AN ABSTRACT OF THE THESIS OF

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in Biology presented on April 18, 1996

Title: Effects of Successional Stage and Plant Association on Moist Soil Unit Macroinvertebrates.

Abstract Approved: Elmer J. Finck

Aquatic macroinvertebrates are an important food resource for waterfowl wintering and staging in seasonally flooded impoundments. Therefore, it is important to manage these areas for maximum production of this food resource. The abundance of aquatic macroinvertebrates in seasonally flooded moist soil units is commonly linked to the type of vegetation present, with early successional stage plants typically having higher numbers of species and greater biomass relative to later successional stages. Little work has been done in Kansas wetlands to ascertain which successional stages produce the highest amount of aquatic macroinvertebrates, so management practices can be employed to ensure an optimal yield of this resource. Additionally, little work has been done to determine which plants are associated with the highest production of aquatic macroinvertebrates and what time of the year aquatic macroinvertebrates are in high enough numbers to be an important food resource in east-central Kansas.

To determine what time of year, what age and what plant associations have the highest number, greatest biomass and highest diversity of aquatic macroinvertebrates I sampled 0,

1, 2, 3 and 20 year old moist soil units on the Flint Hills National Wildlife Refuge (FHNWR) in Lyon and Coffey counties, Kansas and on adjacent private land (McKinney Marsh) in Coffey County, Kansas. After sampling vegetation, I selected the top ten plant association types occurring within these moist soil units and used them to test for differences in invertebrate biomass, number, and diversity among different plant groupings. I captured aquatic macroinvertebrates through the use of activity traps and a core sampler in 8 separate moist soil units during the period of 29 September 1992 to 30 April 1993.

I collected macroinvertebrates from a total of 60 activity traps and 60 core samples for each unit. I found 28 families within 9 orders of aquatic macroinvertebrates during my study. Significant differences were found among the trap and core sample means for both moist soil unit and plant association type invertebrate mean biomass, mean number, and diversity by month, with the exception of moist soil unit trap diversity by month. In most cases biomass, number and diversity were higher in the fall than the winter and spring, suggesting that invertebrates are potentially more important as a food resource to waterfowl staging on the FHNWR rather than overwintering waterfowl.

Although I expected earlier successional stages to have higher amounts of invertebrates, no significant differences were found among the trap and core samples for moist soil unit invertebrate mean biomass, mean number, and diversity

by successional stage, with the exception of moist soil unit mean core biomass by successional stage. I attribute this lack of significance to the flooding that covered my study sites with up to 5 m of water during parts of November through March and prevented access for several weeks at a time. The flooding washed away a majority, and in some cases all, of the standing vegetation and detritus on my study sites.

Similarly, I found no significant differences among the trap and core samples for plant association type invertebrate mean biomass, number, and diversity, with the exception of core diversity. Again I attribute this lack of significance to the flooding.

Although my study is inconclusive relative to the relationship between aquatic macroinvertebrate presence and moist soil unit successional stage and plant association, it has provided a starting point, some baseline data for future research on the FHNWR, and may indicate the importance of flooding as a disturbance to aquatic macroinvertebrate communities in moist soil units.

EFFECTS OF SUCCESSIONAL STAGE AND PLANT ASSOCIATION ON MOIST SOIL UNIT MACROINVERTEBRATES

A Thesis

Submitted to

the Division of Biological Sciences

Emporia State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

By

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May 1996

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all who have helped me in my research. I would like to give special thanks to my major advisor, Dr. Elmer Finck, for his guidance, encouragement, and faith in my ability, my wife, Julia Crider, for her support and assistance in the field, Bernard Sietman for providing invertebrate traps and field assistance, Dr. Larry Scott for his statistical advice, my committee members, Dr. Dwight Moore, and Dr. Carl Prophet for their guidance and help in writing this manuscript, and Dave Wiseman and Mark Vanamin at the Flint Hills National Wildlife Refuge for their assistance and cooperation. Lastly, I would like to thank my grandfather, Compere Loveless, for his wisdom and spirit, and my parents, Francis Earl Durbian II and Dr. Jeanne Ramirez, for their encouragement and allowing me to "roam amongst the environment," which is the basis for all I have done.

PREFACE

My thesis has been prepared in the style appropriate for the Transactions of the Kansas Academy of Science.

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INTRODUCTION

Because of the loss of 54 percent of our nation's wetlands since European settlement (Tiner, 1984) and the limited resources available for the management and preservation of existing wetlands it is becoming increasingly important to obtain maximum benefits from these areas for waterfowl and other wildlife. Management of these areas for waterfowl is especially critical due to the recent downward trend in numbers of ducks. The 1970 fall flight index estimated 94 million ducks (U. S. Fish and Wildlife Service and Canadian Wildlife Service, 1987), while the 1989 fall flight index estimated 64 million (U. S. Fish and Wildlife Service and Canadian Wildlife Service, 1989), which is the second lowest index on record.

Many wetlands are man-made seasonally-flooded impoundments that require careful manipulation of water level to encourage growth of desirable plants (Merendino et al., 1990; Merendino and Smith, 1991), those plants that provide good food and/or cover for waterfowl. A wetland in which water level manipulation takes place is commonly referred to as moist soil unit (MSU). Depending on the area and wetland, benefits to waterfowl may include nesting, brood, wintering, and staging habitats (migration stopover areas). In Kansas, MSUs are usually managed as staging and overwintering habitats. Wintering areas are important as they provide food to enable waterfowl to survive through the winter and then to migrate in the spring. Staging areas are

important because in these areas waterfowl obtain the nutritional requirements for migration and breeding.

Moist soil units in Kansas are typically managed to produce natural plant foods and cover, but may also contain some row crops. Although row crops may provide a high energy food resource, they are typically only available to larger species of waterfowl, such as geese and mallards (Anas platyrhynchos), and typically provide poor cover for waterfowl (Fredrickson and Taylor, 1982). Additionally, naturally occurring moist soil plants are more productive under adverse climatic conditions than row crops that may have a higher rate of failure (Burgess, 1969; Fredrickson and Taylor, 1982).

Management of MSUs usually involves water drawdowns, fire, farming, mechanical manipulation, and sometimes grazing to set back seral successional stages of plants. If these techniques are used effectively the resulting plant communities may initially be highly productive food resources for waterfowl. Vegetation is typically managed for the production of seeds and young palatable shoots that may serve the nutritional needs of waterfowl. Even though seasonal flooding of impoundments sets back seral stages of succession, moist soil plant succession is still taking place and the plant communities in these impoundments vary from year to year (Fredrickson and Taylor, 1982; Valentine, 1984). Thus, as a MSU ages, undesirable plants, from a

waterfowl management perspective, tend to become dominant. Givens and Atkeson (1957) reported that first year MSUs, in the southeastern United States, provided many plant species desirable as waterfowl food, while woody invasion began the second year and by the third year 90% of the desirable waterfowl food plants had been crowded out. In a six year study on the effects of drawdown date on plant succession in Ohio MSUs, Meeks (1969) reported that all of his study units, with the exception of one, followed the same general trend of plant succession, going from semi-aquatic species to predominantly annual weeds. Low and Bellrose (1944) reported that in wetlands, fewer waterfowl foods are available as succession proceeds.

Aside from the desirable plants, MSUs produce another valuable food resource in the form of macroinvertebrates (Fredrickson and Taylor, 1982). Seasonally flooded impoundments tend to produce high densities of aquatic macroinvertebrates (Neckles et al., 1990) that make them important feeding areas for waterfowl and good candidates for aquatic macroinvertebrate oriented management.

