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Abundance, Biomass, and Diversity of Aquatic Invertebrates in Level Ditches and Adjacent Natural Emergent Marsh in an Eastern South Dakota Wetland

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ABUNDANCE, BIOMASS, AND DIVERSITY OF AQUATIC INVERTEBRATES IN LEVEL DITCHES AND ADJACENT NATURAL EMERGENT MARSH IN AN EASTERN SOUTH DAKOTA WETLAND

BY

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ABUNDANCE, BIOMASS, AND DIVERSITY OF AQUATIC INVERTEBRATES

IN LEVEL DITCHES AND ADJACENT NATURAL EMERGENT MARSH

IN AN EASTERN SOUTH DAKOTA WETLAND

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this Degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

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The aquatic invertebrate communities of level ditches and adjacent natural emergent marsh in a South Dakota prairie wetland were sampled during the summer of 1982. Collections were made in both the water column and the bottom substrates. Forty-five taxa were collected. Analysis of variance indicated that a significantly greater mean number of taxa and a larger mean number of all macroinvertebrates were present in level ditches than in the natural emergent marsh. No differences were detected for mean biomass of all macroinvertebrate taxa collectively. Several taxa had a greater mean number and biomass in the level ditches than in the natural emergent marsh. Discussion of the composition of duck diets during the breeding and brood rearing seasons revealed that the level ditches provided an abundance and diversity of the aquatic invertebrates consumed by ducks.

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INTRODUCTION

Wetland losses due to drainage for agriculture, municipal expansion, residential development, and highway construction have been continuing at an alarming rate. It has been estimated from various sources that 51 million ha (127 million acres) of natural wetlands occurred in the United States before 1850 (Shaw and Fredine 1956). The Soil Conservation Service estimated in 1977 that 28.5 million ha (70.5 million acres) of wetlands remained; a decline in wetland area of 44% from the original estimate (U.S.D.A. 1980). Schrader (1955) estimated that by 1955 nearly half of the wetlands of the Prairie Pothole Region had been lost to drainage. In the Prairie Pothole Region of Minnesota, North Dakota, and South Dakota an estimated 40,000 ha (100,000 acres) of Type 3, 4, and 5 wetlands (Shaw and Fredine 1956) were drained from 1966 - 1968 (Haddock and DeBates 1969). This figure must be considered minimal for wetland drainage since Type 1 and 2 wetlands were not included. In Iowa over 95% of the natural wetlands have been drained (Bishop 1981).

Wetland habitat is critical for many wildlife species, particularly waterfowl and aquatic furbearers. In order to counteract these wetland losses and increase the benefit of existing wetlands to wildlife, several wetland management techniques have been implemented (Linde 1969). One such technique is the excavation of level ditches in natural wetland basins. Although some investigations into the value of this technique to wildlife have been conducted, studies are still needed to more completely document wildlife use of wetlands with level ditches.

In marshes with low water levels in east-central Wisconsin, it was shown that the average number of muskrats trapped before ditching was 3.2 per ha (1.3 per acre) per year whereas after ditching the average number trapped was 9.3 per ha (3.8 per acre) per year (Anderson 1948). A comparison of the harvest from experimental level ditches within Horicon Marsh, Wisconsin, and from the surrounding marsh also showed an increase in muskrat productivity as a result of ditch construction. From 1949 - 1954, an average of 23.8 muskrats per ha (9.7 per acre) per year was removed from Horicon Marsh level ditches while an average of 3.7 muskrats per ha (1.5 per acre) per year was taken from the surrounding marsh (Mathiak and Linde 1956).

The value of level ditches to waterfowl has not been studied extensively. Mathiak and Linde (1956) found a minimum of 3.7 duck nests per ha (1.5 per acre) in 1953 in the ditched areas within Horicon Marsh, Wisconsin, a concentration they considered higher than any other known area on the marsh. Lacy (1959) found that increases in the waterfowl breeding population ranged from 3.7 to 18.0 pairs per km (6 to 29 per mile) of shoreline as a result of dugout and ditch development on the Lower Souris National Wildlife Refuge, North Dakota, in 1957 and 1958. A study conducted during 1968 and 1969 in Bottineau and Renville counties, North Dakota, compared breeding pairs and broods observed on 70 level-ditched wetlands and on 70 similar wetlands without level ditches (Nelson 1972). The number of pairs and broods per wetland acre was similar on both the level-ditched and control wetlands. A factor in the inconclusive results was the extreme variation in water conditions between 1968 and 1969.

Some characteristics of level ditches that may improve wetland as wildlife habitat are: 1) increased interspersion of water and cover in marshes having dense, unbroken stands of vegetation, 2) a dependable source of open water habitat in dry years, 3) spoilbanks to furnish waterfowl nesting sites adjacent to open water and provide den sites and feeding and resting places for muskrats, 4) deep water to prevent freeze-out of muskrats and provide access to aquatic food plants during the winter, and 5) aquatic food and cover plants for waterfowl (Anderson 1948, Mathiak and Linde 1956, Hammond and Lacy 1960, Atlantic Waterfowl Council 1972). Another factor that may make level ditches attractive to waterfowl is the presence of aquatic invertebrates, an important food source of waterfowl during the breeding season.

The percentage of aquatic invertebrates in the diet of breeding female waterfowl ranges from 70 - 99%, varying by duck species and the study area (Bartonek and Hickey 1969a; Siegfried 1973; Swanson and Meyer 1973; Krapu 1974a, 1974b; Swanson et al. 1974, 1979). Animal foods also comprise a high percentage of the diet of duck broods, ranging from 43 - 96% (Bartonek and Hickey 1969b, Sugden 1973, Krapu and Swanson 1977). Invertebrates are an important source of protein and are necessary for satisfactory egg production in female waterfowl (Krapu and Swanson 1975, Krapu 1979). A high amount of protein in the diet is also essential for the optimal development of ducklings. Marshall (1951) stated that a high protein content in the diet of young birds encourages rapid growth.

The overall objective of this study was to compare the standing crop of aquatic invertebrates in a level-ditched portion of a wetland to an adjacent non-modified portion. The specific objectives addressed were to determine:

1) abundance, biomass, and diversity of benthic macroinvertebrates,
2) abundance, biomass, and diversity of aquatic macroinvertebrates found in the water column, and
3) numbers of zooplankton.

The null hypothesis tested was that there are no differences in abundance, biomass, and diversity of aquatic invertebrates between the level ditches and the adjacent unmodified natural marsh.

STUDY AREA

Lake Preston is a 2,105 ha (5,200 acre) marsh located in Kingsbury County in east-central South Dakota (Figure 1). This marsh can be classified as a palustrine, emergent, persistent, semipermanently flooded, freshwater wetland (Cowardin et al. 1979). Six separate level ditch units were excavated in the Lake Preston basin from November 1961 through March 1962 (Hart 1963) (Figure 1). Each unit has approximately 2.42 km (1.5 miles) of channel (Twedt 1965). Within a unit, the several ditch sections are arranged in a zig-zag design (Figure 2). Each ditch section is 91.5 m (300 feet) long and 12.2 m (40 feet) wide. Spoil banks are located on alternate sides of the ditches. Units 2 and 6 also have dugouts associated with the level ditches. The specific study area within the Lake Preston marsh was level ditch unit 3 (Figure 2) located in the SW 1/4, Sec 32, T111N, R54W.

The Lake Preston marsh is primarily a dense matted stand of emergent vegetation with very few open water areas other than the level ditches. The dominant plant was cattail (*Typha* spp.) with small, isolated clumps of river bulrush (*Scirpus fluviatilis* (Torr.) Gray), hardstem bulrush (*Scirpus acutus* Muhl.), and common reed (*Phragmites australis* (Cav.) Trin.).

The habitat components within unit 3 were the level ditches and adjacent natural emergent marsh (Figure 2). The level ditch habitat was comprised of open water in the deep central portion of the ditch with stands of aquatic bed vegetation along the shallower edges, though some ditch sections were entirely covered with submergents.

