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EFFECTS OF DIKING AND PLANT ZONATION ON
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COASTAL MARSHES

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COLE DANIEL PROVENCE

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Thomas M. Burton
Major Professor's Signature

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EFFECTS OF DIKING AND PLANT ZONATION ON INVERTEBRATE COMMUNITIES OF LAKE ST. CLAIR COASTAL MARSHES

By

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ABSTRACT

Effects of Diking and Plant Zonation on Invertebrate Communities of Lake St. Clair Coastal Marshes

By

Cole Daniel Provence

Invertebrate communities from emergent plant zones common to two diked and two undiked marshes were compared during July 2006, in order to document differences in the potential prey base of avian fauna of Lake St. Clair deltaic marshes. Invertebrate samples were taken with a 0.5 mm D-frame dip net from the outer 1-2 m edge of the emergent plant zones dominated by *Schoenoplectus acutus, Typha angustifolia,* or the invasive form of *Phragmities australis*. Equal effort consisting of 3 minutes of sweep net collecting per sample was expended in order to quantify catch per unit effort (CPUE) differences in numbers between diked and undiked marshes for each plant zone. A total of 109,649 invertebrates were collected: 93,959 from diked marshes (3,758 per sample, N=25) and 15, 690 from undiked marshes (541 per sample, N=29). Thus, seven times more invertebrates were collected per sample from diked marsh samples than were collected from undiked samples (p=0.03, 2-way ANOVA) suggesting that the prey base for breeding waterfowl and other invertebrate predators is greater in diked marshes than in undiked marshes. I also tested Shannon's Diversity Index, evenness, and taxa richness. Shannon's Diversity and evenness were not significantly different, but taxa richness (p=0.05) was significantly greater in diked marshes compared to undiked marshes. Sorensen Similarity Index revealed that 77% of taxa were similar between diked and undiked marshes. There was no significant difference in the invertebrate community caused by plant zone or location.

To Everyone Who Made This Possible

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INTRODUCTION

There are roughly 217,000 hectares of Great Lakes coastal marshes (SOLEC 2004). Marshes in and along connecting waterways are considered to be Great Lake coastal marshes (SOLEC 2004, Albert 2001, Tsanis et al. 1996, Schloesser 1988). The St. Clair River and Lake St. Clair form the northern part of the connecting waterway between Lake Huron and Lake Erie (Thomas et al. 2006). The more than 13,500 hectares of Lake St. Clair marshes are classified as Great Lake coastal wetlands and roughly 13,146 hectares (96%) of these marshes occur in the delta where the St. Clair River empties via distributary channels into Lake St. Clair (Thomas et al. 2006, SOLEC 2004).

Coastal marshes are important habitat for many fish (Jude and Pappas 1992, French III 1988), amphibians (Herdendorf et al. 1986), birds (Prince et al. 1992) and mammals (De Szalay and Cassidy 2001, Herdendorf 1987). Aquatic invertebrates are important food sources for many of these vertebrates (Herdendorf et al 1986, French III 1988, Krull 1970). Recent studies have described invertebrate communities of Great Lakes marshes and related their occurrence to abiotic and biotic factors including anthropogenic stress (Burton et al. 2004, 2002, 1999, MacKenzie et al. 2004, Stricker et al. 2001, Gathman et al. 1999, Cardinale et al. 1998, Bedford 1992, Krieger 1992, McLaughlin and Harris 1990). These factors include temperature, depth and type of sediment, gradients in geochemistry from the shore to the open lake, groundwater inputs, plant community structure, short and long term changes in lake levels, fetch, and wave action (Burton et al. 2004, 2002, Stricker et al. 2001, Cardinale et al. 1998, Bedford 1992, Krieger 1992).

Most studies cited above have been conducted on riverine and lacustrine Great Lake marshes and may not apply to the deltaic marshes that dominate Lake St. Clair. The marshes in the St. Clair River Delta do not have the characteristic turbidity problems of Green Bay or Saginaw Bay marshes because suspended sediment load is low in the Lake Huron water that is transported by the St. Clair River into the marshes, the rapid exchange of water between the river's distributary channels and the marshes, and the relatively low fetch and exposure to winds in Lake St. Clair compared to marshes of the five larger Great Lakes (Herdendorf et al. 1986). Regardless, there are few studies of the invertebrate community in Lake St. Clair marshes. Instead, most invertebrates studies have been focused on deeper waters of Lake St. Clair (Zanatta et al. 2002, Edsall et al. 2001, 1988, French III 1988, Nalepa and Gauvin 1988, Bricker et al. 1976) or in the St. Clair and Detroit Rivers (Davis et al. 1991, Ciborowski and Corkum 1988, Thornley 1985).