The significance of aquatic macroinvertebrates in the diets of waterfowl has been recognized for many years (Fredrickson and Reid, 1988a). Invertebrates are a major food resource for ducks throughout the annual cycle (Fredrickson and Reid, 1988a) and provide a rich source of protein, when compared to the protein found in seeds (Krapu

and Swanson, 1975). Aquatic macroinvertebrates are also a source of fatty acids nutritionally important to female mallards during the winter (Heitmeyer and Fredrickson, 1990).

Several studies have indicated the importance of aquatic macroinvertebrates as a food resource for waterfowl. In the following citations I used aggregate percentage volume, unless otherwise stated, to describe the quantity of aquatic macroinvertebrates consumed, as this measurement appears to be the least biased method in which food habits are reported (Swanson et al., 1974). A food study, conducted in the United States and Canada, of 16 species of ducks including the mallard, american black duck (Anas rubripes), mottled duck (Anas fulvigula), gadwall (Anas strepera), American widgeon (Anas americana), green-winged teal (Anas crecca), blue-winged teal (Anas discors), cinnamon teal (Anas cyanoptera), northern shoveler (Anas clypeata), redhead (Aythya americana), ring-necked duck (Aythya collaris), canvasback (Aythya valisineria), greater scaup (Aythya marila), lesser scaup (Aythya affinis), common goldeneye (Bucephala clangula), and ruddy duck (Oxyura jamaicensis), in which Martin and Uhler (1939) analyzed 7,998 stomachs, revealed that molluscs, crustaceans and insects occurred 23.02% (by volume) overall in the diet of the cumulative sample. Jones and Drobney (1986) reported that in Michigan the diets of wintering greater scaup

consisted of 24% macroinvertebrates, for lesser scaup 19% and for common goldeneye 21%. In a study of fall and winter diets of northern pintails (Anas acuta) in California, Miller (1987) found plants made up a majority of the diet during the summer, fall and early winter, while invertebrates became an important food during the late winter (February and March) and made up 28.2% of the diet. Afton et al. (1991) reported that invertebrates were the most important food for lesser scaup during spring migration (88.3%) and winter (60.9%) in the Mississippi Flyway. Research on the food habits of ruddy ducks in California revealed that 90.7% of the diet was composed of invertebrates (Hohman et al., 1992). Thompson et al. (1992) found that invertebrates, mainly gastropods, constituted 98% of blue-winged teal diets and 98.6% of northern shovler diets during the early winter period (October to December 15) in Yucatan, Mexico. Blue-winged teal and northern pintails (no data were available for northern pintails during the early winter period) fed on plant matter during the late winter period (after December 15), while northern shovlers continued to rely on invertebrates (75%). Similar results from Sinaloa, Mexico have been reported by Migoya and Baldassarre (1993). They found that invertebrates made up at least 29.2% of the diet of cinnamon teal, 18.9% for green-winged teal, 9.1% for northern pintails, and 32.6% for northern shovlers.

Conversely, several studies on the food habits of waterfowl have shown that invertebrates comprise only a small proportion of the diet. In a study on the feeding ecology of gadwalls wintering in Louisiana, Paulus (1982) found that macroinvertebrates only constituted 3.1% of the diet, but did no sampling to determine the relative abundance of macroinvertebrates in the area. Jorde et al. (1983) found macroinvertebrates constituted <1% of the diet of mallards wintering in Nebraska, but attributed this to the low abundance of macroinvertebrates and the lack of availability of macroinvertebrates due to freeze up. Gruenhagen and Fredrickson (1990) found invertebrates to make up 1.9% - 21.0% of the diet of migrating female mallards in northwestern Missouri, but they stated that this could be low due to the increased need for high energy foods such as agricultural crops rather than a need for foods high in protein. Botero and Rusch (1994) found that invertebrates made up only 8% of blue-winged teal diets, during 1982-83, in Palo Verde Wildlife Refuge, Costa Rica. They found similar results in Cienaga Grande de Santa Marta, Columbia with invertebrates constituting only 29% of blue-winged teal diets during 1979-80. During 1985-88 they found that invertebrates made up 91% of blue-winged teal diets and attributed the increase of invertebrates in the diet to the increasing salinity of the area and the subsequent decrease in available plant foods.

Additional studies revealing the importance of invertebrates in the diet of waterfowl have also been conducted by Griffith (1948), Chura (1961), Kadlek (1962), Olney (1963), Rogers and Korschgen (1966), Dirschl (1969), Burgess (1969), Thompson (1973) and Swanson and Meyer (1973). Further evidence supporting the importance of invertebrates to waterfowl, based on the correlation of invertebrate presence and avian use of wetlands and lakes, has been reported by McKnight and Low (1969), Schroeder (1973), Joyner (1980), Kaminski and Prince (1981), Murkin et al. (1982), Murkin and Kadlec (1986), McNicol and Wayland (1992), Parker et al. (1992), Hanson and Butler (1994) and Staicer et al. (1994).

As mentioned previously, MSUs undergo succession that leads to the dominance of undesirable plants, relative to waterfowl management, that in turn may affect invertebrate production because invertebrate populations are linked to the type of vegetation present (Krull, 1970; Hanson, 1990). Evidence for the linkage of invertebrate populations to various plant communities has been suggested by Fredrickson and Reid (1988a) who stated, "The composition of invertebrate populations is associated with plant succession." Voigts (1976) found the largest number and greatest diversity of aquatic invertebrates in open habitats interspersed with submergent and emergent vegetation (hemi-marsh). Hemi-marsh is a type of habitat frequently

associated with the earlier stages of succession, while the later stages of succession are characterized by more emergent vegetation. Emergent vegetation typically has a majority of its leaves and stems above the surface of the water, thus reducing the amount of food and cover available for macroinvertebrates. Krull (1970) suggested that plants with greater vegetative surface areas harbor more taxonomic groups, higher number, and greater weights of aquatic macroinvertebrates associated with them. In a study conducted on invertebrate abundance on pondweed (Potamogeton nodosus) Beckett et al. (1992) found a positive correlation between plant surface area and invertebrate abundance, as did Gerrish and Bristow (1979) in a similar study. Beckett et al. (1992) went on to suggest that management techniques that eliminated plants would reduce invertebrate abundance and therefore their availability to waterfowl. Bergey et al. (1992) also found a positive correlation between pondweed (Potamogeton pectinus) biomass and the densities of four invertebrate genera. Further evidence for the linkage of invertebrates and aquatic vegetation has been reported by Krecker (1939), McGaha (1952), Rosine (1955), and Moyle (1961). It appears that management for specific plant communities may be the most practical means of increasing invertebrates (Fredrickson and Reid, 1988a). However, not all species of plants that are considered good waterfowl foods harbor large quantities of invertebrates and

conversely some plants that are considered poor as waterfowl food may be good habitat and food for macroinvertebrates (Krull, 1970). There are many questions concerning macroinvertebrate-plant associations that remain unanswered.