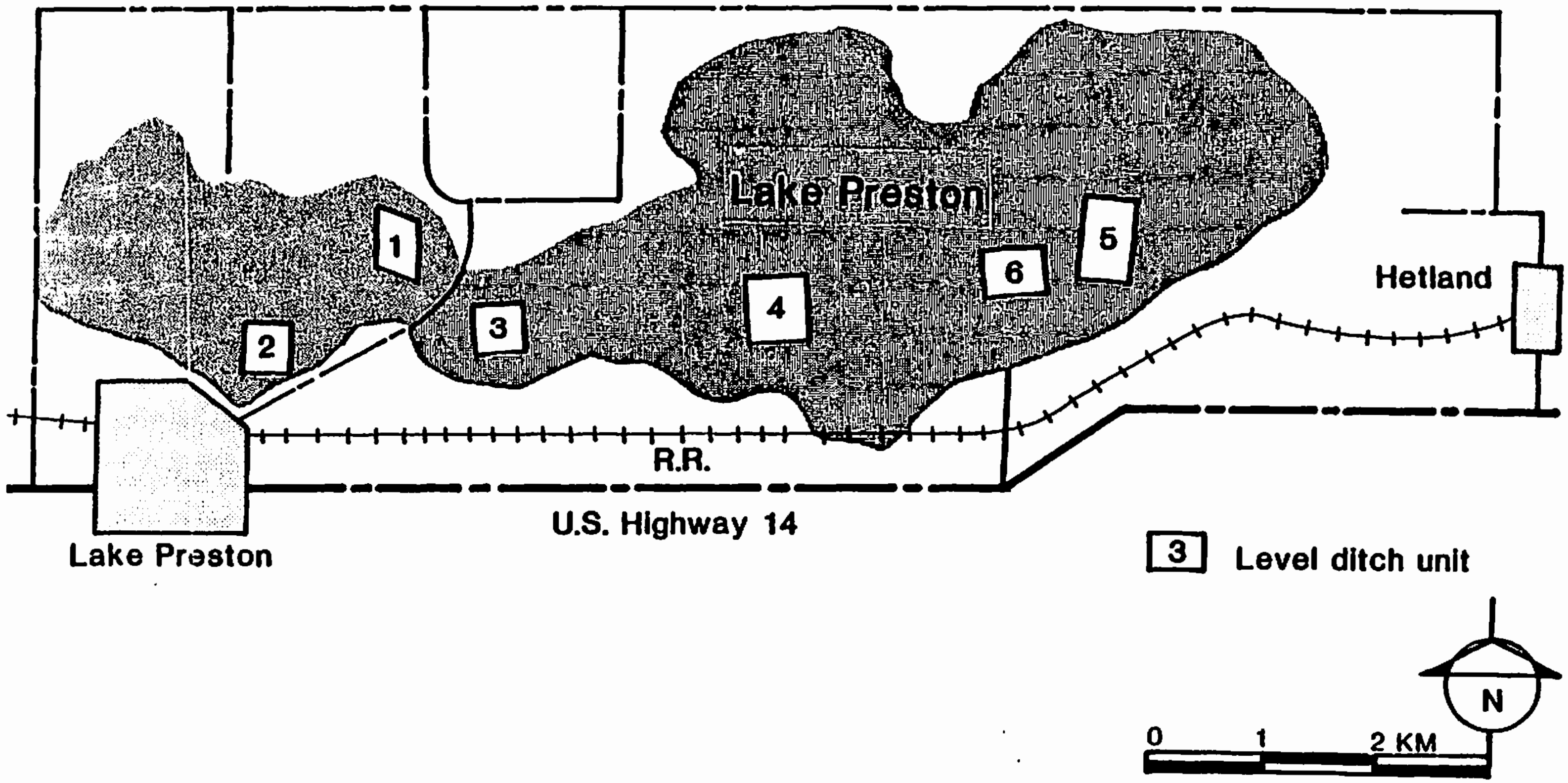

Figure 1. Lake Preston marsh showing location of level ditch units.

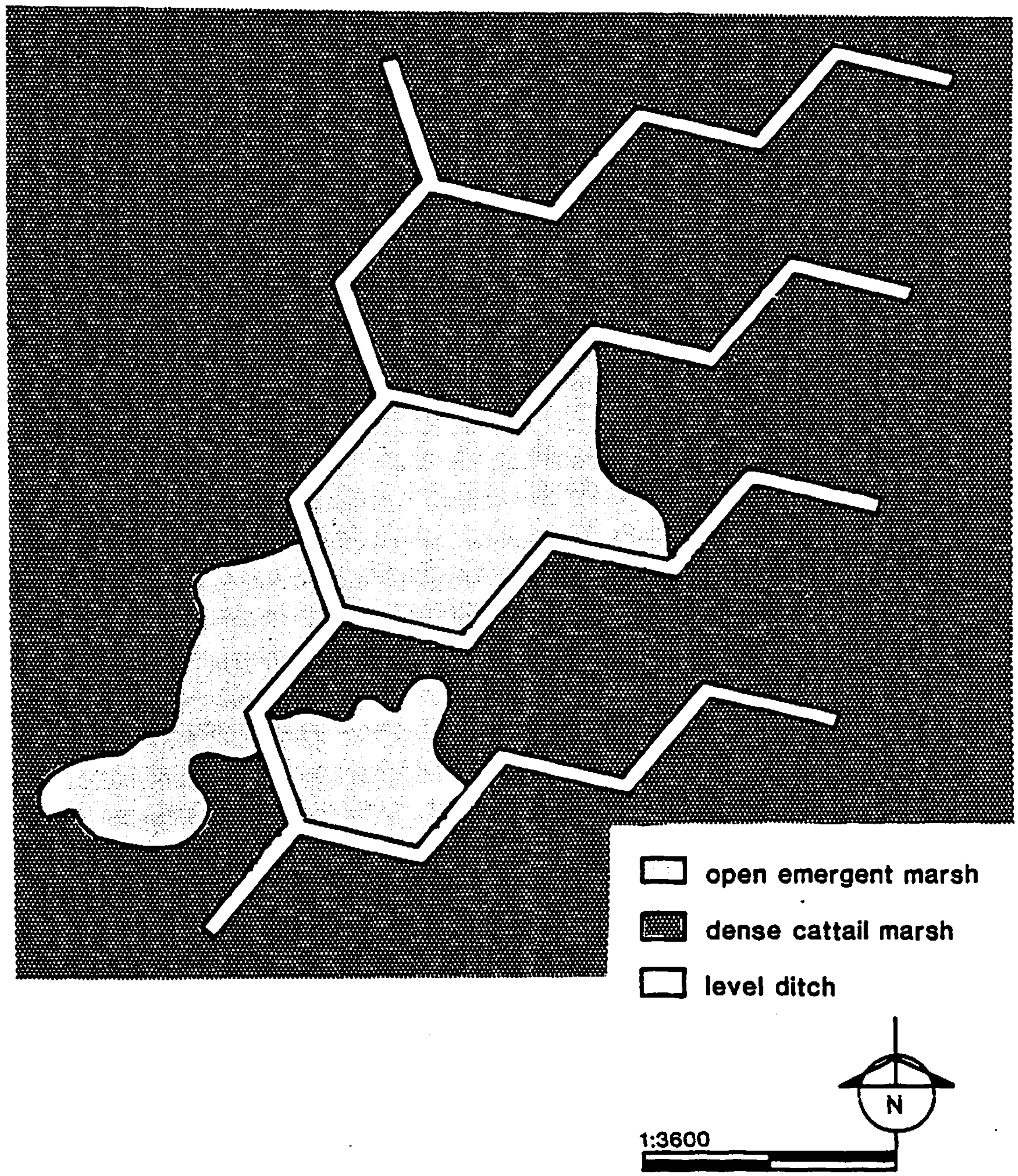

Figure 2. Level ditch unit 3 and adjacent emergent marsh study areas.

Common submergent and floating plants were bladderwort (*Utricularia vulgaris* L.), coontail (*Ceratophyllum demersum* L.), sago pondweed (*Potamogeton pectinatus* L.), star duckweed (*Lemna trisulca* L.), lesser duckweed (*Lemna minor* L.), and big duckweed (*Spirodela polyrhiza* (L.) Schleid.).

Three separate areas of emergent marsh adjacent to the level ditches were studied (Figure 2). These areas contained moderately dense stands of river bulrush interspersed with open water. Star duckweed, lesser duckweed, and big duckweed were also common. All species of submergents present in the level ditches occurred in the emergent marsh but only in scattered locations and in small sparse beds. Invertebrates were not collected from emergent marsh areas that were dominated by thick matted stands of cattail (Figure 2) or in the cattail stands on the berm area between the level ditches and the spoilbanks.

Substrate in the level ditches was predominantly clay with little sand, gravel, or organic matter. Substrate of the emergent marsh was mostly decaying organic matter with some clay and fine silt.

Average depth at the emergent marsh sample sites was 0.40 m and mean depth at sampling locations along the edge of the level ditches was 0.76 m. The deep central portion of the level ditches was approximately 1.83 to 2.44 m in depth.

METHODS

Sampling was conducted during an 11 week field season that started on 10 June 1982 and terminated on 17 August 1982. Samples were collected once a week from 10 sites located in the level ditch habitat and 10 in the adjacent natural emergent marsh.

Sample sites were randomly established within the emergent marsh areas by superimposing an x-y axis over an aerial photograph (scale 1:3600) of the level ditch-emergent marsh complex. A random numbers table was used to select points on the x and y axes. The intersection of lines drawn from these points represented the sample site. If the point of intersection fell outside the designated area, the process was repeated. The sampling stations were located in the field using the aerial photograph and marked with a stake. The initial sample was taken at the staked location. Subsequent collections were made each week by choosing a random distance and compass bearing from the reference stake.

Each of the level ditch sections was assigned a number from 1 to 28. The 10 sections to be sampled for a given week were chosen from a random numbers table. A random distance into the section was also selected. Whether to sample the left or right side of the first ditch section sampled was determined by a flip of a coin. Subsequent ditch sections were sampled on alternate sides. Sampling in the ditches was restricted to the open water/aquatic bed habitat within a zone 1 m from the cattail edge and at depths of 1 m or less.

The bottom substrate and water column were sampled at each site within the level ditches and emergent marsh. Benthic macroinvertebrates were sampled with a core sampler made from PVC pipe (Figure 3). It was designed after the core samplers utilized by Swanson (1978a) and Gale (1971). In order to collect planktonic and nektonic organisms, a water column sampler similar to the one designed by Swanson (1978b) was also constructed from PVC pipe (Figure 3). Both samplers had a diameter of 7.5 cm. In order to measure the water depth of the sample, 0.01 m gradations were marked on the sampling devices.

Three replicate hauls constituted a water column sample and a bottom sample was 4 hauls. Two hundred twenty water column samples (660 hauls) and 220 bottom samples (880 hauls) were taken throughout the study period.

After collecting a water column sample, the pipe was inverted and the contents strained through No. 10 plankton net. Contents of the net were then washed into a plastic wash pan with tap water. Substrate cores were placed in a bucket with U.S. No. 30 screen on the bottom and washed to remove excess silt and debris. All samples were put into plastic bags and preserved in 95% ethyl alcohol. The preservative was mixed with 100 mg/l of rose bengal in order to stain the organisms and increase visability during sorting (Mason and Yevich 1967).