Lake St. Clair marshes have been altered by many different human activities, including diking (Albert 2001, Herdendorf 1987, Herdendorf et al. 1986, Derecki 1985, McCullough 1985, Quinn 1985). Dikes are used to manipulate water levels for waterfowl use and hunter access (Albert 2003, Jude and Pappas 1992, Prince et al. 1992, Herdendorf 1987, Herdendorf et al. 1986). In undiked marshes, natural water levels fluctuate with storm events and wave action (Quinn 1980) and as lake levels rise and fall seasonally and from year to year. The natural water level fluctuations structure the plant and animal communities along Great Lake marshes and lead to dynamic changes in these communities as water levels change from lows to highs (Gathman et al. 2005, Burton et al. 2004, 2002, Herdendorf 1987, Barton and Griffiths 1984).

Diking of coastal marshes has been shown to cause changes in invertebrate (Mclaughlin and Harris 1990, Krieger 1992), fish (Jude and Pappas 1992), and plant communities (Herrick and Wolf 2005, Thiet 2002). Stabilized water levels in diked marshes lead to dominance by plants tolerant of deeper standing water like narrow leaved cattail (*Typha angustifolia),* hard stem bulrush (*Schoenoplectus acutus*) and the common reed (*Phragmites australis)* (Herrick and Wolf 2005, Thiet 2002, Herdendorf et al. 1986).

The invasive form of common reed, *Phragmites australis* (Cav.) Trin. Ex Steud has invaded marshes throughout North America (Saltonstall et al. 2004). In the Great Lakes region, there is a native, non-invasive form, *Phragmites australis* subsp. *americanus* that is limited in distribution and rarely occurs in a monoculture (Saltonstall et al. 2004). The invasive form of *Phragmites australis* is thought to be an import from Europe and is an aggressive invader, particularly of disturbed marshes. Recently, several researchers have documented the occurrence of the exotic *Phragmites* in Great Lake coastal marshes and have examined its effects on wetland communities (Kulesza and Holomuzki 2006, Herrick and Wolf 2005, Wilcox et al. 2003, Thiet 2002). *Phragmites* has been found in Lake Erie (Wilcox et al. 2003, Thiet 2002, Herdendorf 1987), Lake St. Clair (Albert 2003, Herdendorf et al 1986), Lake Huron (Herrick and Wolf 2005, Albert 2003), and Lake Michigan marshes (Herrick and Wolf 2005). In these studies, *Phragmites* has replaced or altered native plant communities (Herrick and Wolf 2005, Thiet 2002) with *Typha* communities being particularly susceptible (Wilcox et al. 2003). In addition, *Phragmites* has been shown to alter food webs in brackish-water marshes by altering benthic microalgae and phytoplankton communities (Wainright et al. 2000). Negative effects have also been documented for aquatic invertebrates (Jivoff and Able 2003, Angradi et al. 2001) and fish (Raichel et al. 2003, Weinstein and Balletto 1999). Parsons

(2003), however suggested that *Phragmites* could have some positive benefits for nesting birds.

The primary objectives of this study were to (1) test the hypothesis that invertebrate community species composition, relative catch, richness, and evenness would differ significantly between diked and undiked coastal marshes; (2) test the hypothesis that the invertebrate parameters listed above would be affected by and correlated with plant zonation in diked and undiked marshes: and (3) document differences in three plant zones common to diked and undiked marshes in order to document changes in the potential prey base for avian fauna in diked and undiked Great Lake coastal marshes.

METHODS

Study Area

The St. Clair River delta is formed in, along, and between distributary channels of the St. Clair River where the river enters Lake St. Clair. It extends along the shoreline away from these channels to form an arcuate wetland in areas where sediments are carried by wind and currents. The St Clair delta is the largest complex of delta marshes in the Great Lakes Basin (Herdendorf et al. 1986). The delta is connected to Lake Huron and Lake Erie and the other Great Lakes via the St. Clair River-Lake St. Clair-Detroit River connecting channel. While the delta shares characteristics with both Lake Huron and Lake Erie, the greatest inputs come from Lake Huron (Thomas et al. 2006, Leach 1980). The Michigan, U.S.A, side of the delta is approximately 16 km long and 24 km wide (Albert 2003, Herdendorf et al. 1986). The delta is formed from eroded shoreline sediments from Lake Huron (Thomas et al. 2006) and the sediments eroded from the St. Clair River Channel by currents and ship traffic. Sandy sediments are generally carried into bays by wave action and overlay glacial clays (Thomas et al. 2006). The deltaic coastal marshes at the mouth of the river occupy 13,146 ha (SOLEC 2004) along the distributary channels of the St. Clair River, in bays around the low lying margins of islands between channels, and along the shoreline of Lake St. Clair extending away from the St. Clair River in the U.S.A. and Canada. The delta has been altered by residential development along the U.S. shoreline, on islands in the delta, and by dredging of channels and movements of vessels along these channels to support commercial shipping in the Great Lakes (Albert 2003, Ball et al. 2003, Derecki 1985, McCullough 1985, Quinn 1985).

