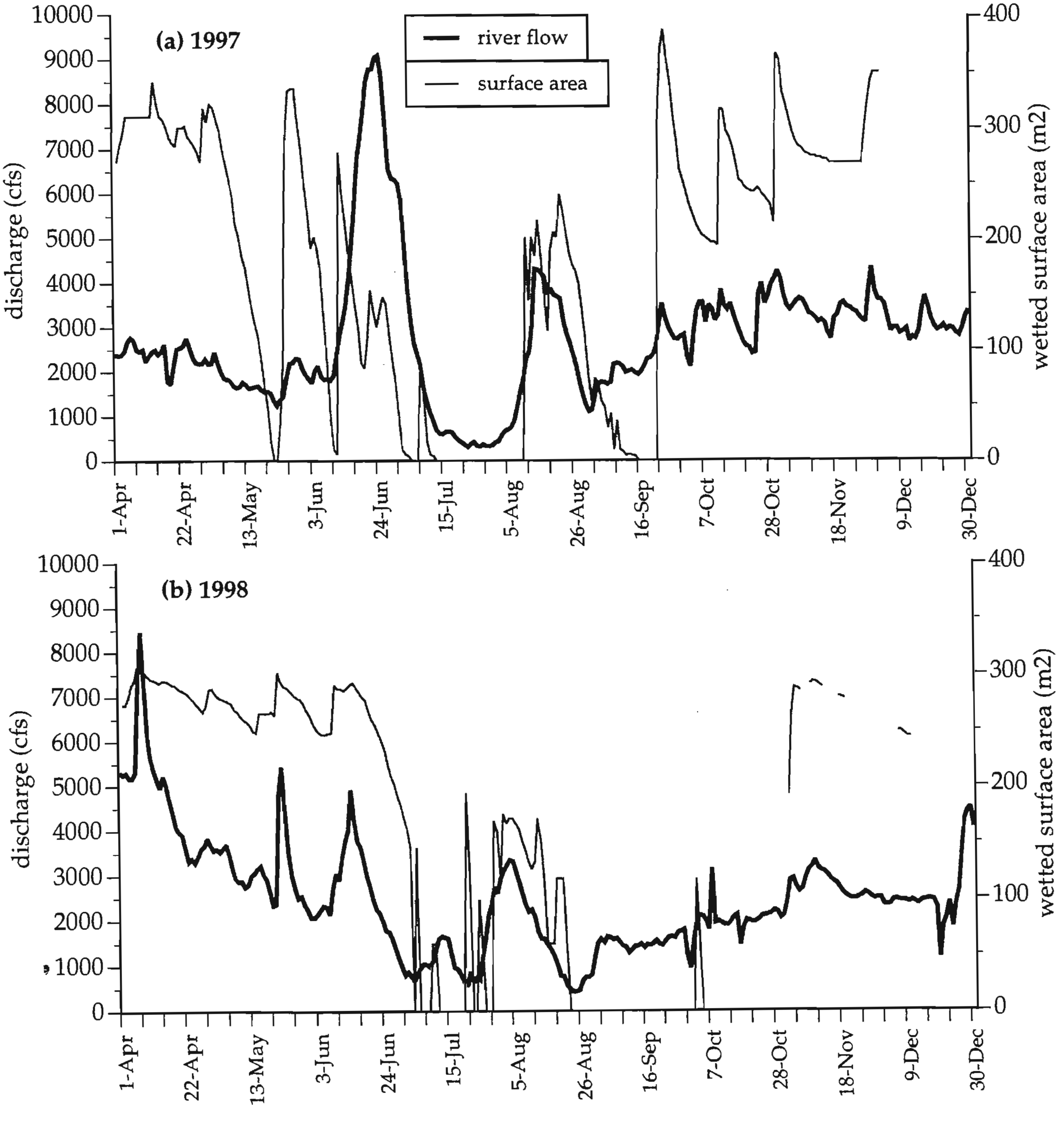

Figure 4. Abundance of emerging insects in the study wetlands. Bars show annual emergence abundance at each study site during 1997 (number of individuals/m2/yr). Sites are arrayed in order of increasing hydroperiod, and length of the hydroperiod (number of days) is given below each site name.