In the laboratory, water column samples were again strained through No. 10 plankton net, concentrated to a fixed volume (100 ml), and preserved in 80% ethyl alcohol. A Henson-Stemple pipette was used to withdraw 3, 1 ml subsamples. These were placed in a circular counting cell and all zooplankton were counted and identified with a

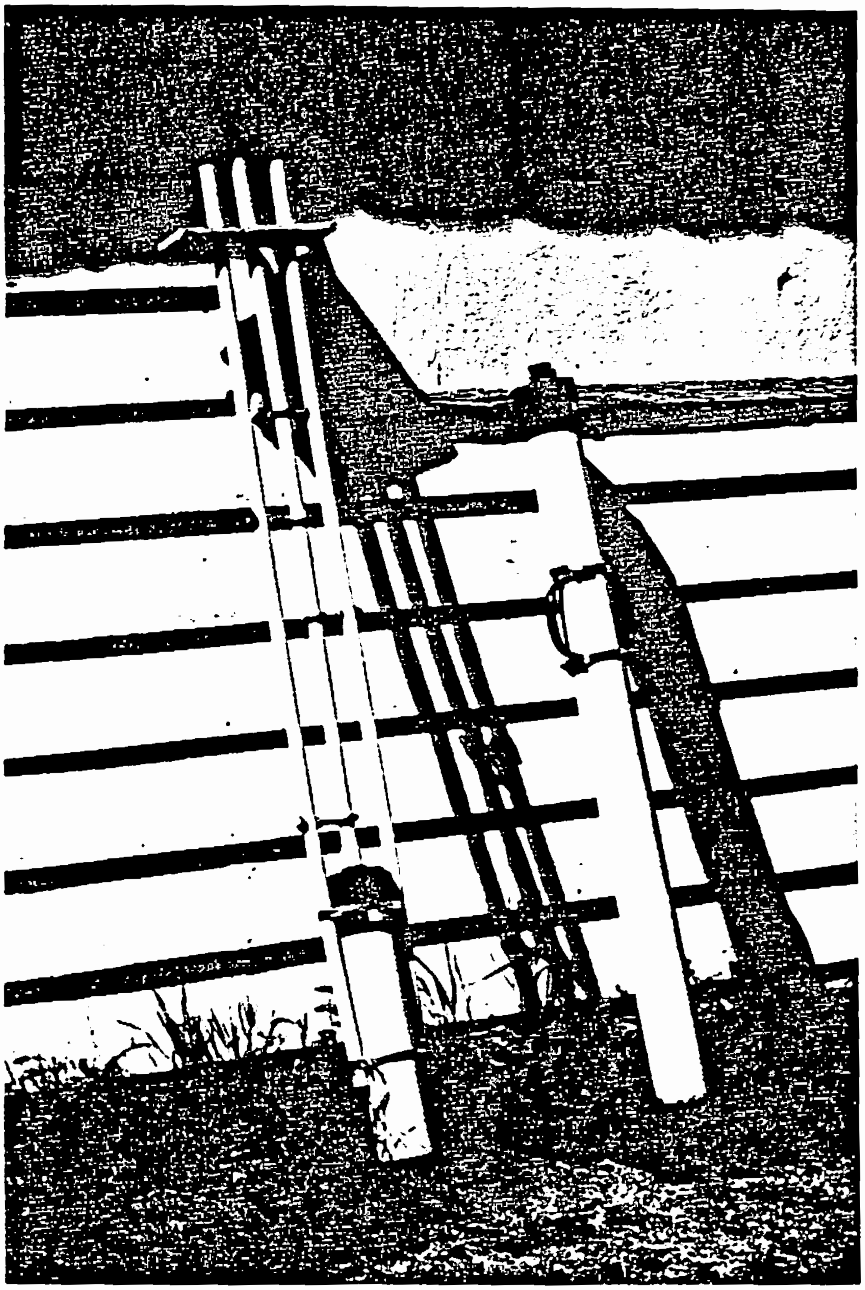

Figure 3. Sampling devices used to collect quantitative samples of aquatic invertebrates, core sampler on left and water column sampler on right.

15x dissecting scope equipped with a 2x doubling lens. Separation of water column and benthic macroinvertebrates from the debris was facilitated by placing the samples in white enamel dissecting pans which were then systematically surveyed using a 15x dissecting scope. All organisms were stored in vials containing 80% ethyl alcohol for subsequent enumeration and biomass determination.

Manuals by Usinger (1956), Merrit and Cummins (1978), and Pennak (1978) were used to identify invertebrates. All macroinvertebrates were oven dried at 105 C for 24 hours and stored in a dessicator until weighed. Dry weights were determined to the nearest 0.0001 g using a Mettler H31AR analytical balance. Weight determinations for all Gastropoda and Pelecypoda included the shells.

Invertebrate standing crops in the level ditches and the unmodified natural emergent marsh were analyzed as organisms/m^2 and mg/m^2 of surface area for the benthic, water column, and zooplankton communities. Expressing the data in this way did not consider differences resulting from variable depths sampled in the water column and provided a measure of differences in availability by surface area. Applegate and Mullan (1967) found this an expedient method of expressing zooplankton standing crops in Beaver and Bull Shoals reservoirs in Arkansas.

Analysis of variance was used to test differences in numbers, biomass, and number of taxa of aquatic invertebrates between the level ditches and the unmodified natural marsh. Testing was at the 0.05 significance level. Significant differences were presented for treatment means over all weeks.

RESULTS AND DISCUSSION

Aquatic Invertebrate Composition, Diversity, and Total Numbers and Biomass

The aquatic invertebrates in samples from the level ditches and emergent marsh represented 45 taxa (Table 1). Larvae, naiads, or nymphs were the most dominant life forms observed for the majority of the macroinvertebrate taxa collected.

Diversity of organisms is one indicator of the value of level ditches as a source of waterfowl invertebrate food. Comparison of the mean number of taxa between the level ditches and emergent marsh showed a significantly larger ($P < 0.05$) number of taxa in the level ditches for both the bottom substrate and water column (Table 2). On 7 excavated ponds in Ontario, it was found that one of the variables by which breeding ducks selected ponds was the number of invertebrate taxa present (Joyner 1980). Kaminski and Prince (1981) suggested that frequent dabbler duck foraging behavior within a given habitat treatment was influenced by the high number of invertebrate families located there. Apparently more taxa means a greater variety of foods for waterfowl to select and consequently a higher probability of acquiring a balanced diet.

There was a significant difference ($P < 0.05$) between the level ditches and the emergent marsh in the mean number of all the macroinvertebrate taxa from both the bottom substrate and the water column, with the larger numbers found in the level ditches (Table 3). The mean

Table 1. Taxa of aquatic invertebrates collected from the level ditches and emergent marsh of the Lake Preston marsh, South Dakota, 1982.

Phylum Nematoda

Phylum Annelida

  Class Oligochaeta

  Class Hirudinea

      Family Glossiphoniidae

Phylum Arthropoda

  Class Crustacea

    Order Conchostraca

    Order Cladocera

      Family Daphnidae

    Order Copepoda

      Suborder Calanoida

      Suborder Cyclopoida

      Suborder Harpacticoida

    Order Ostracoda

    Order Amphipoda

  Class Arachnoidea

    Order Acari

  Class Insecta

    Order Collembola

    Order Ephemeroptera

      Family Caenidae

      Family Baetidae

    Order Odonata

      Suborder Zygoptera

        Family Coenagrionidae

        Family Lestidae

    Order Hemiptera

      Family Corixidae

      Family Pleidae

      Family Notonectidae

Table 1. (Continued)

Family Gerridae
Family Mesoveliidae
Family Belostomatidae
Family Nepidae
Order Lepidoptera
Family Pyralidae
Order Coleoptera
Family Haliplidae
Family Dytiscidae
Family Hydrophilidae
Family Chrysomelidae
Family Curculionidae
Order Diptera
Family Psychodidae
Family Culicidae
Family Chironomidae
Family Ceratopogonidae
Family Stratiomyidae
Family Tabanidae
Family Sciomyzidae
Family Ephydridae
Family Chaoboridae
Family Simuliidae
Family Tipulidae
Phylum Mollusca
Class Gastropoda
Order Basommatophora
Family Physidae
Family Planorbidae
Family Lymnaeidae
Class Pelecypoda
Order Heterodonta
Family Sphaeriidae

Table 2. Mean number of macroinvertebrate taxa collected from the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

	$\bar{X}$ Number of Macroinvertebrate Taxa	
Location Sampled	Level Ditch	Emergent Marsh
Benthos	6.52*	5.69
Water column	8.94*	7.03

*Significant difference ($P < 0.05$) between level ditch and emergent marsh.

Table 3. Mean numbers and biomass of all invertebrate taxa collected from the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

	Organisms/m^2		mg/m^2	
Invertebrates Sampled	Level Ditch	Emergent Marsh	Level Ditch	Emergent Marsh
Benthos macroinvertebrates	7,897.63*	3,533.79	1,745.87	1,313.77
Water column macroinvertebrates	15,193.94*	9,687.08	8,523.93	6,564.17
Zooplankton	802.62×10^3	654.69×10^3	-	-

*Significant difference ($P < 0.05$) between level ditch and emergent marsh.

numbers of all zooplankton collected were not significantly different between habitats (Table 3). The mean biomass of all macroinvertebrates showed no significant difference between the level ditches and the emergent marsh (Table 3), indicating a similar macroinvertebrate standing crop for both habitats. This data suggests the presence of many small organisms in the level ditches and larger but fewer organisms in the emergent marsh. The higher number of organisms in the level ditches may attract ducks. Joyner (1980) found that breeding duck use of excavated ponds was correlated with invertebrate numbers. Dabbling duck foraging behavior was found to be concentrated on areas with the highest abundance of invertebrates (Kaminski and Prince 1981).

Composition, Numbers, and Biomass of Benthic Macroinvertebrates

The most abundant organisms within the level ditches were the nematodes which comprised 60% of the total mean numbers (Table 4). Chironomidae was next in importance with 22.9% of the total mean numbers. Next in order of abundance were Oligochaeta, Corixidae, Sphaeriidae, Physidae, and Planorbidae.

Gravimetrically, organisms of the Family Physidae made up the highest percentage in the level ditches with 53.6% of the total mean biomass of all organisms (Table 5). Glossiphoniidae and Sphaeriidae were next in importance with 10.4% and 10.2% of the total mean biomass, respectively. Chironomidae, Nematoda, Planorbidae, Oligochaeta, Corixidae, and Belostomatidae all contributed greater than 1% to the total mean biomass in the level ditches.