The study area was located in the St. Clair Flats Wildlife Management Area on Harsen's and Dickinson Islands (Figure 1). The St. Clair Flats is managed by the Michigan Department of Natural Resources (MDNR). The two diked marshes were located on Harsen's Island. One of the undiked marshes was located in the Little Muscamoot Bay area of Harsen's Island near the Middle Channel and the other was located in the Goose Bay and Mud Lake area of Dickinson Island between the Middle and North Channels (Figure 1). Dickinson Island is the largest (approximately 1,200 hectares) naturally functioning wetland complex along Lake St. Clair (Herdendorf et al. 1986), and Little Muscamoot Bay is the only area along Harsens Island that has remained an undiked wetland with natural water flow (Herdendorf et al. 1986). The undiked marshes experience natural water level fluctuations caused by storm events, but generally water levels remain stable during the months of June, July, and August (Albert 2001, Herdendorf et al. 1986). Along the shoreline which experiences the most wave action, *Phragmites* has become the most dominant vegetation type and, in areas that are protected from wave action, dense stands of *Typha angustifolia* often dominate. *Schoenoplectus acutus* is the dominant bulrush type in the St. Clair delta and occupies deeper water than either *Typha* or *Phragmites*.

Diked marshes, located on Harsen's Island, are separated into East and West units (Figure 1) and are managed for migratory waterfowl hunting by the MDNR (Herdendorf et al. 1986). Water levels are controlled and maintained by the MDNR at depths that vary from year to year. During some years, water levels are maintained at high levels throughout the year, as during this study, while in other years, water levels are allowed to drop to expose large mud flats. Most diked marshes during this study were covered with emergent plants, mainly *Typha angustifolia*, with channels cut between stands to allow boat access for hunters. These channels often contained dense growths of water-lily (*Nymphaea*), yellow water-lily (*Nuphar*), hardstem-bulrush (*Schoenoplectus acutus),* and submersed plants. *Phragmites* appeared to have colonized the diked marshes along the edges of hunter access channels and in mud flats. To control *Phragmites* spread, MDNR uses herbicides and controlled burns within diked marshes.

Both diked and undiked marshes in the St. Clair Flats were dominated by three emergent plant zones: bulrush zones dominated by hardstem bulrush, *Schoenoplectus acutus,* cattail zones dominated by *Typha angustifolia* and *Typha X glauca,* and common reed zones dominated by the invasive form of *Phragmites australis* (Albert 2001, Herdendorf et al. 1986). Each of these zones in diked and undiked marshes was sampled.

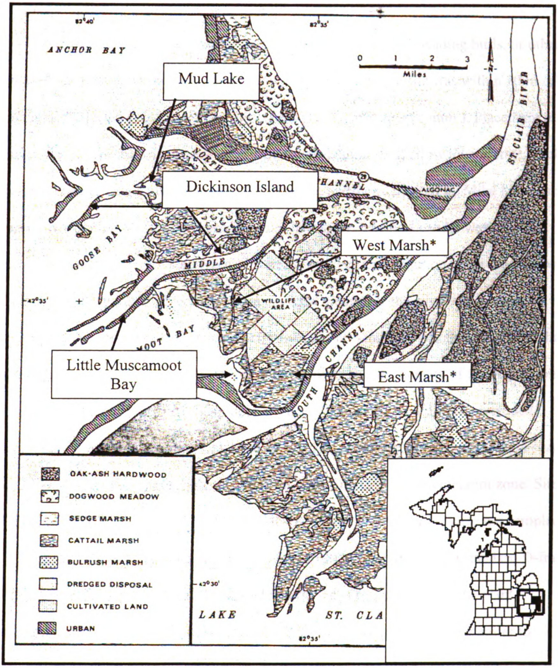

Figure 1. Location of study areas in the St. Clair River Delta. Diked marshes are indicated with a * (figure from Herdendorf et al. 1986; they adapted it from Raphael and Jaworski 1982).

Field Sampling

I selected sites based on two criteria: migratory waterfowl, wading birds, or other wetland dependant birds were observed feeding on-site, or the site was within 10 m of the randomly selected points used for bird counts (M. Monfils, pers.comm.). Placement of invertebrate sampling areas near sites used for bird counts will allow invertebrate results to be related to data on distribution of birds in the marshes collected by Mike Monfils and his crew from the Michigan Natural Feature Inventory. The bird results were not part of this thesis and correlations between bird and invertebrate distribution in the marshes will be published separately. Since birds heavily used areas near the edge of the emergent zones and the open water of the channels, invertebrate sampling was limited to sampling the outer 1-2 m edges of emergent zones. In many places, the density of the vegetation, or the lack of standing water in the middle of vegetation stands would have precluded sampling far enough into the plant stand to avoid edge effects. In most *Schoenoplectus* and *Phragmites* sites, I was able to sample at least 1 meter into the emergent zone. Sites where MDNR had burned or applied herbicide to control *Phragmites* were not sampled.