Little work has been done in the wetlands of Kansas to discover which plant associations and which wetland successional stages produce an optimal amount of aquatic macroinvertebrates that can be used as a food resource by waterfowl and other wildlife. The purpose of my study is to test the following hypotheses: 1) The age of moist soil units is correlated with specific plant associations, that is younger moist soil units will contain early successional stage plants and older moist soil units will contain late successional stage plants, 2) different moist-soil plant associations produce different numbers, biomass, and diversity of aquatic macroinvertebrates, and 3) as fall becomes winter the number, biomass, and diversity of aquatic macroinvertebrates will decrease, and as winter becomes spring, these variables will increase. Diversity is being used as a variable because Joyner (1980) found a positive correlation between duck usage of a particular pond and invertebrate numbers and taxa present, as did Kaminski and Prince (1981) in a similar study. Hypothesis 3 will demonstrate the significance of aquatic macroinvertebrates in relationship to staging and overwintering waterfowl.

MATERIALS AND METHODS

I studied MSUs in east-central Kansas on the Flint Hills National Wildlife Refuge (FHNWR) and on adjoining private land (McKinney Marsh) during the fall, winter, and spring of 1992-1993 (Figure 1). These areas are located in the Neosho River Basin in both Lyon and Coffey counties. The river basin consists of riparian timber interspersed with agricultural croplands, including wheat, sorghum, corn, soybeans, and fallow cropland, as well as Conservation Reserve Program (CRP) grasslands. The uplands surrounding the river basin are composed of rolling hills (Osage Cuesta) that contain native tallgrass prairie, grazed pastures and CRP, and some patches of the agricultural crops listed previously. The wetlands in this area are typically small (< 10 ha) and shallow (< 1 m) man-made impoundments consisting of a single pool with a dirt dike and water control structure on the drainage side. These MSUs are flooded on a seasonal basis, usually in late September-early October, and drained in late spring. They can be flooded with natural run off or water pumped from the Neosho River. Management is structured towards staging and overwintering waterfowl and consists of seasonal drawdowns, mowing and discing to enhance the production of early successional stage moist soil plants.

Age classes included 0, 1, 2, 3 and 20 year old MSUs (Figure 1). The age refers to the number of years each MSU has been in production as a wetland or the age from the last

disturbance, whichever is most recent. The 0, 1, 2, and 3 year old MSUs represent early successional stage wetlands, while the 20 year old MSUs represent late successional stage wetlands. Two replicates were used for all age classes of MSUs except the 2 and 3 year age classes for which no replicates were available.

I determined what major plant communities were present in each MSU, through visual observation, and used these as my sample sites within each MSU. I selected three sample sites, within each major plant community, for each MSU. Within each site I established a randomly selected transect consisting of 5 metal fence posts, 2 m apart, for my permanent trap site markers, giving me a total of 15 trap sites for each MSU. To determine the composition of the plant associations that occurred in each MSU, and their respective percent cover, I centered a 1 m square polyvinyl chloride frame around each fence post to use as my quadrant. I then identified and estimated percent cover for each genus present in the quadrant (Table 1). Macrophyte identification was based on a key by Prescott (1980).

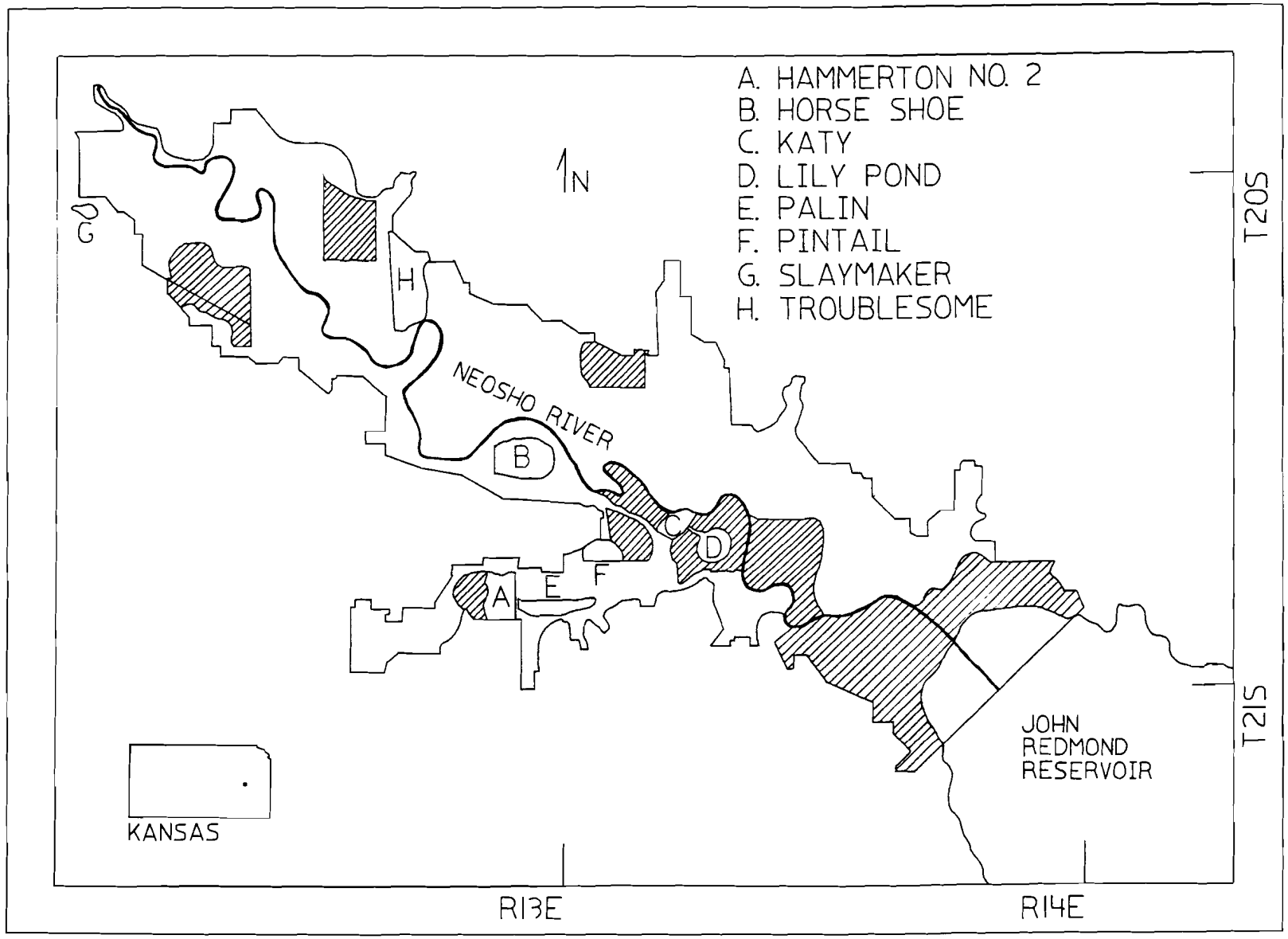
I started sampling invertebrates when the MSUs were flooded in late September-early October and continued to sample until the end of April. My original intention was to sample two MSUs per day, for a period of four days each month, so that each of the eight units would be sampled once every 28 days for a period of seven months, giving me seven

samples for each MSU. Because of severe flooding I actually only obtained four samples from each MSU, representing four months of data.