Table 4. Mean numbers of benthic macroinvertebrates sampled in the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

Taxa	Level Ditch		Emergent Marsh	
	Organisms/ m^2	Percent of Total	Organisms/ m^2	Percent of Total
Nematoda	4,730.07*	60.0	365.86	10.0
Chironomidae	1,805.23	22.9	1,967.70	54.0
Oligochaeta	391.96	5.0	421.67	11.6
Corixidae	281.00	3.6	203.05	5.6
Physidae	122.18*	1.6	220.22	6.0
Sphaeriidae	181.13*	2.3	1.14	tr[a]
Planorbidae	93.76	1.2	133.00	3.7
Chaoboridae	74.70*	tr	20.54	tr
Caenidae	41.66*	tr	4.62	tr
Amphipoda	30.42	tr	38.35	1.1
Glossiphoniidae	26.94	tr	10.96	tr
Coenagrionidae	24.14*	tr	4.62	tr
Pleidae	22.66	tr	18.49	tr
Haliplidae	14.89	tr	18.83	tr
Ephydridae	13.12	tr	0.51	tr
Conchostraca	9.76	tr	8.79	tr
Ceratopogonidae	7.70*	tr	20.15	tr
Dytiscidae	3.60	tr	1.03	tr
Lymnaeidae	3.60	tr	7.88	tr
Pyralidae	3.60	tr	3.71	tr
Notonectidae	2.05	tr	2.57	tr
Hydrophilidae	1.54	tr	4.11	tr
Belostomatidae	0.51	tr	0.51	tr
Gerridae	0.51	tr	2.05	tr
Sciomyzidae	0.51	tr	0.00	0.00
Psychodidae	0.00	0.00	102.72	2.8
Culicidae	0.00	0.00	51.36	1.4
Stratiomyidae	0.00*	0.00	6.16	tr

Table 4. (Continued)

Taxa	Level Ditch		Emergent Marsh	
	Organisms/ m^2	Percent of Total	Organisms/ m^2	Percent of Total
Collembola	0.00	0.00	1.03	tr
Baetidae	0.00	0.00	0.51	tr
Chrysomelidae	0.00	0.00	0.51	tr
Simuliidae	0.00	0.00	0.51	tr
Tabanidae	0.00	0.00	0.51	tr

[a]tr = < 1.0%.

*Significant difference ($P < 0.05$) between level ditch and emergent marsh.

Table 5. Mean biomass of benthic macroinvertebrates sampled in the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

Taxa	Level Ditch		Emergent Marsh	
	mg/m^2	Percent of Total	mg/m^2	Percent of Total
Physidae	935.56	53.6	585.84	43.8
Glossiphoniidae	181.09*	10.4	12.82	tr[a]
Sphaeriidae	178.17*	10.2	0.46	tr
Chironomidae	116.74	6.7	171.82	12.8
Nematoda	108.50*	6.2	16.68	1.3
Planorbidae	61.09	3.5	242.96	18.2
Oligochaeta	30.77	1.8	44.65	3.3
Corixidae	29.65	1.7	42.17	3.2
Belostomatidae	25.73	1.5	38.37	2.9
Conchostraca	15.97	tr	18.07	1.4
Amphipoda	10.87	tr	6.84	tr
Caenidae	10.80*	tr	0.26	tr
Chaoboridae	8.06*	tr	3.06	tr
Pleidae	6.64*	tr	2.88	tr
Lymnaeidae	5.03	tr	76.15	5.7
Hydrophilidae	4.67	tr	17.87	1.3
Haliplidae	4.43	tr	4.55	tr
Notonectidae	4.37	tr	4.57	tr
Pyralidae	2.11	tr	0.88	tr
Dytiscidae	2.00	tr	0.31	tr
Coenagrionidae	1.54*	tr	0.46	tr
Ephydridae	0.86	tr	0.05	tr
Ceratopogonidae	0.85*	tr	3.79	tr
Sciomyzidae	0.58	tr	0.00	0.0
Stratiomyidae	0.00	0.00	33.40	2.5
Tabanidae	0.00	0.00	7.96	tr
Chrysomelidae	0.00	0.00	1.18	tr
Gerridae	0.00	0.00	0.37	tr

Table 5. (Continued)

Taxa	Level Ditch		Emergent Marsh	
	mg/m^2	Percent of Total	mg/m^2	Percent of Total
Baetidae	0.00	0.00	0.21	tr
Simuliidae	0.00	0.00	0.15	tr
Collembola	0.00	0.00	0.10	tr
Culicidae	0.00	0.00	0.05	tr
Psychodidae	0.00	0.00	0.05	tr

[a]tr = < 1.0%.

*Significant difference ($P < 0.05$) between level ditch and emergent marsh.

Of the benthic macroinvertebrates located within the emergent marsh, Chironomidae were numerically the most important, comprising 54% of the total mean numbers (Table 4). Second in abundance were the Oligochaeta with 11.6% of the total mean density. The remaining taxa each comprising greater than 1% of total composition were Nematoda, Physidae, Corixidae, Planorbidae, Psychodidae, Culicidae, and Amphipoda in that order.

Biomass determinations within the emergent marsh showed that Physidae, Planorbidae, and Chironomidae were the 3 most important taxa, accounting for 43.8%, 18.2%, and 12.8% of the total dry weight of all organisms, respectively (Table 5). In order of importance, the remaining macroinvertebrate taxa comprising greater than 1% each of the total biomass were Lymnaeidae, Oligochaeta, Corixidae, Stratiomyidae, Belostomatidae, Conchostraca, Hydrophilidae, and Nematoda.

Comparison of the mean numbers and biomass between the level ditches and the emergent marsh for each individual taxa showed several instances in which significant differences occurred (Tables 4 and 5). In most cases where differences were indicated, the level ditches contained the greater mean numbers and biomass. The exceptions were Physidae, Ceratopogonidae, and Stratiomyidae which were more abundant within the emergent marsh and Ceratopogonidae which had a greater biomass in the emergent marsh habitat. However, for the majority of benthic macroinvertebrate taxa sampled, there were no significant differences in abundance or dry weight between the 2 habitats. Additionally, many invertebrate groups were not present in sufficient numbers to provide an adequate sample, therefore making some comparisons of dubious value.

Few studies of the benthic macroinvertebrate fauna present in the wetlands of the Prairie Pothole Region have been undertaken. The most numerous benthic animals found in Lake Kampeska, South Dakota, a lacustrine wetland with a mean depth of 2.5 m, were Chironomidae larvae Oligochaeta, and *Hexagenia limbata* (Ephemeroptera, Ephemeridae) (Hartung 1968). Gravimetrically, the most important benthic organisms in Lake Kampeska were Chironomidae, *Hexagenia limbata*, Hirudinea (leeches), Sphaeriidae, Oligochaeta, and Corixidae (Hartung 1968). In Lake Poinsett, South Dakota, another shallow, lacustrine wetland, Smith (1971) found that Chironomidae, Oligochaeta, and Caenidae were the most significant macroinvertebrate benthos dwellers in terms of both mean annual numbers and biomass. Based on weekly mean weights and numbers of organisms, Chironomidae, Oligochaeta, Amphipoda, Turbellaria, and Ephemeroptera encompassed 99.9% of the organisms collected from Clear Lake, Iowa (Mrachek and Bachman 1967). At the deep water sampling stations within Lizard Lake, Iowa, Tendipedidae (Chironomidae), *Hyalella knickerbockeri* (Amphipoda), Gastropoda, and Oligochaeta were the taxonomic groups constituting the greatest biomass and numbers (Tebo 1955). Of those organisms collected from the shallow water stations of Lizard Lake, Gastropoda, Tendipedidae (Chironomidae), Oligochaeta, *Hyalella knickerbockeri* (Amphipoda), Odonata, other Diptera, Baetidae, and Corixidae were the most significant (Tebo 1955). Donaldson (1976) found that Chironomidae larvae comprised 93% of the total density and 96% of total dry weight of all benthic organisms collected from Bothwell Marsh, a palustrine emergent seasonal wetland in eastern South Dakota. In Lund Marsh, another palustrine emergent seasonal marsh in eastern South Dakota, Chironomidae larvae were the preponderate benthic animals by both density and dry weight, with Gastropoda (Planorbidae and Physidae) second in importance (Donaldson 1976). The data from Lake Preston marsh seems to be consistent with the findings from other wetlands in the Prairie Pothole Region. Any differences can be accounted for by dissimilar wetland characteristics, geographic locality, time period of study, and collection techniques.

Composition, Numbers, and Biomass of Water Column Macroinvertebrates

Corixidae were the most numerous organisms collected from the water column within the level ditches, making up 30.7% of the total mean number of organisms (Table 6). Second in importance was Chironomidae (24.9%), followed in order by Amphipoda, Oligochaeta, Physidae, Pleidae, Nematoda, Caenidae, Coenagrionidae, and Planorbidae.

For the level ditches, Physidae contributed the most in terms of biomass, constituting 74.2% of the total mean biomass (Table 7). All the Gastropoda combined (Physidae, Lymnaeidae, and Planorbidae) made up 80.8% of the total dry weight. Also of relative importance to the total biomass in the level ditches were Corixidae, Amphipoda, Sphaeriidae, Conchostraca, Dytiscidae, Chironomidae, and Pleidae.