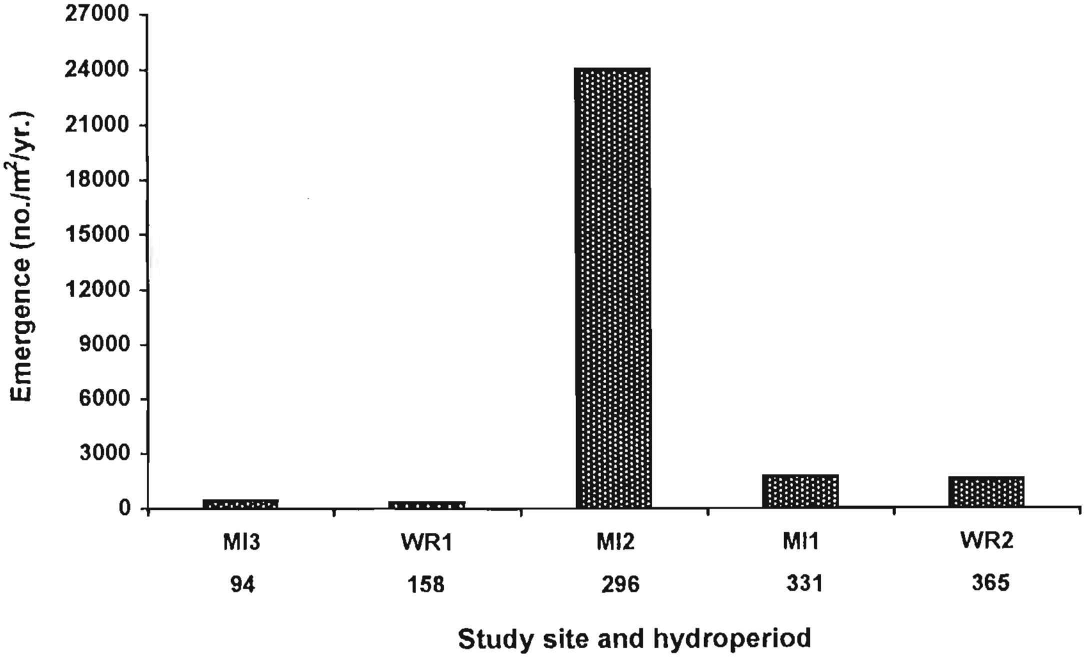

Figure 5. Emergence production in the five study wetlands. Bars show annual emergence production at each study site during 1997 (g DM/$m^2$/yr). Sites are arrayed in order of increasing hydroperiod, and length of the hydroperiod (number of days) is given below each site name.

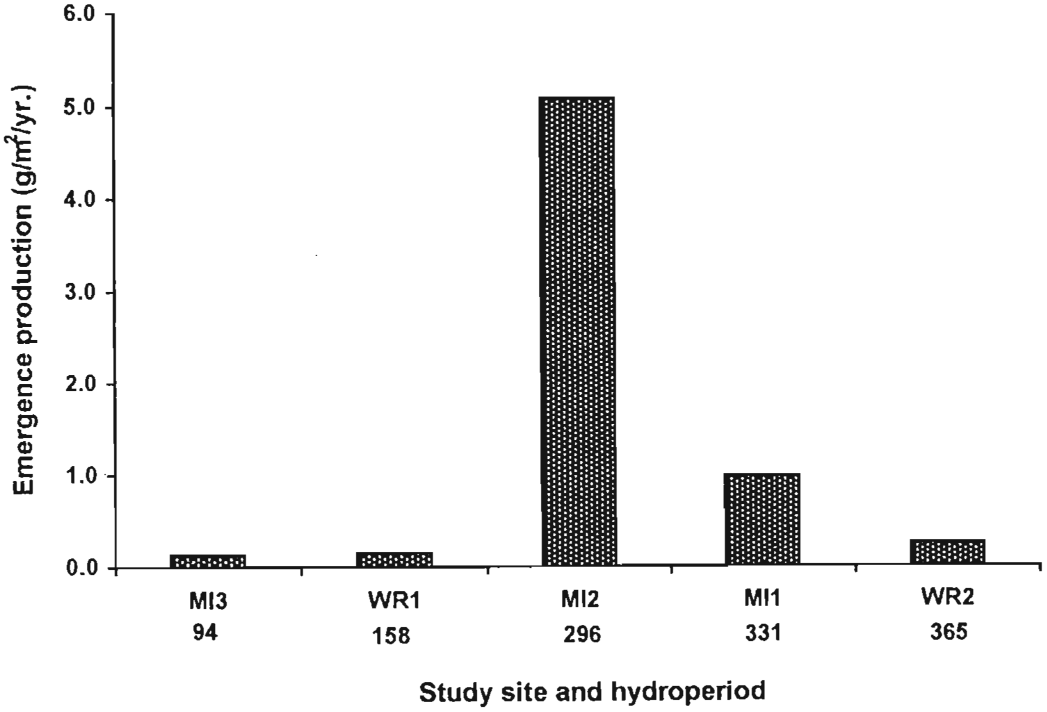

Figure 6. Total annual emergence production in the five study wetlands (g DM/yr). Total emergence production is calculated by multiplying areal production (per $m^2$) and average wetted surface area of each site ($m^2$) during sampling intervals. Sites are arrayed in order of increasing hydroperiod.