Water column macroinvertebrates were sampled with activity traps, similar to those described by Murkin et al. (1983). Each activity trap consisted of a 3.78 l wide mouth jar with a funnel inverted into the mouth of the jar. The funnel served as a channel to guide invertebrates into the jar and was attached to the jar with wire. The funnel stem had an opening of 2.5 cm. Activity traps, which capture only actively swimming or drifting animals, standardize the procedure, provide samples free of plant material and work well in areas with heavy emergent vegetation (Fredrickson and Reid, 1988b; Murkin et al., 1983), that are typical of the MSUs on the FHNWR. Traps were attached to the fence post marker pole and suspended horizontally in the middle of the water column at a randomly chosen depth. Traps were set for a period of 24 hours. At the end of each sample period the contents of the trap were washed through a sieve and all invertebrates were preserved in a 5% ethyl alcohol solution for later identification and determination of biomass in the laboratory.

One core sample was also taken at each trap site to obtain benthic macroinvertebrate samples, using a modified core sampler developed by Swanson (1983). These samples were washed in a floating screen (Swanson, 1978) and all

Fig. 1. A map of the Flint Hills National Wildlife Refuge. The MSUs utilized in my study are marked by a letter and the hatched region represents other existing MSUs. The number of years since the last disturbance for each MSU are as follows: A=20, B=20, C=0, D=1, E=3, F=2, G=0, and H=3.


A. HAMMERTON NO. 2
B. HORSE SHOE
C. KATY
D. LILY POND
E. PALIN
F. PINTAIL
G. SLAYMAKER
H. TROUBLESOME
N
NEOSHO RIVER
A
B
C
D
E
F
G
H
JOHN
REDMOND
RESERVOIR
KANSAS
T20S
T21S
R13E
R14E

invertebrates were preserved in a 5% ethyl alcohol solution for later identification and determination of biomass in the laboratory.

Macroinvertebrates were identified to family, which is adequate for management studies (Fredrickson and Reid, 1988b). Keys (Pennak, 1978; Lehmukuhl, 1979) were used to aid in identification. After identification and quantification, all samples were dried to a constant weight at 105 degrees celsius for biomass estimates. A Metler balance was used to weigh samples to the nearest 0.0001 g.

I then calculated a mean per trap/core sample for the total number of individual invertebrates and total invertebrate biomass for each MSU by month (Tables 4 and 5). These means were in turn used in the statistical analysis. Therefore, whenever a "mean" is mentioned in the results of the statistical analysis I am actually referring to the grand mean, which consists of the mean of the means for each MSU. I also calculated a Shannon-Weaver diversity index for each MSU by month and sample technique (Tables 4 and 5).

I used one way repeated measures analysis of variance (Zar, 1984) to test for differences between the following variables: invertebrate mean biomass per trap sample, mean biomass per core sample, mean number per trap sample, and mean number per core sample, by age (successional stage). To test for differences between invertebrate mean biomass per trap sample, mean biomass per core sample, mean number

per trap sample, and mean number per core sample, by month, I used one way analysis of variance (Zar, 1984), as there were no repeated measures for individual units within each month of data. I also tested for differences between invertebrate diversity per trap sample and diversity per core sample by age. Since the diversity index is calculated using a logarithm (base 10) I used Friedman repeated measures analysis of variance on ranks (Zar, 1984) to test for differences between calculated diversity indexes. Similarly, I used Kruskal-Wallis one way analysis of variance on ranks to test for differences between invertebrate diversity per trap sample and diversity per core sample by month (Zar, 1984).

When I originally selected the MSUs and ran vegetation transects I found that all of them, regardless of age, contained high proportions (based on percentage cover) of early successional stage plants (Table 1), thus rejecting my hypothesis 1. This demonstrated that the age of the MSU does not necessarily correspond to the stage of succession and that some of the older MSUs may contain similar biomass and number of aquatic macroinvertebrates as well as similar diversity, when compared to younger MSUs. I then concluded that it would be important to compare the production, in terms of biomass, number, and diversity of aquatic macroinvertebrates among the different plant groupings or associations that occurred within the MSUs I utilized. This

would enable me to tell if any differences in biomass, number, or diversity were due simply to the age of the MSU or due to the particular type or grouping of vegetation present (hypothesis 2). After examining my vegetation transects, I divided the data set into the most prominently occurring plant association type (PAT), based on order of occurrence, within the MSUs (Table 2). Six of these major plant groupings were monocultures and three were polycultures. Additionally, I used open water samples as one of the groupings, giving me a total of ten PATs. I classified all of the plant groupings as early successional stage based on the type of vegetation present. Therefore, I expected little or no difference in invertebrate mean biomass, invertebrate mean number, and invertebrate diversity. Any differences that might occur would most likely be due to differences in vegetation density or aquatic macroinvertebrate species specific-preferences for particular plant types. I calculated a mean per trap/core sample for invertebrate number and invertebrate biomass for each PAT by month and used these means (Tables 6 and 7) in the statistical analysis. Therefore, as discussed previously, whenever a mean is mentioned in the results of the statistical analysis I am actually referring to the grand mean. A Shannon-Weaver diversity index (Tables 6 and 7) was also calculated for each PAT by month and sampling technique. One way repeated measures analysis of variance

Table 1. The common names, genera and percent cover of plants and open water found within each MSU at FHNWR, Kansas.

MSU	Common Name	Genus	% Cover
Hammerton #2	Open Water		89
	Chara*	Chara	7
	Spike Rush*	Eleocharis	4
Horse Shoe	Open Water		71
	Smart Weed*	Polygonum	16
	Spike Rush*		8
	Pond Weed	Potamogeton	4
	Chara*		1
	Cotton Wood	Populus	1
Katy	Open Water		84
	Spike Rush*		13
	Smart Weed*		2
	Rag Weed*	Ambrosia	1
Lily Pond	Open Water		57
	Spike Rush*		31
	Smart Weed*		10
	Willow	Salix	1
	Pond weed		1
Palin	Open Water		82

Table 1 Continued.

MSU	Common Name	Genus	% Cover
	Smart Weed*		18
Pintail	Open Water		73
	Barnyard Grass*	Echinochloa	19
	Pigweed*	Amaranthus	7
	Cocklebur*	Xanthium	1
Slaymaker	Smart Weed*		61
	Open Water		31
	Bulrush*	Scirpus	7
	Cotton Wood		1
Troublesome	Reed Canary grass*	Phalaris	63
	Open Water		26
	Bulrush*		11

* Early successional stage plants

Table 2. PATs, abbreviation and total number (N) of quadrants sampled for each PAT.

Abbreviation	Plant Association Type	N
CHOP	Chara (*Chara spp.*)	6
SROP	Spike Rush (*Eleocharis spp.*)	13
BGPWOP	Barnyard Grass (*Echinochloa spp.*) Pigweed (*Amaranthus spp.*)	15
PWOP	Pond Weed (*Potamogeton spp.*)	4
RCOP	Reed Canary Grass (*Phalaris spp.*)	10
BROP	Bulrush (*Scirpus spp.*)	5
BRSWOP	Bulrush (*Scirpus spp.*) Smart Weed (*Polygonum spp.*)	5
SWSROP	Smart Weed (*Polygonum spp.*) Spike Rush (*Eleocharis spp.*)	13
SWOP	Smart Weed (*Polygonum spp.*)	38
OP	Open Water	11

(Zar, 1984) was then used to test for differences between invertebrate mean biomass per trap sample, mean biomass per core sample, mean number per trap sample, and mean number per core sample, by PAT. To test for differences between invertebrate mean biomass per trap sample, mean biomass per core sample, mean number per trap sample, and mean number per core sample, by month I used one way analysis of variance (Zar, 1984). Due to the factor mentioned in the analysis of the MSU data, I used Friedman repeated measures analysis of variance on ranks (Zar, 1984) to test for differences between invertebrate diversity per trap sample and diversity per core sample by PAT and Kruskal-Wallis one way analysis of variance on ranks to test for differences between invertebrate diversity per trap sample and diversity per core sample by month (Zar, 1984). In all statistical tests where the data were not normally distributed, analogous non-parametric tests were used in place of parametric tests.