The most abundant water column macroinvertebrates within the emergent marsh were Chironomidae with 32.7% of the total mean numbers (Table 6). Next in importance was Corixidae (17.5%) followed by Physidae (14.1%). Amphipoda, Oligocaheta, Planorbidae,

Table 6. Mean numbers of macroinvertebrates collected from the water column in the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

Taxa	Level Ditch		Emergent Marsh	
	Organisms/ m^2	Percent of Total	Organisms/ m^2	Percent of Total
Corixidae	4,666.99*	30.7	1,696.69	17.5
Chironomidae	3,786.98	24.9	3,165.86	32.7
Amphipoda	1,268.60	8.4	885.64	9.1
Oligochaeta	989.43	6.5	589.24	6.1
Physidae	635.86*	4.2	1,368.76	14.1
Pleidae	601.67*	4.0	278.66	2.9
Nematoda	477.59*	3.1	255.27	2.6
Caenidae	440.72*	2.9	96.94	1.0
Coenagrionidae	440.19*	2.9	49.83	tr[a]
Planorbidae	303.64	2.0	439.45	4.5
Ephydridae	253.82*	1.7	14.41	tr
Haliplidae	247.06*	1.6	123.58	1.3
Dytiscidae	191.78*	1.2	37.01	tr
Chaoboridae	154.36	1.0	119.55	1.2
Conchostraca	96.85	tr	65.82	tr
Notonectidae	92.70*	tr	26.83	tr
Pyralidae	88.65	tr	57.58	tr
Ceratopogonidae	82.41	tr	47.58	tr
Sphaeriidae	72.08*	tr	2.05	tr
Gerridae	47.35	tr	24.66	tr
Acari	45.14	tr	45.38	tr
Mesoveliidae	41.26	tr	27.28	tr
Glossiphoniidae	39.19	tr	58.12	tr
Lymnaeidae	26.81	tr	30.82	tr
Baetidae	20.60*	tr	2.06	tr
Collembola	20.60	tr	10.34	tr
Hydrophilidae	18.54	tr	31.19	tr
Stratiomyidae	18.51*	tr	64.59	tr

Table 6. (Continued)

Taxa	Level Ditch		Emergent Marsh	
	Organisms/ m^2	Percent of Total	Organisms/ m^2	Percent of Total
Culicidae	10.30	tr	22.65	tr
Psychodidae	6.18	tr	28.65	tr
Lestidae	4.11	tr	6.18	tr
Nepidae	2.07	tr	0.00	0.00
Curculionidae	1.90	tr	6.17	tr
Tipulidae	0.00	0.00	6.17	tr
Chrysomelidae	0.00	0.00	2.06	tr

[a]tr = < 1.0%.

*Significant difference (P < 0.05) between level ditch and emergent marsh.

Table 7. Mean biomass of macroinvertebrates collected from the water column in the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

	Level Ditch		Emergent Marsh	
Taxa	mg/m^2	Percent of Total	mg/m^2	Percent of Total
Physidae	6,473.11*	74.2	3,141.06	47.2
Corixidae	510.39*	5.9	261.77	3.9
Lymnaeidae	291.72	3.3	138.64	2.1
Planorbidae	284.01*	3.3	2,158.85	32.4
Amphipoda	164.33	1.9	129.97	2.0
Sphaeriidae	121.35*	1.4	0.62	tr[a]
Conchostraca	116.65	1.3	98.67	1.5
Dytiscidae	111.09*	1.3	11.62	tr
Chironomidae	107.45	1.2	130.44	2.0
Pleidae	90.20*	1.0	40.19	tr
Glossiphoniidae	76.12	tr	59.03	tr
Haliplidae	65.77*	tr	26.40	tr
Caenidae	53.31*	tr	14.23	tr
Coenagrionidae	34.31*	tr	8.84	tr
Notonectidae	26.54	tr	83.64	1.3
Oligochaeta	24.79	tr	16.20	tr
Hydrophilidae	24.39*	tr	219.07	3.3
Stratiomyidae	23.70	tr	59.45	tr
Ephydridae	22.88*	tr	2.63	tr
Chaoboridae	21.83*	tr	4.66	tr
Gerridae	20.82	tr	6.63	tr
Pyralidae	17.56	tr	8.92	tr
Nepidae	11.61	tr	0.00	0.00
Nematoda	7.86	tr	5.49	tr
Acari	6.98	tr	2.83	tr
Mesoveliidae	4.21	tr	3.22	tr
Ceratopogonidae	3.97	tr	3.57	tr
Culicidae	3.08	tr	1.75	tr

Table 7. (Continued)

	Level Ditch		Emergent Marsh	
Taxa	mg/m^2	Percent of Total	mg/m^2	Percent of Total
Baetidae	1.40	tr	0.62	tr
Curculionidae	1.33	tr	1.85	tr
Lestidae	1.23	tr	5.16	tr
Psychodidae	0.83	tr	3.07	tr
Collembola	0.82	tr	0.21	tr
Tipulidae	0.00	0.00	5.56	tr
Chrysomelidae	0.00	0.00	1.03	tr

[a]tr = < 1.0%.

*Significant difference ($P < 0.05$) between level ditch and emergent marsh.

Pleidae, and Nematoda also contributed to the total density within the emergent marsh.

Forty-seven percent of the total mean biomass for the emergent marsh was made up of Physidae (Table 7). All Gastropoda combined made up 81.7% of the total dry weight. Other taxonomic groups each contributing greater than 1% of the total mean biomass were Corixidae, Hydrophilidae, Amphipoda, Chironomidae, Conchostraca, and Notonectidae.

Comparison of the various taxa represented in both the level ditches and emergent marsh showed significant differences in both numbers and biomass (Tables 6 and 7). In the majority of cases for an individual taxon the greater abundance and dry weight was within the level ditches. Several exceptions to this occurred. Physidae occurred in greater numbers in the emergent marsh yet a larger biomass was indicated for the level ditches. Evidently fewer organisms of a larger size were located in the level ditches. In spite of the rare occurrence within the samples, greater numbers of Stratiomyidae were present in the emergent marsh with no difference in biomass between the 2 habitats. This suggests that many Stratiomyidae organisms of a small size were present in the emergent marsh. Both Planorbidae and Hydrophilidae had a greater biomass within the emergent marsh but no difference in abundance, indicating that individual organisms of these families were of a larger size in the emergent marsh than in the level ditches.

In other studies of macroinvertebrates found in the water column of prairie wetlands, many of the same taxa were recorded as in this study. However, the percent composition of numbers and biomass were often dissimilar. Among the macroinvertebrate nekton collected from Bothwell Marsh, a seasonal wetland in eastern South Dakota, over 95% of the total numbers were comprised of Glossiphoniidae, Baetidae, Dytiscidae, Planorbidae, Physidae, Acari, Corixidae, Libellulidae, Coenagrionidae, Lymnaeidae, and Haliplidae (Donaldson 1976). Glossiphoniidae were the most abundant organisms making up 42.5% of the total number. Approximately 36% of the biomass of Bothwell Marsh was made up of Ambystoma tigrinum (a salamander), while the macroinvertebrates Lymnaeidae, Physidae, Glossiphoniidae, Libellulidae, and Planorbidae collectively made up 57% (Donaldson 1976). In Lund Marsh, also a seasonal wetland located in eastern South Dakota, Donaldson (1976) found that 99% of the total number of nektonic organisms was made up of Planorbidae, Glossiphoniidae, Dytiscidae, Hydrophilidae, Coenagrionidae, Acari, Baetidae, Haliplidae, Ambystoma tigrinum, Corixidae, and Physidae. Planorbids were the most abundant and comprised 38% of the total. Ambystoma tigrinum contributed 71% to the total animal biomass in Lund Marsh while the macroinvertebrates Planorbidae, Lymnaeidae, Coenagrionidae, Glossiphoniidae, Physidae, Dytiscidae, and Hydrophilidae collectively amounted to approximately 27% of the total biomass. The most abundant macroinvertebrate group collected from semipermanent wetlands in Iowa was Amphipoda while other taxa that occurred in large enough numbers to be analyzed were Chironomidae, Isopoda, Physidae, and Planorbidae (Voigts 1976).

Although no quantitative information was presented, Hohman (1977) stated that the major invertebrate groups encountered in seasonal and semipermanent wetlands in Minnesota were Oligochaeta, Hirudinea, Amphipoda, Coenagrionidae (Enallagma spp.), Corixidae, Pleidae, Coleoptera, Chironomidae, Ephemeroptera, Trichoptera, Lepidoptera, Pelecypoda, and Gastropoda. McCrady (1982) did not present abundance and biomass data for individual taxa, however, some of the more conspicuous macroinvertebrate taxa he found in an eastern South Dakota palustrine semipermanent wetland were Culicidae, Chironomidae, Gastropoda, Hemiptera, Amphipoda, Ephemeroptera, Hirudinea, Hydracarina, Odonata, and Coleoptera. In a study of macroinvertebrates associated with the star duckweed community of a palustrine semipermanent wetland in eastern South Dakota, Meyers (1982) found that Amphipoda (68.6%) and Gastropoda (22.2%) were the most abundant organisms. The macroinvertebrate groups of Hydracarina, Pleidae, Diptera, and Corixidae each contributed less than 2.5% of the total density. Those taxa that collectively made up 2.4% of the total number of invertebrates in the star duckweed community were Ephemeroptera, Hirudinea, Ondonata, Coleoptera, Notonectidae, Mesoveliidae, Veliidae, and Nematoda. The dominant macroinvertebrates in the star duckweed community in terms of biomass were Gastropoda and Amphipoda (Meyers 1982).

Composition and Numbers of Zooplankton

The dominant microinvertebrate taxa found in the level ditches were Cyclopoida with 42.8% of the total numbers, followed in importance by Daphnidae (32.3%) and Ostracoda (24.2%) (Table 8). The most bundant zooplankton taxon collected from the emergent marsh was ›stracoda which made up 61.2% of the total mean numbers, while :yclopoida and Daphnidae were next in importance, constituting 29% ınd 9.5% of the total density, respectively (Table 8). Calanoida ınd Harpacticoida were present only in trace densities in both the level ditches and emergent marsh.

Mean numbers of zooplankton in the level ditches versus the emergent marsh were significantly different ($P < 0.05$) for Cyclopoida and Ostracoda (Table 8). Cyclopoida were more abundant in the level ditches whereas Ostracoda were more numerous in the emergent marsh.