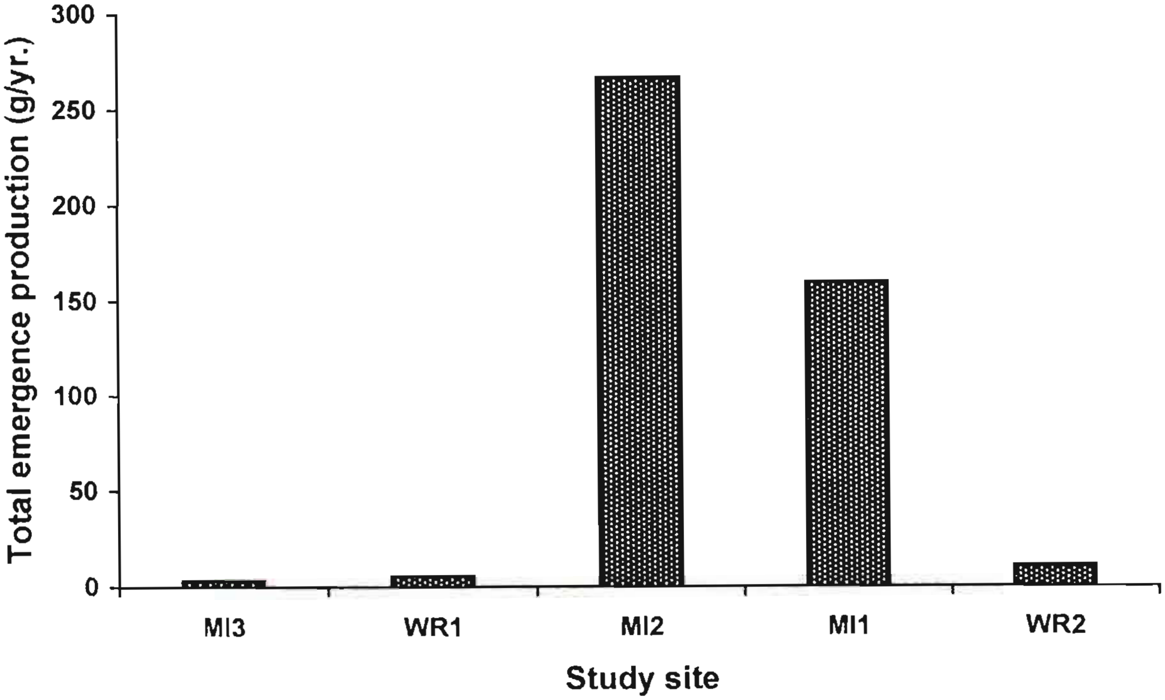

Figure 7. Seasonal changes in emergence production and wetted surface area of the five study wetlands. Bars show emergence production for the one-month period ending on the date of bar placement (g DM/$m^2$/sampling interval). Lines show wetted surface area of each study site ($m^2$) daily. A. Mormon Island 1 (intermittent site). B. Mormon Island 2 (intermittent site). C. Mormon Island 3 (ephemeral site). D. Wild Rose 1 (ephemeral site). E. Wild Rose 2 (perennial site). (Note that scales vary.)

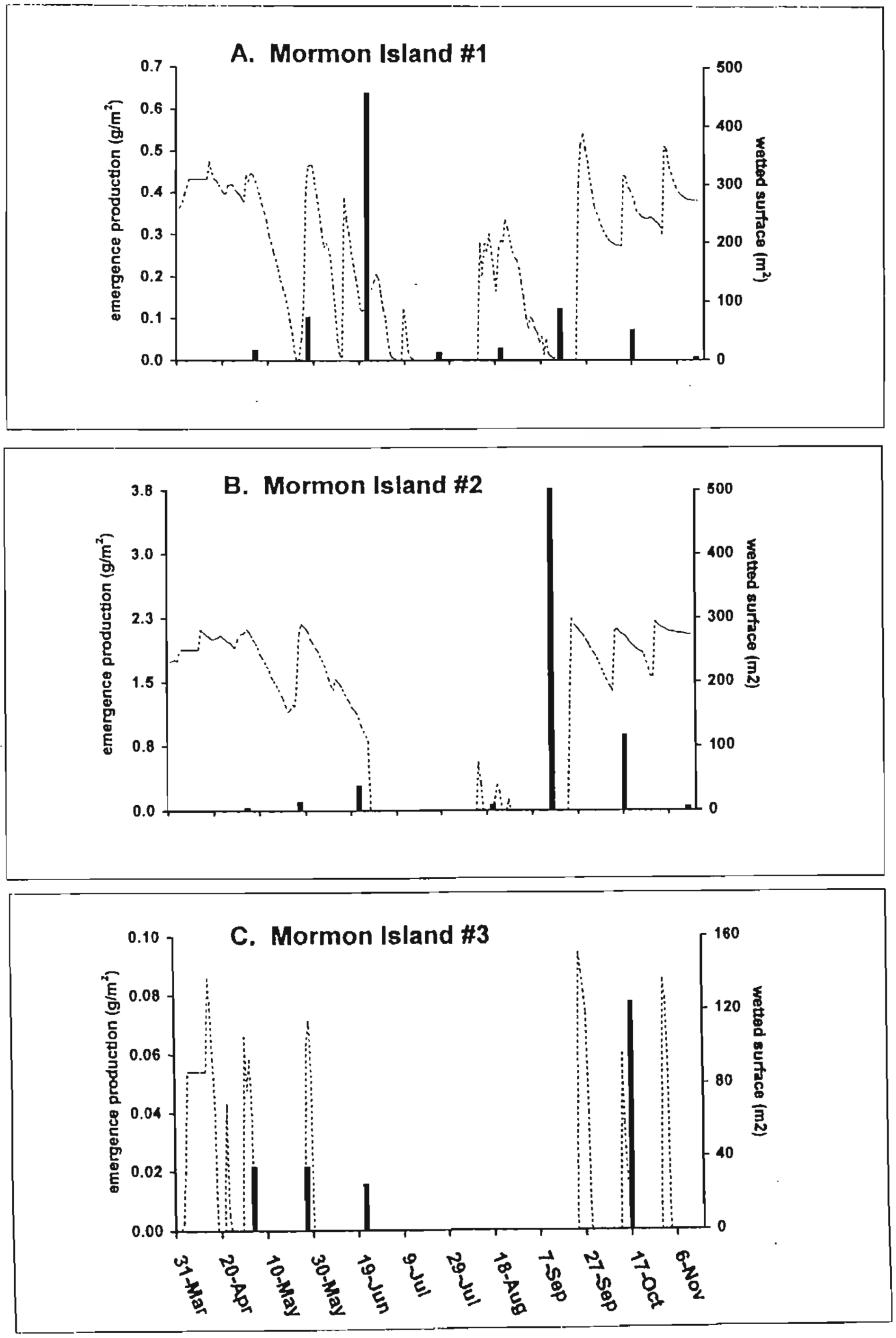

Figure 7 (continued)