The data for core samples and trap samples were not pooled and statistical tests were run separately for these two collection methods. Samples taken by these methods represent two different collection techniques, habitat types and host different families with little overlap. Therefore pooling the data was unsuitable.

RESULTS

Three major floods occurred in the Neosho River drainage during my study from November through March. Thus, my study sites were often under 3-5 m of water, and when not under water, silt and mud prevented access. The flooding also prevented me from collecting data on consecutive days. Additionally, a large quantity, in some cases all, of the standing vegetation and detritus was removed from sites A through E (Figure 1). Thus, I collected 4 months of data. The dates corresponding to each month of data collection are: month 1 from 29 September 1992 - 6 October 1992, month 2 from 26 October 1992 - 9 November 1992, month 3 from 5 March 1993 - 15 March 1993, and month 4 from 26 April 1993 - 30 April 1993.

I collected a total of 9 orders and 28 families of aquatic macroinvertebrates in my 8 MSUs (Table 3). Additionally, I collected several leeches, which I could not identify beyond class and listed them under Hirudinea in Table 2. This would make a minimum of 29 families. I also could not identify several larval and pupal insects belonging to the orders Anisoptera, Diptera, Odonata, and Plecoptera. These individuals were used in the number and biomass data, but were not used in any of the diversity calculations, as these calculations were based on the number of families.

The top five most prevalent families occurring in the 8 MSUs and 10 PATs, according to total number collected and

total biomass collected, are listed. The total number collected in the MSUs by trapping was Corixidae (1276), Baetidae (759), Chironomidae (269), Coenagriidae (254), and Caenidae (222). The total biomass collected in the MSUs by trapping was Hydrophilidae (2.2771 g), Physidae (0.9990 g), Planorbidae (0.9884 g), Belostomatidae (0.9726 g), and Hirudinae (class) (0.5983 g). The total number collected in the MSUs by core sampling was Chironomidae (482), Hirudinae (class)(34), Heleidae (27), Physidae (26), and Corixidae (25). The total biomass collected in the MSUs by core sampling was Hirudinae (class) (0.1676 g), Planorbidae (0.1601 g), Physidae (0.1408 g), Chironomidae (0.897 g), and Corixidae (0.0113 g). The total number collected in the PATs by trapping was Corixidae (1276), Baetidae (759), Chironomidae (265), Caenidae (222), and Coenagriidae (185). The total biomass collected in the PATs by trapping was Hydrophilidae (2.2771 g), Planorbidae (0.9884 g), Physidae (0.9803 g), Belostomatidae (0.9726 g), and Hirudunae (class) (0.5983 g). The total number collected in the PATs by core sampling was Chironomidae (482), Hirudinae (class) (33), Heleidae (27), Physidae (26), and Corixidae (25). The total biomass collected in the PATs by core sampling was Hirudinae (class) (0.1662 g), Planorbidae (0.1601 g), Physidae (0.1408 g), Chironomidae (0.0897 g), and Corixidae (0.0096 g). In all cases the top five families are the same for both the MSUs and the PATs. This was expected because the PATs are

simply a rearrangement of the MSU collection sites. However, the MSU data are not identical to the PAT data because not all of the trap and core sites used in the MSU data set were used in the PAT data sets. Therefore, in some instances, the PAT data contains lower values than the MSU data. A large number of my samples were not normally distributed and thus I used Friedman repeated measures ANOVA on ranks as a non-parametric substitute for one way repeated measures ANOVA and Kruskal-Wallis one way ANOVA on ranks as a non-parametric substitute for one way ANOVA. This explains why some of the results are given as Chi Square values and H values, respectively, rather than F values.

For the trap data no significant differences were found among the means for MSUs (successional stage) by invertebrate mean biomass (Chi Square = 13.411; d.f. = 7; P = 0.063), mean number (Chi Square = 6.749; d.f. = 7; P = 0.456), and diversity (Chi Square = 12.083; d.f. = 7; P = 0.098) (Table 3). Conversely, the trap data produced significant differences among the means for months by invertebrate mean biomass (H = 8.524; d.f. = 3; P = 0.036) and mean number (H = 24.055; d.f. = 3; P < 0.001) (Table 3). Student-Newman-Keuls multiple range tests isolated significant differences between month 1 and months 2, 3, and 4 for month by invertebrate mean biomass (Appendix 1) and significant differences between months 1 and 2, 3, and 4 for month by mean number (Appendix 2). There were no

significant differences found after analyzing month by invertebrate diversity value (H = 6.207; d.f. = 3; P = 0.102) (Table 3). The results from the core data revealed significant differences among the means for MSUs (successional stage) by invertebrate mean biomass (Chi Square = 20.419; d.f. = 7; P = 0.005). Student-Newman-Keuls multiple range test isolated a significant difference between Horse Shoe and Troublesome, while there was no difference among the rest of the MSUs (Appendix 3). There were no significant differences detected among the means by MSU (successional stage) for invertebrate number (Chi Square = 8.058; d.f. = 7; P = 0.328) and diversity (Chi Square = 8.569; d.f. = 7; P = 0.285) (Table 4). Significant differences were found among the means for invertebrate biomass (H = 17.471; d.f. = 3; P < 0.001), number (H = 21.817; d.f. = 3; P < 0.001), and diversity (H = 17.841; d.f. = 3; P < 0.001) (Table 4) for months. Student-Newman-Keuls multiple range test indicated significant differences between month 1, months 2 and 3, and month 4 for month by invertebrate mean biomass (Appendix 4); between months 1 and 2, month 3, and month 4 for month by mean number (Appendix 5); and between months 1 and 2, month 3, and month 4 for diversity (Appendix 6).

Analysis of variance on the trap data, yielded significant differences among the means for invertebrate mean biomass (Chi Square = 21.219; d.f. = 9; P = 0.012) and

Table 3. Orders, families and common names of aquatic macroinvertebrates occurring in MSUs of the FHNWR and adjacent land.

Order	Family	Common Name
Coleoptera		
	Curculionidae	Snout Beetles
	Dytiscidae	Predaceous Diving Beetles
	Gyrinidae	Whirlygig Beetles
	Hydrophilidae	Water Scavenger Beetles
Decapoda		
	Astacidae	Crayfish
	Palaemonidae	Freshwater Shrimp
Diptera		
	Heleidae	Biting Midges
	Chaoboridae	Phantom Midges
	Chironomidae	Blood Midges
	Culicidae	Mosquitoes
	Tabanidae	Horse Flies
	Tipulidae	Crane Flies
Ephemeroptera		
	Baetidae	Mayflies
	Caenidae	Mayflies
	Heptageniidae	Mayflies

Table 3 Continued.