Microinvertebrates associated with the star duckweed community of a semipermanent marsh in South Dakota were Cladocera, Copepoda, and Ostracoda contributing 74.1%, 13.7%, and 11.8%, respectively, to the total zooplankton density (Meyers 1982). McCrady (1982) found that the most commonly encountered zooplankton taxa in Paul L. Errington Memorial Marsh were Cyclopoida, Calanoida, Cladocera, and Ostracoda. In the study of semipermanent marshes in Iowa, the most abundant zooplankton groups were Cladocera and Copepoda (Voigts 1976). The dominant microinvertebrates collected from Bothwell Marsh were Daphnia pulex and Ceriodaphnia quadrangula which contributed 33% and 21% of the zooplankton density, respectively (Donaldson 1976). Both of these organisms are in the Order Cladocera, Family Daphnidae. Rotifera and Ostracoda were also present in the marsh. In Lund Marsh the dominant zooplankter was Diaptomus leptopus (Suborder Calanoida) which made up 58% of the total density (Donaldson 1976). Next in importance was Daphnia pulex which made up 17% of the total numbers. Ostracoda,

Table 8. Mean numbers of zooplankton collected from the level ditches and emergent marsh between 10 June and 17 August 1982, Lake Preston marsh, South Dakota.

Taxa	Level Ditch		Emergent Marsh	
	Organisms/ m^2	Percent of Total	Organisms/ m^2	Percent of Total
Cyclopoida	$114.53 \times 10^{3*}$	42.8	63.20×10^3	29.0
Daphnidae	86.42×10^3	32.3	20.83×10^3	9.5
Ostracoda	$64.94 \times 10^{3*}$	24.2	133.58×10^3	61.2
Calanoida	1.24×10^3	tr[a]	0.14×10^3	tr
Harpacticoida	0.41×10^3	tr	0.48×10^3	tr

[a]tr = < 1.0%.

*Significant difference ($P < 0.05$) between the level ditch and emergent marsh.

Rotifera, and Harpacticoida were sporadically present in the samples. The most abundant zooplankton group collected from Saarinens Pond in eastern South Dakota was Cyclopoida with a mean seasonal density of 126.24/liter (Walker 1975). The next most dominant taxa were *Daphnia* spp., *Bosmina* spp., and Calanoida having mean seasonal numbers of 27.29/liter, 9.06/liter, and 3.15/liter, respectively. The microfauna encountered in Lake Preston marsh appeared consistent with the findings in other prairie wetlands despite some differences in percent composition.

Lake Preston Marsh as an Invertebrate Food Source of Waterfowl

Information concerning waterfowl diet composition is necessary to evaluate the potential of the level ditches and emergent marsh at Lake Preston marsh as sources of waterfowl food during the breeding and brood rearing season. Female blue-winged teal (*Anas discors*) consume primarily aquatic invertebrates during the breeding season, the most important of which are Gastropoda, dipterans (Chironomidae and Culicidae) and crustaceans (Amphipoda, Ostracoda, Copepoda, Cladocera, Conchostraca, and Anostraca) (Swanson et al. 1974, Swanson et al. 1979). Some of the more significant aquatic animal foods in the diet of breeding female pintails (*Anas acuta*) are Chironomidae, Gastropoda, Anostraca, Odonata, Coleoptera, Conchostraca, and Cladocera (Krapu 1974a, 1974b; Krapu and Swanson 1977; Swanson et al. 1979). Laying female gadwalls (*Anas strepera*) feed on various crustaceans (Cladocera, Ostracoda, Copepoda, Conchostraca, Amphipoda, and Anostraca) as well as insects (Chironomidae, Dytiscidae, Corixidae, and Odonata) (Serie and Swanson 1976, Swanson et al. 1979). Among laying female northern shovelers (*Anas clypeata*) the diet is dominated by Gastropoda and crustaceans (Cladocera, Conchostraca, Anostraca, Copepoda, and Ostracoda) (Swanson et al. 1979). Female mallards (Anas platyrhynchos) during the laying state prefer an aquatic invertebrate diet of Gastropoda, Conchostraca, Cladocera, Lepidoptera, Odonata, Chironomidae, and Amphipoda (Swanson et al. 1979). During the spring and summer, adult female canvasbacks (Aythya valisineria) consume an animal diet of primarily Gastropoda with larval forms of Trichoptera, Chironomidae, Ephemeroptera, and Zygoptera comprising the remainder of invertebrate foods (Bartonek and Hickey 1969a). Adult female lesser scaup (Aythya affinis) feed on Amphipoda, Chironomidae, Gastropoda, Corixidae, and Trichoptera during the breeding season (Bartonek and Hickey 1969a).

Aquatic invertebrates are also an important component of the diet of duck broods. Gastropoda and Chironomidae are the primary animal foods consumed by juvenile pintails with Cladocera, Coleoptera, Hemiptera, and Conchostraca contributing to the diet (Sugden 1973; Krapu and Swanson 1977). Immature gadwalls feed primarily on Chironomidae, Curculionidae, Dytiscidae, Haliplidae, Corixidae, and Cladocera (Sugden 1973). Sugden (1973) found that the most important animal foods eaten by juvenile American wigeon (Anas americana) are Chironomidae and Gastropoda. The dominant animal foods in the diet of the lesser scaup broods are Amphipoda, Gastropoda, Chironomidae, and Corixidae (Sugden 1973, Bartonek and Hickey 1969a). Chura (1961) stated that Chironomidae are the most important aquatic invertebrate in the diet of young mallards. Trichoptera, Gastropoda and Chrionomidae are the main invertebrate taxa upon which juvenile canvasbacks feed (Bartonek and Hickey 1969a, 1969b). The majority of the diet of juvenile redheads (Aythya americana) is composed of Trichoptera, Gastropoda, Cladocera, and Chironomidae (Bartonek and Hickey 1969a, 1969b). Chironomidae constitute the principle item in the diet of juvenile ruddy ducks (Oxyura jamaicensis rubida) (Siegfried 1973).

From the above studies concerning the important aquatic invertebrate components in the diet of breeding ducks and ducklings and analysis of the composition of aquatic organisms present in the level ditches and emergent marsh of Lake Preston (Tables 4, 5, 6, 7, and 8), it appeared that both habitats contained an abundance of duck foods. Several of the taxa found in the level ditches and emergent marsh have also been shown to be nutritionally valuable to breeding female ducks and ducklings. Chironomidae larvae, Gammarus spp. (Amphipoda), Corixidae, Notonectidae, and Gastropoda all contain high levels of crude protein (Sugden 1973, Krapu 1979, Reinecke and Owen 1980). Gastropoda shells and tissue are also an excellent source of calcium which is required in formation of the egg shell (Krapu and Swanson 1975). However, Sugden (1973) found that few of the duck foods subjected to nutrient analysis would alone provide the nutrients in adequate proportions required by ducklings. A mixed diet of several different types of invertebrates may provide a nutritionally balanced diet for ducklings (Sugden 1973). Kaminski and Prince (1981) also suggested that a more balanced diet may be obtainable on areas with more aquatic invertebrate diversity. It has been shown that a more diverse macroinvertebrate fauna was present in the level ditches (Table 2).

CONCLUSIONS AND RESEARCH RECOMMENDATIONS

This study indicated that level ditches contained an abundant source of the aquatic invertebrate fauna utilized by breeding ducks and broods. The level ditches were more important in terms of mean number of taxa, total mean numbers, and mean numbers and biomass for certain specific taxa. Based on these findings, it can be concluded that the level ditches are at least as important as the emergent marsh as a habitat suitable to aquatic organisms. During periods of drought when the emergent marsh may not have the water levels necessary for ducks to feed on invertebrates, the level ditches may indeed be an important alternative duck feeding habitat.

This was not a definitive study on the value of level ditches as a source of invertebrate foods for waterfowl, due to limitations in both the duration and scope of this project. Further intensive research into the value of level ditches as a marsh management technique is required. One avenue of research is to study more thoroughly the aquatic invertebrate communities of the level ditches and natural emergent marshes over an extended period of time covering both the wet and dry wetland cycles. Some factors that may contribute to differences between level ditches and emergent marshes should also be investigated such as vegetation, bottom substrate, water chemistry, temperature, dissolved oxygen concentration, and water depth. A 5-year study of a natural emergent wetland prior to the construction of level ditches and a 5-year post-modification study should provide useful information to evaluate the effect of level ditching on the aquatic invertebrate community. Comparison of the dietary composition of ducks utilizing level ditches and natural emergent marshes as feeding sites should also be an illuminating investigation.

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APPENDIX

APPENDIX

Appendix Table 1. Analysis of variance for mean number of all macroinvertebrates collected from the bottom substrate.

Source	df	MS	F
TRT	1	1,033,069,788.44	42.90*
Error	215	24,081,987.34	
Total	216		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of all macroinvertebrates collected from the bottom substrate.

Source	df	MS	F
TRT	1	10,128,933.12	1.76
Error	215	5,763,737.55	
Total	216		

Analysis of variance for mean numbers of all macroinvertebrates collected from the water column.

Source	df	MS	F
TRT	1	1,667,905,421.43	10.86*
Error	218	153,585,807.02	
Total	219		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean biomass of all macroinvertebrates collected from the water column.

Source	df	MS	F
TRT	1	211,236,102.39	1.86
Error	218	113,741,172.39	
Total	219		

Analysis of variance for mean numbers of all zooplankton collected from the water column.

Source	df	MS	F
TRT	1	1,203,565.88	0.79
Error	218	1,528,779.06	
Total	219		

Analysis of variance for mean number of taxa in bottom substrate.

Source	df	MS	F
TRT	1	37.17	5.38*
Week	10	47.44	6.87*
TRT * Week	10	3.38	0.49
Error	195	6.91	
Total	216		

*Significance level (P < 0.05).

Appendix Table 1 cont.

Analysis of variance for mean numbers of Nematoda collected from the bottom substrate.