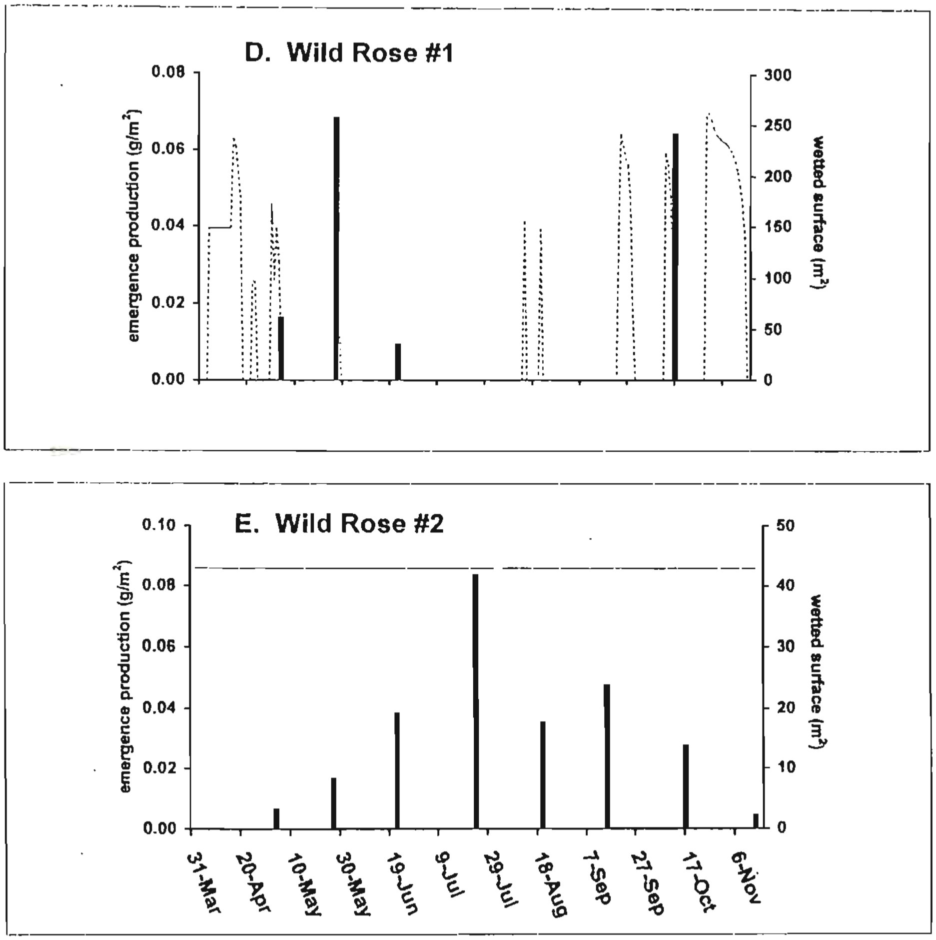

Figure 8. Relationship between hydroperiod and taxon richness of emerging insects at the five study wetlands. Taxon richness is the total number of emerging insect taxa collected at each site (insects were identified to genus or, in some cases, family level). The data fit a quadratic equation, as shown.

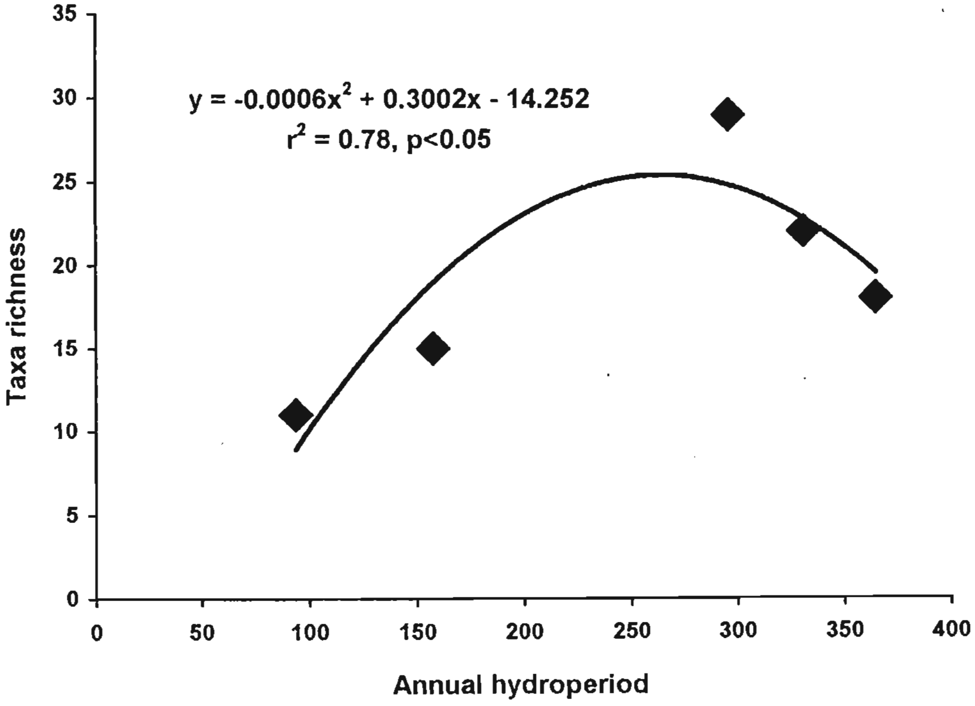

Figure 9. Relationship between hydroperiod and unique taxa of emerging insects at the five study wetlands. Number of unique taxa per site is calculated as the total number of emerging insect taxa that were collected only at that site (taxa determined at genus or family level). The data fit a quadratic equation, as shown.