Order	Family	Common Name
	Neoephemeridae	Mayflies
Basommatophora		
	Physidae	Pouch Snails
	Planorbidae	Orb Snail
Hemiptera		
	Belostomatidae	Giant Water Bugs
	Corixidae	Water Boatmen
	Mesoveliidae	Water Treaders
Odonata		
	Aeshnidae	Dragonflies
	Coenagriidae	Damselflies
	Lestidae	Damselflies
	Libellulidae	Dragonflies
Polecypoda		
	Sphaeriidae	Fingernail Clams
Trichoptera		
	Limnephilidae	Caddisflies
Hirudinae (class)		Leeches

mean number (Chi Square = 19.052; d.f. = 9; P = 0.025) (Table 5) among PATs. Student-Newman-Keuls multiple range tests showed no significant difference among the means for invertebrate biomass (Appendix 7) and number (Appendix 8) by PAT. There was also no significant difference detected for invertebrate diversity among PATs (Chi Square = 8.917; d.f. = 9; P = 0.445) (Table 5). Significant differences were found among the means for month by invertebrate mean biomass (H = 12.374; d.f. = 3; P = 0.006), mean number (H = 31.471; d.f. = 3; P < 0.001), and diversity (H = 14.316; d.f. = 3; P = 0.003) (Table 5). Student-Newman-Keuls multiple range tests isolated differences between month 1, months 2 and 3, and month 4 for month by invertebrate mean biomass (Appendix 9); between months 1 and 2, month 3, and month 4 for mean number (Appendix 10); and between months 1, 2, 3 and month 4 for diversity (Appendix 11).

The core data revealed significant differences among the means for invertebrate mean biomass (Chi Square = 22.805; d.f. = 9; P = 0.007) and diversity (Chi Square = 21.793; d.f. = 9; P = 0.010) (Table 6) among PATs. Student-Newman-Keuls multiple range tests located no significant differences among invertebrate mean biomass for PATs (Appendix 12). However, significant differences in invertebrate diversity were found between PAT SROP, PAT SWSROP, and PATs SWOP, CHOP, OP, PWOP, RCOP, BRSWOP, BGPWOP, and BROP (Appendix 13). No significant differences were

found among PATs by invertebrate mean number (Chi Square = 4.032; d.f. = 9; P = 0.909) (Table 6). Significant differences were found among the means for month by invertebrate mean biomass (H = 21.455; d.f. = 3; P < 0.001), mean number (H = 29.824; d.f. = 3; P < 0.001), and diversity (H = 16.642; d.f. = 3; P < 0.001) (Table 6). Student-Newman-Keuls multiple range tests, isolated differences between months 1 and 2, month 3, and month 4 for month by invertebrate mean biomass (Appendix 14); between months 1 and 2, month 3, and month 4 for month by mean number (Appendix 15); and between months 1 and 2, month 3, and month 4 for month by diversity (Appendix 16).

Table 4. The mean number of individuals, mean biomass (grams), and diversity of trapped aquatic macroinvertebrates for each MSU, by month (M). SE = standard error.

MSU	M	Number	SE	Biomass	SE	Diversity
Hammerton #2	1	11.00	9.47	0.0656	0.1649	0.8423
	2	16.60	26.07	0.0462	0.0691	0.6198
	3	3.20	3.00	0.0042	0.0044	0.4357
	4	0.20	0.41	0.0003	0.0007	0.4771
Horseshoe	1	59.87	67.50	0.0177	0.0202	0.4254
	2	7.53	4.13	0.0055	0.0056	0.5274
	3	1.14	1.29	0.0006	0.0013	0.2107
	4	0.27	0.59	0.0007	0.0016	0.2442
Katy	1	22.73	19.21	0.0246	0.0346	0.1839
	2	4.13	2.77	0.0208	0.0216	0.7007
	3	0.36	0.93	0.0100	0.0370	0.5786
	4	3.50	4.07	0.0184	0.0210	0.2349
Lily Pond	1	4.00	4.29	0.0387	0.1460	0.5580
	2	3.53	4.14	0.0019	0.0034	0.6644
	3	2.00	1.65	0.0040	0.0108	0.6556
	4	0.73	1.03	0.0045	0.0069	0.3846
Palin	1	7.20	6.81	0.0026	0.0025	0.4658
	2	10.13	3.89	0.0018	0.0011	0.4555
	3	1.40	1.64	0.0006	0.0015	0.3615

Table 4 Continued.

MSU	M	Number	SE	Biomass	SE	Diversity
	4	0.29	0.61	0.0261	0.0960	0.4515
Pintail	1	4.20	4.23	0.0353	0.0687	0.3717
	2	16.13	11.09	0.0040	0.0043	0.4558
	3	1.92	1.38	0.0081	0.0120	0.4165
	4	0.36	0.50	0.0008	0.0014	0.2173
Slaymaker	1	10.40	7.39	0.1718	0.3612	0.8640
	2	2.67	2.35	0.0173	0.0266	0.6266
	3	1.00	1.24	0.0004	0.0007	0.5441
	4	0.60	0.99	0.0008	0.0015	0.4990
Troublesome	1	6.40	5.05	0.0012	0.0013	0.8231
	2	7.67	8.29	0.0011	0.0011	0.3981
	3	1.00	1.00	0.0177	0.0483	0.8497
	4	0.15	0.38	0.0002	0.0005	0.3010

Table 5. The mean number of individuals, mean biomass (grams), and diversity of core sampled aquatic macroinvertebrates for each MSU, by month (M). SE = standard error.

MSU	M	Number	SE	Biomass	SE	Diversity
Hammerton #2	1	4.20	4.09	0.0012	0.0013	0.1314
	2	2.67	2.26	0.0024	0.0034	0.4263
	3	0.40	0.63	0.0003	0.0008	0.3768
	4	0.00	0.00	0.0000	0.0000	0.0000
Horseshoe	1	5.20	4.26	0.0036	0.0051	0.5987
	2	1.80	2.34	0.0013	0.0020	0.2915
	3	0.07	0.26	0.0030	0.0116	0.0000
	4	0.07	0.26	0.0002	0.0006	0.0000
Katy	1	1.60	2.13	0.0067	0.0126	0.6574
	2	1.33	1.68	0.0019	0.0055	0.3377
	3	0.29	0.61	0.0009	0.0032	0.3010
	4	0.00	0.00	0.0000	0.0000	0.0000
Lily Pond	1	0.40	0.74	0.0019	0.0046	0.3768
	2	1.00	1.51	0.0114	0.03200	0.7194
	3	0.13	0.35	0.0013	0.0036	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
Palin	1	1.27	1.53	0.0009	0.0013	0.3722
	2	3.00	2.17	0.0005	0.0005	0.5043

Table 5 Continued.

MSU	M	Number	SE	Biomass	SE	Diversity
	3	0.60	1.12	0.0019	0.0068	0.1515
	4	0.00	0.00	0.0000	0.0000	0.0000
Pintail	1	0.07	0.26	0.0004	0.0014	0.0000
	2	10.00	9.83	0.0025	0.0022	0.0599
	3	0.27	0.59	0.0001	0.0002	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
Slaymaker	1	2.93	3.15	0.0012	0.0025	0.4290
	2	0.93	1.58	0.0017	0.0066	0.2849
	3	2.36	2.59	0.0005	0.0007	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
Troublesome	1	1.60	2.13	0.0002	0.0004	0.5053
	2	1.53	1.19	0.0003	0.0003	0.0777
	3	0.53	1.06	0.0000	0.0000	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000

Table 6. The mean number of individuals, mean biomass (grams), and diversity of trapped aquatic macroinvertebrates for each PAT, by month (M). SE = standard error.