Source	df	MS	F
TRT	1	1,031,911,989.03	136.24*
Week	10	5,571,454.93	0.74
TRT * Week	10	5,315,226.86	0.70
Error	195	7,574,147.68	
Total	216		

*Significance level ($P < 0.05$).

Analysis of variance for mean number of Physidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	520,784.36	8.97*
Week	10	71,004.46	1.22
TRT * Week	10	87,729.61	1.51
Error	195	58,048.10	
Total	216		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean number of Caenidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	74,320.62	16.60*
Week	10	20,017.04	4.47*
TRT * Week[a]	10	10,331.37	2.31*
Error	195	4,478.32	
Total	216		

[a]TRT means significantly different ($P < 0.05$) for weeks 9, 10, and 11.

*Significance level ($P < 0.05$).

Weekly means for Caenidae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	22.60	0.00
2	0.00	0.00
3	5.65	0.00
4	0.00	0.00
5	6.28	0.00
6	0.00	0.00
7	39.55	0.00
8	28.25	0.00
9	79.10*	5.65
10	112.99*	16.95
11	163.84*	28.25

*Significant difference ($P < 0.05$) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Sphaeriidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	1,755,252.27	5.24*
Week	10	311,789.49	0.93
TRT * Week	10	314,533.43	0.94
Error	195	335,263.39	
Total	216		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Sphaeriidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	1,711,120.27	9.81*
Week	10	177,846.31	1.02
TRT * Week	10	175,183.53	1.00
Error	195	174.369.52	
Total	216		

*Significance level ($P < 0.05$)

Appendix Table 1 cont.

Analysis of variance for mean number of Ceratopogonidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	8,385.77	7.94*
Week	10	2,738.39	2.59*
TRT * Week[a]	10	2,174.79	2.06*
Error	195	1,056.68	
Total	216		

[a]TRT means significantly different ($P < 0.05$) for weeks 4 and 5.

*Significance level ($P < 0.05$).

Weekly means for Ceratopogonidae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	11.30	0.00
2	0.00	0.00
3	0.00	16.95
4	5.65*	69.05
5	0.00*	33.90
6	0.00	0.00
7	16.94	22.60
8	11.30	16.95
9	33.90	28.25
10	5.65	11.30
11	0.00	22.60

*Significant difference ($P < 0.05$) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Chaoboridae collected from the bottom substrate.

Source	df	MS	F
TRT	1	158,908.93	12.53*
Week	10	45,800.93	3.61*
TRT * Week[a]	10	39,564.58	3.12*
Error	195	12,680.87	
Total	216		

[a]TRT means significantly different (P < 0.05) for week 11.

*Significance level (P < 0.05).

Weekly means for Chaoboridae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	22.60	0.00
3	16.95	0.00
4	11.30	6.28
5	81.61	5.65
6	79.10	50.22
7	90.40	28.25
8	16.95	16.95
9	124.29	39.55
10	62.15	67.80
11	316.38*	11.30

*Significant difference (P < 0.05) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Stratiomyidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	2,058.17	10.48*
Week	10	426.77	2.17*
TRT * Week[a]	10	426.77	2.17*
Error	195	196.43	
Total	216		

[a]TRT means significantly different ($P < 0.05$) for weeks 9 and 11.

*Significance level ($P < 0.05$).

Weekly means for Stratiomyidae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	0.00	5.65
3	0.00	0.00
4	0.00	0.00
5	0.00	11.30
6	0.00	0.00
7	0.00	0.00
8	0.00	0.00
9	0.00*	28.25
10	0.00	5.65
11	0.00*	16.95

*Significant difference ($P < 0.05$) determined by LSD comparison.

Appendix Table I cont.

Analysis of variance for mean number of Coenagrionidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	20,637.54	6.55*
Week	10	7,544.97	2.39*
TRT * Week	10	4,034.76	1.28
Error	195	3,152.59	
Total	216		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Nematoda collected from the bottom substrate.

Source	df	MS	F
TRT	1	407,472.39	69.35*
Week	10	14,209.23	2.42*
TRT * Week	10	3,863.24	0.66
Error	176	5,875.30	
Total	197		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Caenidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	5,777.40	6.81*
Week	10	1,539.26	1.81
TRT * Week	10	1,518.97	1.79
Error	188	848.72	
Total	209		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Glossiphoniidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	1,518,930.97	3.91*
Week	10	341,857.00	0.88
TRT * Week	10	248,547.62	0.64
Error	193	388,342.56	
Total	214		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean biomass of Ceratopogonidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	449.14	9.31*
Week	10	75.54	1.57
TRT * Week	10	70.81	1.47
Error	187	48.22	
Total	208		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Chaoboridae collected from the bottom substrate.

Source	df	MS	F
TRT	1	1,265.39	8.88*
Week	10	233.49	1.64
TRT * Week [a]	10	293.11	2.06*
Error	182	142.52	
Total	203		

[a] TRT means significantly different ($P < 0.05$) for weeks 5 and 11.

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Weekly means for Chaoboridae biomass by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	6.78	0.00
3	2.83	0.00
4	2.83	8.16
5	16.32*	1.13
6	10.67	2.83
7	10.67	6.91
8	2.51	1.70
9	7.91	5.65
10	4.94	7.26
11	23.23*	0.00

*Significant difference ($P < 0.05$) determined by LSD comparison.

Analysis of variance for mean biomass of Pleidae collected from the bottom substrate.

Source	df	MS	F
TRT	1	757.38	6.17*
Week	10	584.80	4.76*
TRT * Week	10	86.03	0.70
Error	192	122.78	
Total	213		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean biomass of Coenagrionidae collected from bottom substrate.

Source	df	MS	F
TRT	1	60.42	4.46*
Week	10	44.42	3.28*
TRT * Week	10	14.32	1.06
Error	189	13.55	
Total	210		

*Significance level ($P < 0.05$).

Analysis of variance for mean number of taxa collected from the water column.

Source	df	MS	F
TRT	1	200.45	30.21*
Week	10	153.27	23.10*
TRT * Week	10	11.92	1.80
Error	198	6.63	
Total	219		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean number of Physidae collected from the water column.

Source	df	MS	F
TRT	1	29,543.184.34	29.80*
Week	10	2,715,999.57	2.74*
TRT * Week[a]	10	2,844.145.49	2.87*
Error	198	991,479.12	
Total	219		

[a]TRT means significantly different ($P < 0.05$) for weeks 2, 3, and 4.

*Significance level ($P < 0.05$).

Weekly means for Physidae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	90.61	658.20
2	580.77*	1,853.37
3	587.50*	2,724.71
4	589.08*	2,327.31
5	406.48	1,242.32
6	407.82	1,223.25
7	724.96	1,422.14
8	861.88	522.64
9	1,271.07	1,180.78
10	636.41	881.56
11	837.86	1,020.11

*Significant difference ($P < 0.05$) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Nematoda collected from the water column.

Source	df	MS	F
TRT	1	2,718,268.85	5.45*
Week	10	414,877.88	0.83
TRT * Week[a]	10	1,187,819.52	2.38*
Error	198	498, 444.68	
Total	219		

[a]TRT means significantly different ($P < 0.05$) for weeks 5 and 7.

*Significance level ($P < 0.05$).

Weekly means for Nematoda numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	384.17	385.41
2	294.80	681.05
3	271.48	476.48
4	611.99	45.31
5	1,293.62*	45.22
6	270.58	520.33
7	791.69*	134.73
8	226.74	68.16
9	339.65	113.60
10	181.11	270.00
11	587.63	67.71

*Significantly different ($P < 0.05$) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Stratiomyidae collected from the water column.

Source	df	MS	F
TRT	1	116,788.84	7.51*
Week	10	35,812.52	2.30*
TRT * Week	10	18,642.06	1.20
Error	198	15,553.22	
Total	219		

*Significance level (P < 0.05).

Analysis of variance for mean number of Corixidae collected from the water column.

Source	df	MS	F
TRT	1	485,247,366.44	28.88*
Week	10	456,270,404.40	27.15*
TRT * Week[a]	10	191,823,216.10	11.42*
Error	198	16,803,926.82	
Total	219		

[a]TRT means significantly different (P < 0.05) for weeks 10 and 11.

*Significance level (P < 0.05).

Analysis of variance for mean number of Dytisadae collected from the water column.

Source	df	MS	F
TRT	1	1,317,457.96	12.80*
Week	10	230,314.16	2.24
TRT * Week	10	172,137.27	1.67
Error	198	102,921.63	
Total	219		

*Significance level (P < 0.05).

Appendix Table 1 cont.

Weekly means for Corixidae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	45.46	22.76
2	89.03	22.74
3	203.38	157.76
4	294,74	181.14
5	790.85	247.98
6	2,212.63	862.87
7	2,355.82	2,298.81
8	2,674.57	1,614.92
9	6,588.13	3,431.57
10	9,751.91*	4,454.78
11	26,330.34*	5,368.23

*Significant difference ($P < 0.05$) determined by LSD comparison.

Analysis of variance for mean number of Caenidae collected from the water column.

Source	df	MS	F
TRT	1	6,500,439.76	19.53*
Week	10	817,775.19	2.46*
TRT * Week	10	359,460.55	1.08
Error	198	332,875.59	
Total	219		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean number of Coenagrionidae collected from the water column.

Source	df	MS	F
TRT	1	8,380,904.28	26.38*
Week	10	1,825,648.22	5.75*
TRT * Week[a]	10	1,243,507.64	3.91*
Error	198	317,661.87	
Total	219		

[a]TRT means significantly different ($P < 0.05$) for weeks 8, 9, 10, and 11.

*Significance level ($P < 0.05$).

Weekly means for Coenagrionidae number by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	45.28	0.00
2	22.70	0.00
3	0.00	0.00
4	0.00	0.00
5	22.50	0.00
6	203.03	45.00
7	363.21	69.78
8	565.91*	0.00
9	1,576.74*	90.95
10	1,227.41*	182.71
11	815.33*	159.71

*Significant difference ($P < 0.05$) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Haliplidae collected from the water column.