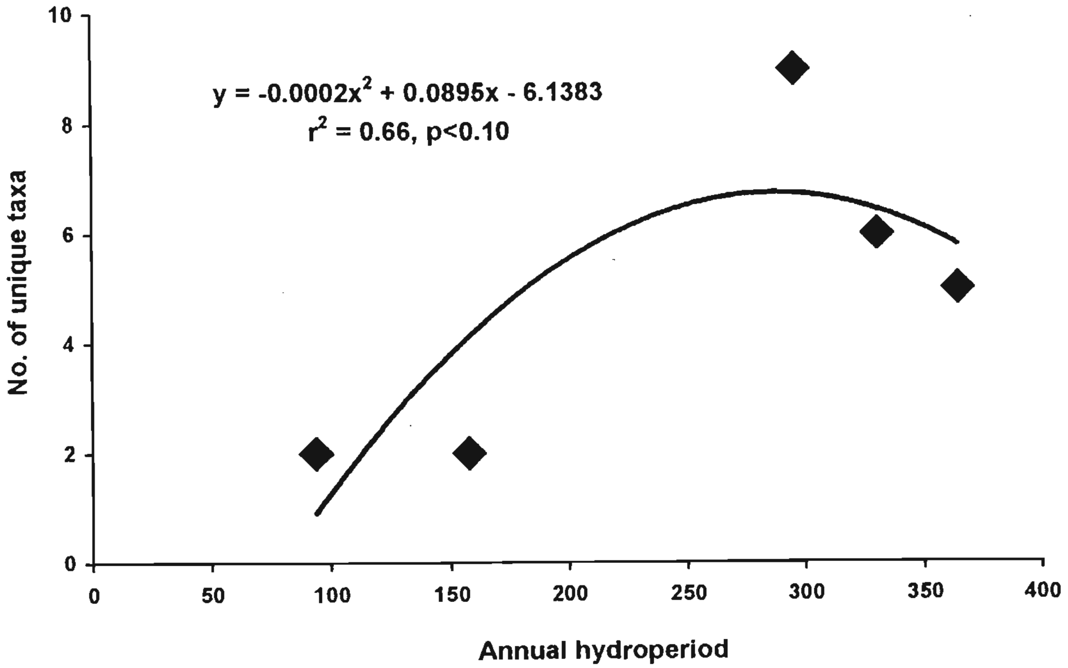

Figure 10. Amphibian captures at the five study wetlands. Bars represent the total number of captures from all five study sites during each month from April-December in (a) 1997 (top) and (b) 1998 (bottom).

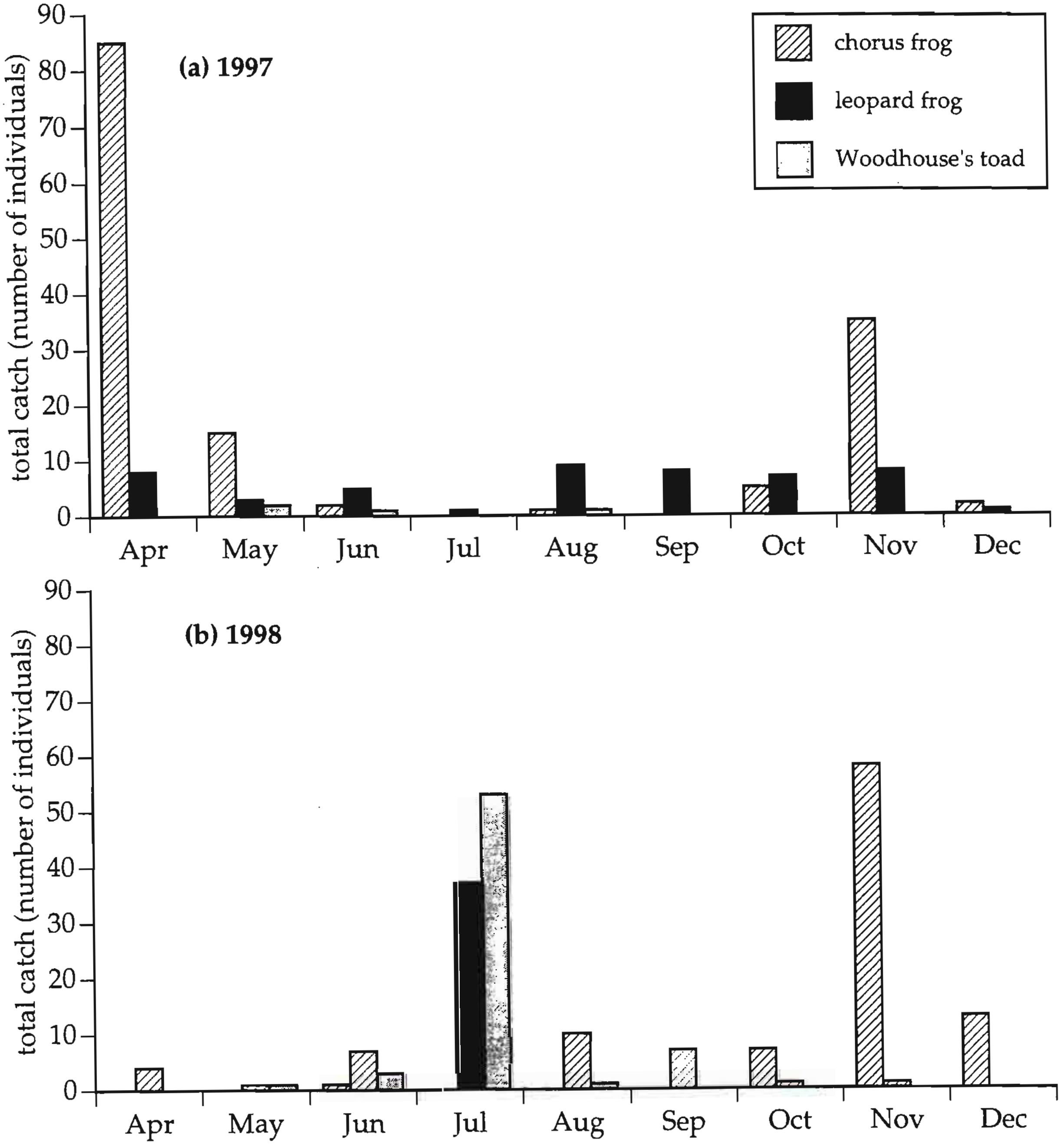

Figure 11. Relationship between hydroperiod and number of chorus frogs (*Pseudacris triseriata*) captured at the five study wetlands. Catch is the total number of individuals captured during April-December (length of sampling period=274 days) in (a) 1997 (top) and (b) 1998 (bottom). The data fit quadratic equations, as shown; the relationship was significant in 1997 ($p<0.05$) but not in 1998.