Association	M	Number	SE	Biomass	SE	Diversity
CHOP	1	6.83	3.92	0.0094	0.0070	0.8046
	2	6.33	5.32	0.0238	0.0420	0.7825
	3	3.33	3.39	0.0040	0.0066	0.3435
	4	0.17	0.41	0.0002	0.0000	0.0000
SROP	1	10.08	13.69	0.0776	0.1771	0.6460
	2	8.23	14.82	0.0087	0.0196	0.6281
	3	1.83	1.90	0.0049	0.0119	0.7471
	4	0.25	0.45	0.0025	0.0054	0.2173
BGPWOP	1	4.20	4.23	0.0353	0.0687	0.3717
	2	16.13	11.09	0.0040	0.0043	0.4558
	3	1.92	1.38	0.0081	0.0120	0.4165
	4	0.36	0.50	0.0008	0.0014	0.2173
PWOP	1	98.50	49.63	0.0296	0.0204	0.5200
	2	10.00	2.16	0.8058	0.0016	0.2775
	3	2.00	1.73	0.0010	0.0018	0.3768
	4	0.25	0.50	0.0004	0.0007	0.0000
RCOP	1	7.40	5.87	0.0014	0.0013	0.8520
	2	8.40	9.86	0.0013	0.0013	0.3909
	3	0.80	0.92	0.0062	0.0140	0.6773

Table 6 Continued.

Association	M	Number	SE	Biomass	SE	Diversity
	4	0.22	0.44	0.0002	0.0006	0.3010
BROP	1	4.40	2.07	0.0008	0.0012	0.6634
	2	6.20	4.21	0.0007	0.0005	0.3304
	3	1.40	1.14	0.0408	0.0821	0.7591
	4	0.00	0.00	0.0000	0.0000	0.0000
BRSWOP	1	7.80	6.53	0.0355	0.0651	0.7536
	2	3.60	3.13	0.0122	0.0077	0.6003
	3	0.20	0.45	0.0004	0.0008	0.0000
	4	0.60	1.34	0.0005	0.0011	0.0000
SWSROP	1	28.69	37.10	0.0544	0.1545	0.3458
	2	6.00	3.83	0.0051	0.0103	0.7534
	3	1.38	1.80	0.0007	0.0018	0.5884
	4	1.54	1.94	0.0093	0.0183	0.2551
SWOP	1	10.16	10.48	0.0686	0.2371	0.7013
	2	6.37	4.88	0.0134	0.0222	0.7011
	3	1.22	1.47	0.0006	0.0013	0.5645
	4	1.22	2.82	0.0051	0.0118	0.4536
OP	1	33.00	63.21	0.0127	0.0184	0.4877
	2	13.27	28.37	0.0441	0.0776	0.4978
	3	1.73	1.35	0.0151	0.0411	0.6900
	4	0.64	0.92	0.0304	0.1080	0.5011

Table 7. The mean number of individuals, mean biomass, and diversity of core sampled aquatic macroinvertebrates for each PAT, by month (M). SE = standard error.

Association	M	Number	SE	Biomass	SE	Diversity
CHOP	1	3.67	2.50	0.0014	0.0016	0.2380
	2	2.68	1.21	0.0028	0.0016	0.4447
	3	0.50	0.55	0.0005	0.0011	0.2764
	4	0.00	0.00	0.0000	0.0000	0.0000
SROP	1	1.77	2.39	0.0050	0.0106	0.5454
	2	1.61	2.10	0.0112	0.0347	0.4940
	3	0.42	0.79	0.0019	0.0041	0.4581
	4	0.00	0.00	0.0000	0.0000	0.0000
BGPWOP	1	0.07	0.26	0.0004	0.0014	0.0000
	2	10.00	9.83	0.0025	0.0022	0.0600
	3	0.27	0.59	0.0001	0.0002	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
PWOP	1	7.75	4.11	0.0080	0.0074	0.5667
	2	2.00	2.00	0.0005	0.0009	0.1636
	3	0.00	0.00	0.0000	0.0000	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
RCOP	1	1.90	2.13	0.0002	0.0005	0.4532
	2	1.60	1.34	0.0003	0.0003	0.1015
	3	0.20	0.42	0.0000	0.0000	0.0000

Table 7 Continued.

Association	M	Number	SE	Biomass	SE	Diversity
	4	0.00	0.00	0.0000	0.0000	0.0000
BROP	1	1.00	2.24	0.0001	0.0001	0.0000
	2	1.40	0.89	0.0003	0.0004	0.0000
	3	1.20	1.64	0.0001	0.0001	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
BRSWOP	1	3.80	4.09	0.0015	0.0031	0.1778
	2	1.60	2.30	0.0001	0.0002	0.0000
	3	1.00	2.24	0.0001	0.0000	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000
SWSROP	1	3.69	3.86	0.0025	0.0034	0.6345
	2	1.23	2.39	0.0260	0.0057	0.4897
	3	0.15	0.38	0.0035	0.0124	0.3010
	4	0.08	0.28	0.0002	0.0006	0.0000
SWOP	1	1.45	1.94	0.0019	0.0061	0.7231
	2	1.76	1.90	0.0016	0.0052	0.5425
	3	1.05	1.86	0.0013	0.0046	0.0878
	4	0.00	0.00	0.0000	0.0000	0.0000
OP	1	3.27	5.02	0.0012	0.0019	0.2017
	2	2.27	2.65	0.0025	0.0037	0.4730
	3	0.09	0.30	0.0000	0.0000	0.0000
	4	0.00	0.00	0.0000	0.0000	0.0000

DISCUSSION

The significant differences among the means for month by trap and core mean biomass, mean number, and diversity for the MSU data and the PAT data, with the exception of month by MSU trap diversity ($P = 0.102$), were expected (hypothesis 1), although I predicted that they would decrease in the winter and increase in the spring, which in most cases they did not. I found a general decrease in number, biomass, and diversity as time progressed, demonstrating the possible effects of habitat loss due to flooding and/or the natural seasonal decline of macroinvertebrate abundance and activity. There were two exceptions to this trend, MSU core mean biomass by month (Table 5) and PAT mean trap biomass by month (Table 6). In both of these cases the biomass actually increased from month 1 (fall) to months 2 and 3 (winter) and then decreased in month 4 (spring). Since the last month of data was collected in the spring (April), I would have expected macroinvertebrate numbers to increase as temperatures increased, in a fashion similar to that reported by Judd (1953) and Krull (1969), but they did not. I attribute this to the extensive flooding that removed a great deal, and in some cases all, of the vegetative cover and detritus from my study sites. Thus, no suitable habitat for emerging and hatching macroinvertebrates remained. Support for the link between the presence of vegetation and invertebrate number and biomass has been provided by Krull (1970), who found

that macroinvertebrate numbers were higher in vegetated sites than non-vegetated sites. Additionally, Murkin et al. (1991) reported that the loss of vegetative substrate due to flooding probably contributed to a reduction in invertebrate numbers during prolonged flooding in small diked marshes.

The lack of significant differences among the means, when looking at the trap data, for biomass, number, and diversity of MSU by age, and biomass, number, and diversity by PAT, I also attribute to the extensive flooding. Although this forced me to reject hypothesis number 2, which stated that there would be a difference in the number, biomass, and diversity between each of the MSUs, there might have been a difference had the flooding not occurred or if my sample size had been larger. Another explanation for the lack of significance in the PAT data could be attributed to the fact that they are all considered to be early successional stages and would therefore contain relatively equal mean biomass, mean number, and diversity, as I explained in the materials and methods. The reason that all of the MSUs, and therefore all of the PATs, consist mainly of early successional stage plants could again be contributed to flooding. In the last 22 years the FHNWR has been flooded to the point of having 95% of the area covered (encompassing all of my MSUs), 5 times, including 1973, 1985, 1986, 1993, and 1995 (Wiseman, 1992; Wiseman, 1994). I suggest that this constant large scale flooding, combined

with the small scale flooding, which has occurred during this same time period, has helped facilitate the growth of earlier successional stage plants while hindering the growth of older successional stage plants. This continual disturbance of late successional stage growth resulted in the occurrence of mainly early successional stage plant growth in all of the MSUs located on the area.