Source	df	MS	F
TRT	1	838,523.05	9.44*
Week	10	347,514.93	3.91*
TRT * Week	10	149,898.88	1.69
Error	198	88,849.67	
Total	219		

*Significance level ($P < 0.05$).

Analysis of variance for mean numbers of Ephydridae collected from the water column.

Source	df	MS	F
TRT	1	3,152,514.97	7.99*
Week	10	959,434.14	2.43*
TRT * Week[a]	10	899,090.69	2.28*
Error	198	394.775.03	
Total	219		

[a]TRT means significantly different ($P < 0.05$) for weeks 8 and 9.

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Weekly means for Ephydridae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	0.00	22.46
3	0.00	22.63
4	0.00	22.63
5	22.56	0.00
6	0.00	0.00
7	113.30	0.00
8	927.59*	0.00
9	1,253.35*	45.59
10	181.70	0.00
11	293.54	45.19

*Significant difference ($P < 0.05$) determined by LSD comparison.

Analysis of variance for mean number of Pleidae collected from the water column.

Source	df	MS	F
TRT	1	5,738,243.58	14.00*
Week	10	5,572,136.77	13.59*
TRT * Week[a]	10	1,215,312.57	2.97*
Error	198	409,827.29	
Total	219		

[a]TRT means significantly different ($P < 0.05$) for weeks 8, 9, and 11.

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Weekly means for Pleidae numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	22.83	0.00
3	45.12	68.04
4	45.25	0.00
5	90.24	22.62
6	181.07	0.00
7	476.99	269.59
8	1,743.17*	408.89
9	1,634.44*	589.65
10	591.72	700.69
11	1,787.49*	1,005.80

*Significant difference (P < 0.05) determined by LSD comparison.

Analysis of variance for mean number of Sphaeriidae collected from the water column.

Source	df	MS	F
TRT	1	269,694.64	10.42*
Week	10	42,105.58	1.63
TRT * Week	10	44,332.63	1.71
Error	198	25,875.67	
Total	219		

*Significance level (P < 0.05).

Appendix Table 1 cont.

Analysis of variance for mean biomass of Sphaeriidae collected from the water column.

Source	df	MS	F
TRT	1	801.772.76	5.85*
Week	10	154,101.98	1.12
TRT * Week	10	155,652.56	1.14
Error	198	137,073.59	
Total	219		

*Significance level (P < 0.05).

Analysis of variance for mean biomass of Notonectidae collected from the water column.

Source	df	MS	F
TRT	1	238,614.08	9.13*
Week	10	9,642.89	3.47*
TRT * Week	10	40,297.30	1.54
Error	198	26,127.46	
Total	219		

*Significance level (P < 0.05).

Analysis of variance for mean biomass of Hydrophilidae collected from the water column.

Source	df	MS	F
TRT	1	2,084,415.40	4.48*
Week	10	687,613.84	1.48
TRT * Week	10	664,692.17	1.43
Error	198	464,872.04	
Total	219		

*Significance level (P < 0.05).

Appendix Table 1 cont.

Analysis of variance for mean number of Baetidae collected from the water column.

Source	df	MS	F
TRT	1	18,912.65	5.17*
Week	10	5,658.93	1.55
TRT * Week	10	4,543.86	1.24
Error	198	3,660.90	
Total	219		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Physidae collected from the water column.

Source	df	MS	F
TRT	1	604,534,404.61	7.75*
Week	10	213,221,383.40	2.73*
TRT * Week	10	67,437,020.61	0.86
Error	196	78,043,794.16	
Total	217		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Dytiscidae collected from the water column.

Source	df	MS	F
TRT	1	511,270.41	6.58*
Week	10	67,694.47	0.78
TRT * Week	10	83,849.51	1.08
Error	186	77,730.54	
Total	207		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean biomass of Planorbidae collected from the water column.

Source	df	MS	F
TRT	1	189,499,033.85	5.51*
Week	10	20,558,203.77	0.60
TRT * Week	10	18,621,115.65	0.54
Error	194	34,393,951.28	
Total	215		

*Significance level (P < 0.05).

Analysis of variance for mean biomass of Corixidae collected from the water column.

Source	df	MS	F
TRT	1	3,247,757.76	14.96*
Week	10	3,595,236.41	16.57*
TRT * Week[a]	10	772,141.79	3.56*
Error	189	217,027.11	
Total	210		

[a]TRT means significantly different (P < 0.05) for weeks 8, 9, and 11.

*Significance level (P < 0.05).

Appendix Table 1 cont.

Weekly means for Corixidae biomass by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	15.92	9.10
2	55.34	9.10
3	135.61	135.25
4	161.28	83.69
5	55.26	42.71
6	183.48	93.43
7	165.41	229.78
8	766.26*	202.15
9	1,237.45*	544.97
10	1,087.51	970.18
11	1,750.74*	559.15

*Significant difference ($P < 0.05$) determined by LSD comparison.

Analysis of variance for mean biomass of Caenidae collected from the water column.

Source	df	MS	F
TRT	1	75,046.52	6.49*
Week	10	15,875.48	1.37
TRT * Week[a]	10	22,096.40	1.91*
Error	178	11,571.65	
Total	199		

[a]TRT means significantly different ($P < 0.05$) for weeks 1 and 2.

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Weekly means for Caenidae biomass by treatments.

	Treatments	
Week	Level ditch	Emergent marsh
1	140.24*	0.00
2	184.25*	0.00
3	52.06	27.29
4	2.27	0.00
5	56.52	4.53
6	2.53	11.33
7	34.02	84.71
8	25.48	9.77
9	32.47	5.69
10	17.02	10.03
11	39.56	3.23

*Significant difference ($P < 0.05$) by LSD comparison.

Analysis of variance for mean biomass of Coenagrionidae collected from the water column.

Source	df	MS	F
TRT	1	31,589.53	5.38*
Week	10	9,465.41	1.61
TRT * Week	10	3,931.87	0.67
Error	178	5,873.74	
Total	199		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean biomass of Haliplidae collected from the water column.

Source	df	MS	F
TRT	1	75,789.22	9.70*
Week	10	13,764.63	1.76
TRT * Week	10	14,720.36	1.88
Error	176	7,814.92	
Total	197		

*Significance level ($P < 0.05$).

Analysis of variance for mean biomass of Chaoboridae collected from the water column.

Source	df	MS	F
TRT	1	13,805.73	7.22*
Week	10	2,018.39	1.06
TRT * Week	10	1,509.27	0.79
Error	173	1,912.08	
Total	194		

*Significance level ($P < 0.05$).

Appendix Table 1 cont.

Analysis of variance for mean biomass of Ephydridae collected from the water column.

Source	df	MS	F
TRT	1	21,532.39	9.42*
Week	10	6,382.27	2.79*
TRT * Week[a]	10	5,690.04	2.49*
Error	189	2,286.91	
Total	210		

[a]TRT means significantly different (P < 0.05) for week 9.

*Significance level (P < 0.05).

Weekly means for Ephydridae biomass by treatments.

	Treatments	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	0.00	0.00
3	0.00	11.32
4	0.00	0.00
5	6.77	0.00
6	0.00	0.00
7	0.00	0.00
8	33.91	0.00
9	116.66*	0.00
10	37.93	0.00
11	56.42	17.56

*Significant difference (P < 0.05) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean biomass of Pleidae collected from the water column.

Source	df	MS	F
TRT	1	131,111.56	8.64*
Week	10	137.953.87	9.09*
TRT * Week[a]	10	32,392.59	2.13*
Error	189	15,183.12	
Total	210		

[a]TRT means significantly different (P < 0.05) for weeks 8, 9, and 11.

*Significance level (P < 0.05).

Weekly means for Pleidae biomass by treatment.

	Treatments	
Week	Level ditch	Emergent marsh
1	0.00	0.00
2	18.26	0.00
3	31.59	38.57
4	33.93	0.00
5	16.96	4.52
6	29.49	0.00
7	22.70	15.02
8	171.82*	19.85
9	219.42*	82.97
10	65.95	117.37
11	382.11*	163.78

*Significant difference (P < 0.05) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Cyclopoida collected from the water column.

Source	df	MS	F
TRT	1	434,772.80	17.29*
Week	10	190,692.88	7.58*
TRT * Week[a]	10	97,092.88	3.86*
Sample (TRT * Week)	198	25,147.53	
Error	440	2,471.73	
Total	659		

[a]TRT means significantly different ($P < 0.05$) for weeks 8, 9, and 10.

*Significance level ($P < 0.05$).

Weekly means for Cyclopoida numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	117.04	91.49
2	31.55	80.59
3	45.32	18.88
4	25.66	10.55
5	39.88	42.19
6	49.75	94.01
7	130.07	64.42
8	165.89*	26.50
9	142.05*	43.80
10	271.27*	49.97
11	244.34	172.75

*Significant difference ($P < 0.05$) determined by LSD comparison.

Appendix Table 1 cont.

Analysis of variance for mean number of Ostracoda collected from the water column.

Source	df	MS	F
TRT	1	777,376.83	7.35*
Week	10	355,238.43	3.36*
TRT * Week[a]	10	209,321.06	1.98*
Sampler (TRT * Week)	198	105,737.46	
Error	440	3,186.55	
Total	659		

[a]TRT means significantly different ($P < 0.05$) for week 1.

*Significance level ($P < 0.05$).

Weekly means for Ostracoda numbers by treatment.

	Treatment	
Week	Level ditch	Emergent marsh
1	102.67*	512.71
2	136.78	202.72
3	108.59	71.97
4	59.72	58.81
5	47.50	106.12
6	63.37	87.64
7	37.05	120.55
8	26.24	56.68
9	36.31	52.85
10	52.16	100.05
11	43.99	99.31

*Significant difference ($P < 0.05$) determined by LSD comparison.