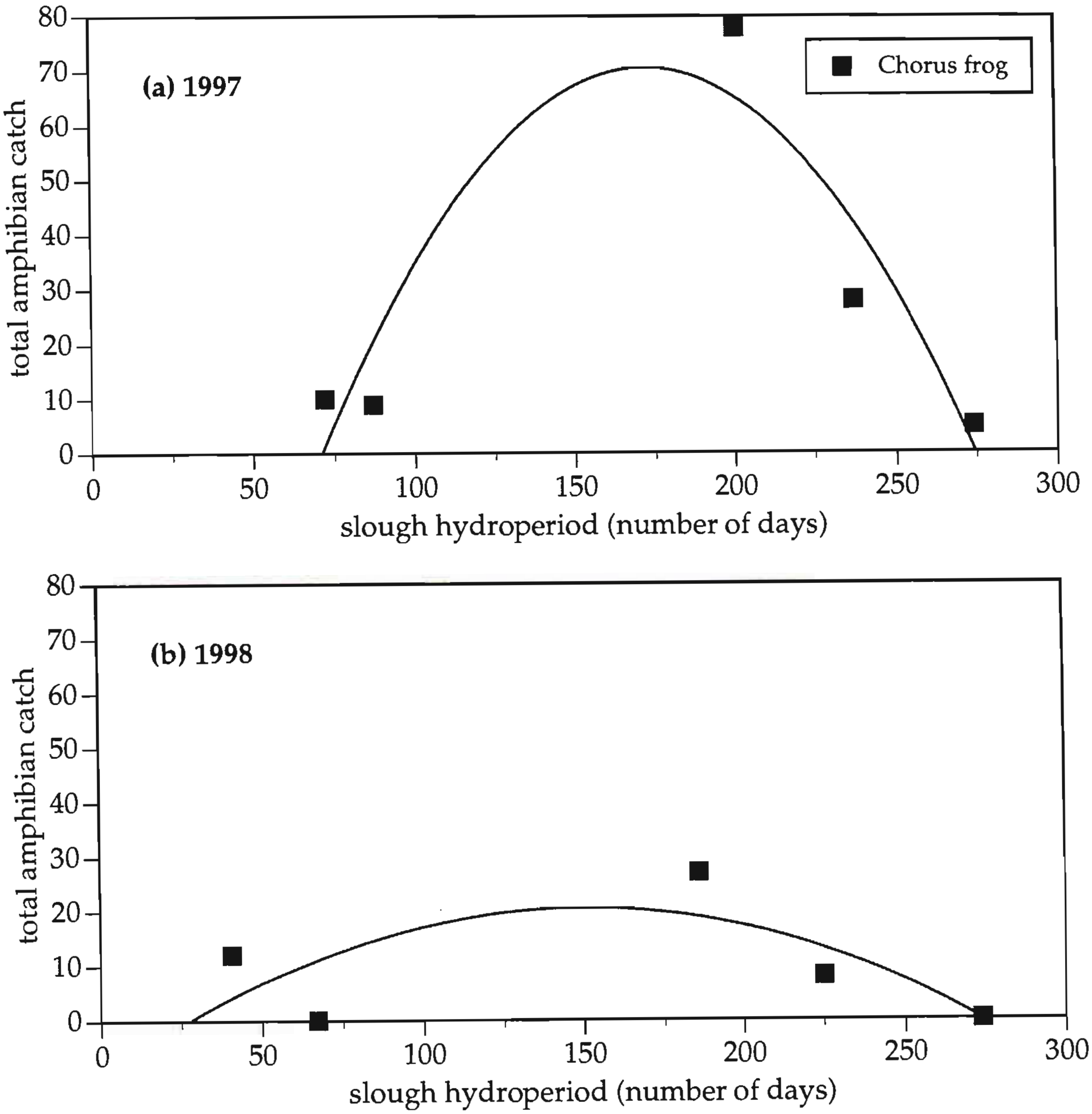

Figure 12. Relationship between hydroperiod and number of leopard frogs (*Rana blairi*) captured at the five study wetlands. Catch is the total number of individuals captured during April-December (length of sampling period=274 days) in (a) 1997 (top) and (b) 1998 (bottom). The data fit exponential equations, as shown; the relationship was significant in 1997 ($p<0.01$) but not in 1998.