Similarly, there was no significant difference among the means in the core data for number and diversity of MSUs by age and biomass and number by PATs. I also attribute these results to the flooding, the small sample size or large variances in the data, that are probably due to the small sample size. Alternately, in the case of the PAT data, I could also hypothesize that the lack of significance is due to the lack of difference in successional stage of each unit as explained in the previous paragraph.

There was, however, a significant difference among the mean core biomass by MSU and core diversity by PAT. In the case of mean core biomass by MSU, Horse Shoe had a significantly higher median biomass than Troublesome, but both were not significantly different from the other six MSU (Table 5). I can only attribute this to the flooding, which may have affected Troublesome on a greater scale than Horse Shoe. Similarly, the data for core diversity by PAT indicate for median diversity that SROP was greater than SWSROP, which was greater than the remaining eight PATs,

which were equal in value. As the PAT quadrants were located in several different MSUs I cannot attribute this to the flooding. I suggest that SROP and SWSROP were affected by variables, other than vegetation type that enabled the diversity values to remain relatively higher than the other eight PATs. Neckles et al. (1990) suggested that the life history traits of invertebrates are more important to density than habitat features that would explain why vegetation type might not be the deciding factor for macroinvertebrate number, biomass, and density. Further study will be needed to ascertain what these variables could possibly be.

As the number and biomass of aquatic macroinvertebrates were higher in the fall than the winter and should have been higher in the spring, I suggest that in the FHNWR invertebrates are more important as a food resource to staging waterfowl than to overwintering waterfowl. Waterfowl overwintering in the FHNWR are probably using a higher proportion of plant material in their diets relative to invertebrates. Although my study failed to show a significance relationship in aquatic macroinvertebrate presence between MSU successional stage and PAT, it did provide a starting point and some baseline data for future research on the FHNWR. Flooding appeared to have a great influence on the results and may have prevented any existing relationships among the variables from surfacing due to the

destruction of habitat important to aquatic macroinvertebrates and the subsequent reduction in my sample size. I suggest that future work be conducted in a similar manner so information can be collected that would enable these wetlands to be managed for optimal production of aquatic macroinvertebrates, as these are an important food resource for waterfowl as well as other wetland fauna. I also suggest that flooding as a disturbance to these MSUs be modelled and studied.

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APPENDICES

Appendix 1. Student-Newman-Keuls multiple range test on month by moist soil unit trap mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	8	0.0300	
2	8	0.0048	|
3	8	0.0041	|
4	8	0.0008	|

Appendix 2. Student-Newman-Keuls multiple range test on month by moist soil unit trap mean number of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	8	8.80	
2	8	7.30	|
3	8	1.24	
4	8	0.33	

Appendix 3. Student-Newman-Keuls multiple range test on moist soil unit by core mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

MSU	N	Median		
Horseshoe	4	0.0022		
Lily Pond	4	0.0017		
Katy	4	0.0014		
Slaymaker	4	0.0009		
Palin	4	0.0007		
Hammerton #2	4	0.0007		
Pintail	4	0.0003		
Troublesome	4	0.0001		

Appendix 4. Student-Newman-Keuls multiple range test on month by moist soil unit core mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	8	0.0012	
2	8	0.0018	|
3	8	0.0007	|
4	8	0.0000	

Appendix 5. Student-Newman-Keuls multiple range test on month by moist soil unit core mean number of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	8	1.60	|
2	8	1.67	|
3	8	0.34	
4	8	0.00	

Appendix 6. Student-Newman-Keuls multiple range test on month by moist soil unit core diversity of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	8	0.4029	|
2	8	0.3146	|
3	8	0.0000	
4	8	0.0000	

Appendix 7. Student-Newman-Keuls multiple range test on plant community type by trap mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Plant Community Type	N	Median	
OP	4	0.0245	|
SWOP	4	0.0093	|
SROP	4	0.0068	|
CHOP	4	0.0067	|
BRSWOP	4	0.0064	|
BGPWOP	4	0.0061	|
SWSROP	4	0.0050	|
PWOP	4	0.0036	|
RCOP	4	0.0014	|
BROP	4	0.0008	|

Appendix 8. Student-Newman-Keuls multiple range test on plant community type by trap mean number of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Plant Community Type	N	Median	
OP	4	7.3200	|
PWOP	4	5.7500	|
SROP	4	5.0300	|
CHOP	4	4.8300	|
SWOP	4	3.7750	|
SWSROP	4	3.7700	|
RCOP	4	3.6000	|
BGPWOP	4	3.0600	|
BROP	4	2.9000	|
BRSWOP	4	2.1000	|

Appendix 9. Student-Newman-Keuls multiple range test on month by plant community type trap mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	10	0.0318	
2	10	0.0073	|
3	10	0.0045	|
4	10	0.0007	

Appendix 10. Student-Newman-Keuls multiple range test on month by plant community type trap mean number of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	10	8.94	|
2	10	6.94	|
3	10	1.45	
4	10	0.22	

Appendix 11. Student-Newman-Keuls multiple range test on month by plant community type trap diversity of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	10	0.6547	|
2	10	0.5491	|
3	10	0.5765	|
4	10	0.2173	

Appendix 12. Student-Newman-Keuls multiple range test on plant community type by core mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Plant Community Type	N	Median	
SWSROP	4	0.0026	|
SROP	4	0.0019	|
SWOP	4	0.0014	|
PWOP	4	0.0010	|
CHOP	4	0.0010	|
OP	4	0.0006	|
BGPWOP	4	0.0003	|
BRSWOP	4	0.0001	|
BROP	4	0.0001	|
BRSWOP	4	0.0001	|

Appendix 13. Student-Newman-Keuls multiple range test on plant community type by core diversity of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Plant Community Type	N	Median	
SROP	4	0.4761	
SWSROP	4	0.3954	
SWOP	4	0.3152	|
CHOP	4	0.2572	|
OP	4	0.1009	|
PWOP	4	0.0818	|
RCOP	4	0.0508	|
BRSWOP	4	0.0000	|
BGPWOP	4	0.0000	|
BROP	4	0.0000	|

Appendix 14. Student-Newman-Keuls multiple range test on month by plant community type core mean biomass of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	10	0.0015	|
2	10	0.0023	|
3	10	0.0001	
4	10	0.0000	

Appendix 15. Student-Newman-Keuls multiple range test on month by plant community type core mean number of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	10	2.59	|
2	10	1.69	|
3	10	0.34	
4	10	0.00	

Appendix 16. Student-Newman-Keuls multiple range test on month by plant community type core diversity of aquatic macroinvertebrates. Vertical lines represent maximum nonsignificant ($P > 0.05$) ranges.

Month	N	Median	
1	10	0.3456	|
2	10	0.3042	|
3	10	0.0000	
4	10	0.0000	

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4-28-96

Date

Effects of Successional Stage and Plant Association on Moist Soil Unit Macroinvertebrates.

Title of Thesis

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