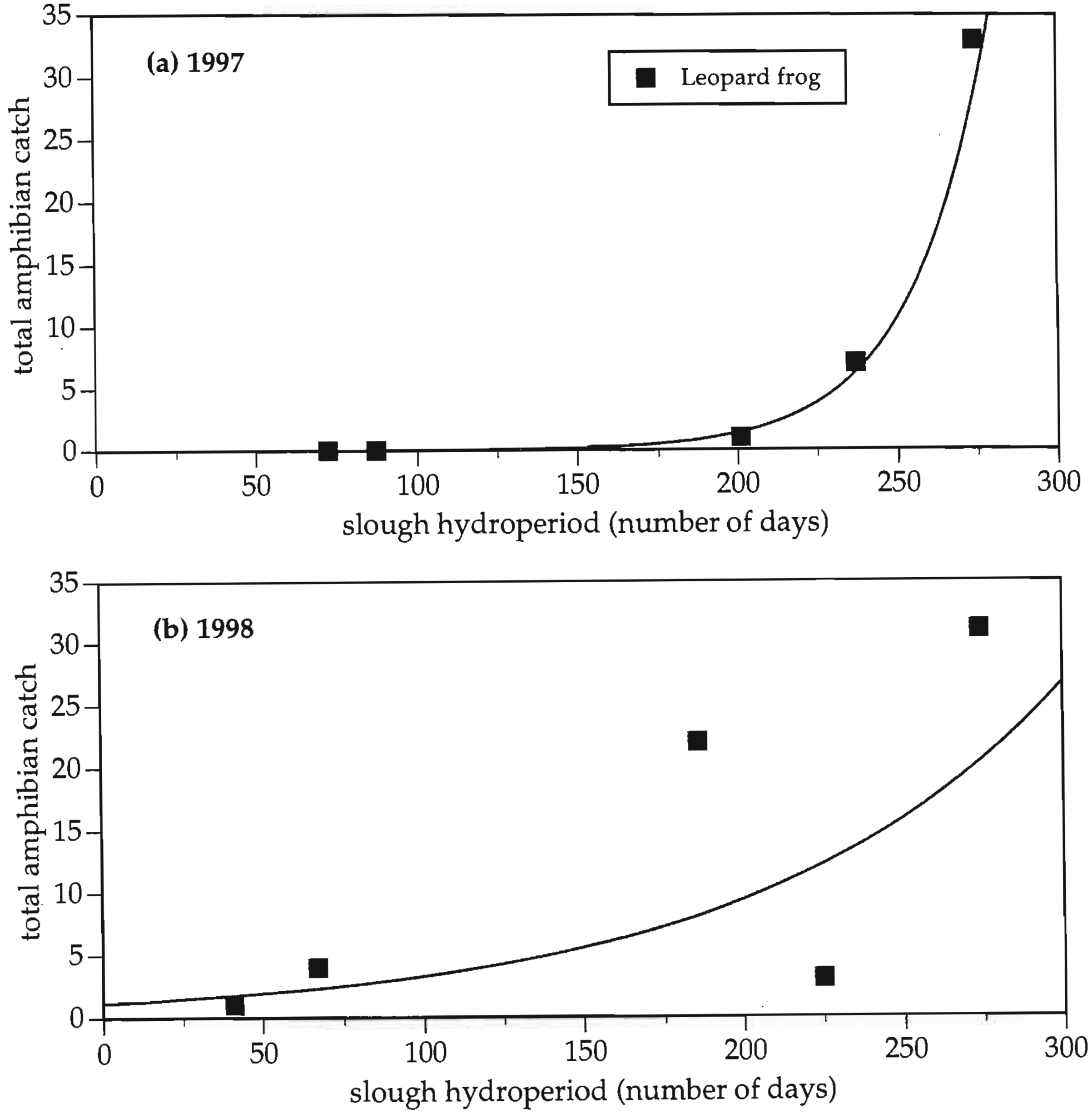

Figure 13. Relationship between hydroperiod and number of Woodhouse's toads (*Bufo woodhousii*) captured at the five study wetlands. Catch is the total number of individuals captured during April-December (length of sampling period=274 days) in (a) 1997 (top) and (b) 1998 (bottom).

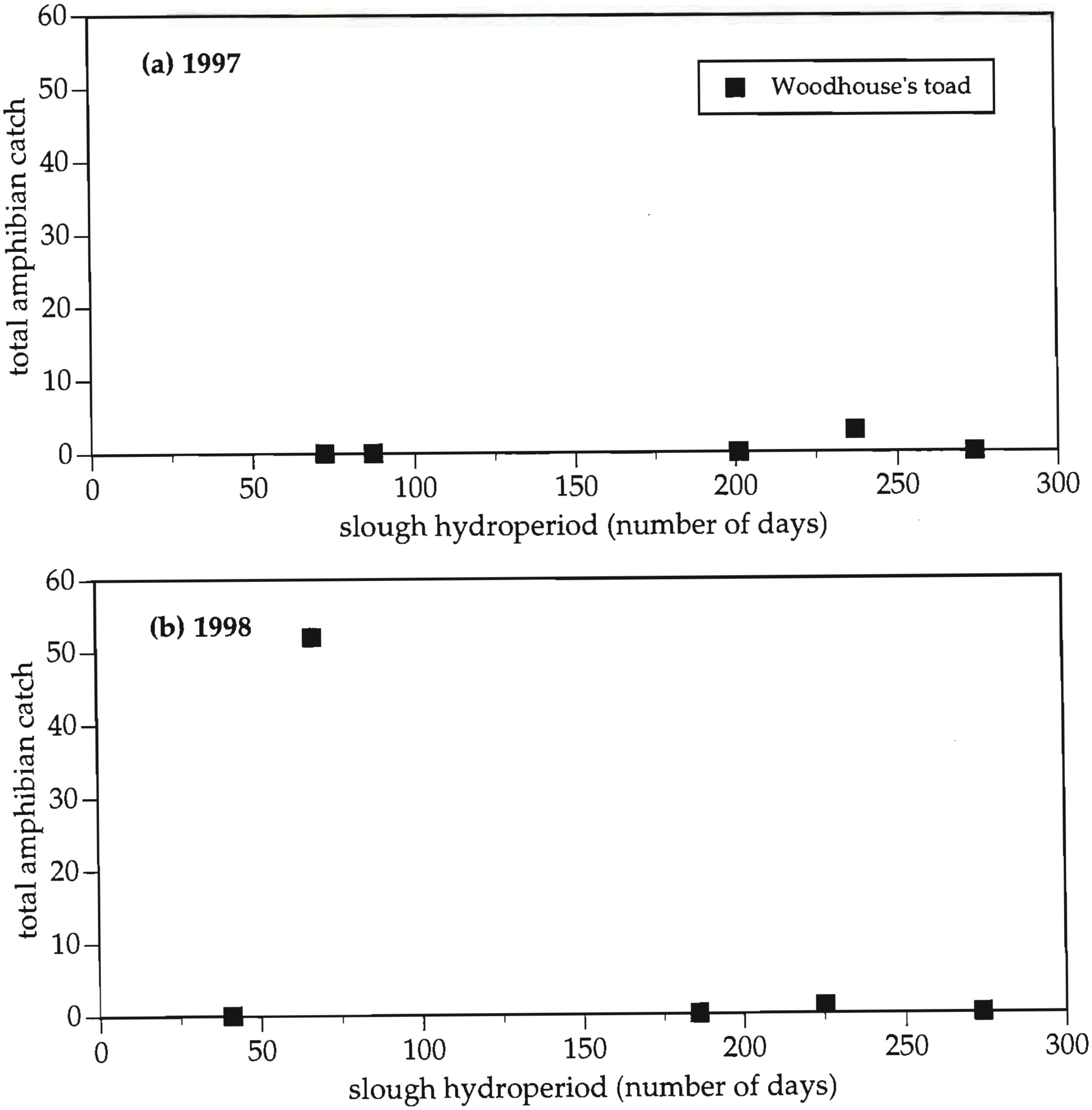

Figure 14. Relative abundance of fishes collected at the intermittent site, Mormon Island 1. Bars show the proportional contribution of each species to the total collection during each month from April-December in (a) 1997 (top) and (b) 1998 (bottom). This slough dried during July of both years. Fish sampling was not conducted in November and December 1997 and December 1998, because the slough was completely covered by ice.

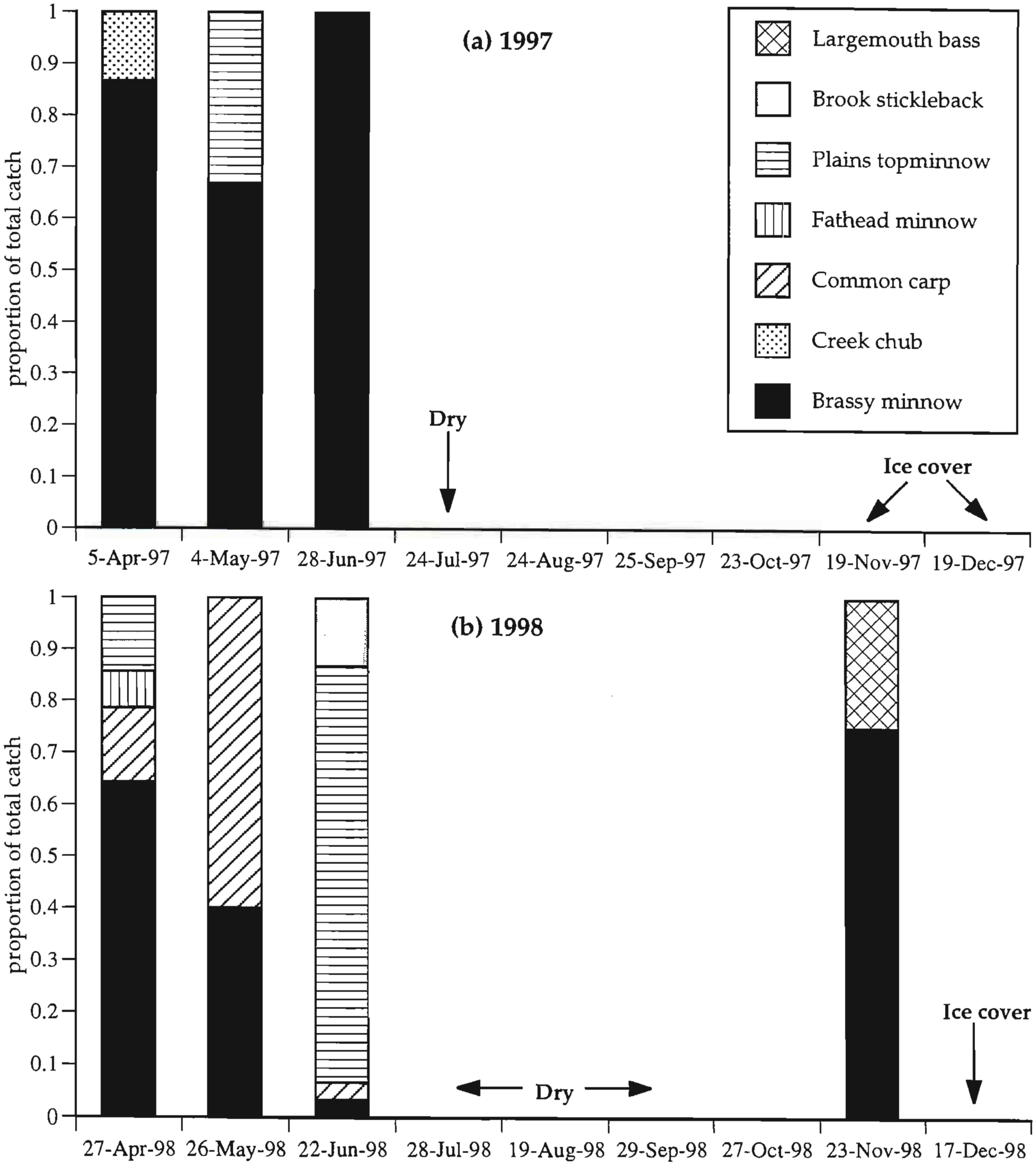

Figure 15. Relative abundance of fishes collected at the perennial site, Wild Rose 2. Bars show the proportional contribution of each species to the total collection during each month from April-December in 1997 (top) and 1998 (bottom). Six species that contributed less than 5% each to the total are grouped together ("others").