Invertebrates were collected from July 10 to July 21, 2006 using a standard D-frame dip net with 0.5-mm mesh net. I sampled invertebrates in July to allow the plant community to fully develop and invertebrates to become larger, making it easier to identify them (Burton et al. 2004, 1999, Uzarski et al. 2004, De Szalay and Cassidy 2001, McLaughlin and Harris 1990). The net was swept through the water column in each plant zone at the surface, above the sediments, and along plant stems for a period of 60 seconds per replicate. At the end of 60 seconds, the contents of the net were placed into a whirl pack with 95% ethanol and labeled as one of three replicates taken per sample. Even though each replicate was sorted and picked separately, data from the three replicates per sample were combined and treated as a single sample for statistical analyses. Thus, each sample consisted of combined data from three 60 second sweeps or a total of 3 minutes of dip net sweeps per sample. Sampling in three separate areas within a 2 meter radius of a sample point and combining data from these 3 sweeps ensured a representative area was sampled. The one minute of sweeping per replicate for 3 replicates per sample standardized effort for each sample so semi-quantitative comparisons could be made in terms of total catch and catch per unit effort (CPUE).

In diked marshes, 13 samples (39 replicates) from East Marsh and 12 samples (36 replicates) from West Marsh were collected (Figure 1). From undiked marshes, 18 samples (54 replicates) were collected from Dickinson Island and 11 samples (33 replicates) were collected from Little Muscamoot Bay (Figure 1). I collected replicates by making the midpoint of the front of the boat the point around which samples were collected. From the mid-point, I collected one replicate left of the point, one replicate right of the point, and one replicate straight ahead of the point. Initially, I planned to take five samples from each of the three vegetation zones so that there would be a total of 15 samples (45 replicates) from each marsh, but I was limited in Little Muscamoot Bay, East Marsh, and West Marsh by the number of available sites. While large areas of East and West marshes were covered with *Typha* and *Phragmites,* they remained above the water surface by forming dense floating islands. A minimum of three samples per vegetation zone was collected from each of the four marshes. At Dickinson Island, I increased the number of samples to six from each zone, based on the suggestions of Dr. Thomas Burton and Dr. Patrick Brown to include samples from Mud Lake.

Laboratory Identification

In the laboratory, three invertebrate samples from each of three plant zones from the two diked and two undiked marshes were completely picked and sorted. Since hundreds of invertebrates were picked from each replicate of the diked wetland samples, picking took many hours to complete. To speed up the process, the remaining replicates from the diked marshes were first sieved through a 4-mm sieve to remove larger pieces of organic detritus and then into a 250 micrometer sieve. The invertebrates picked from the larger debris were added to the contents of the 250 micrometer sieve. The contents of the sieve were then split into four sub samples using a Folsom plankton splitter. One sub-sample was picked and the rest were discarded for the 16 samples collected from diked marshes that were not completely picked. Fewer undiked samples were sub-sampled because they were easier to pick than were diked marsh samples because of fewer invertebrates and less debris per sample. Only five samples from undiked marshes were sub-sampled compared to 16 samples from diked marshes. Samples were picked and sorted, under 10x magnification, to the lowest operational taxonomic unit (usually Family or Genus) using a variety of taxonomic keys (Merritt and Cummins 1996, Thorp and Covich 1991, Peckarsky et al. 1990, Burch 1982, Burch and Tottenham 1980, and Wiggins 1978). Insects were assigned to functional feeding and functional habitat groups using Merritt and Cummings (1996). The other invertebrates were assigned to feeding group and habitat group using De Szalay and Cassidy (2001), Thorp and Covich (2001), Clifford (1991) and Peckarsky et al. (1990).

Water Chemistry

Water chemistry was measured in the field between June 17 to August 2, 2006 from sampling stations where invertebrates were collected and points where breeding bird and shore bird surveys took place across all four marshes. Measurements were taken at mid-depth at each site. Dissolved oxygen (D.O) (mg/L), salinity, specific conductivity (mS/L), pH, and temperature (°C) were measured using a Hydrolab water quality probe (Hydrolab Corporation, Austin, TX). Water depth was measured with a meter stick. Alkalinity (mg $CaCO_3$/L) was measured with a Hach Test Kit (Model AL-AP, Drop Count Titration), and turbidity was measured in NTU (nephelometer turbidity units) with an Oakton T-100 Turbidimeter.

Statistical Analyses

The mean number of invertebrates per sample (±standard error) was calculated for each plant zone sampled. The number of invertebrates for each of the three replicates was summed to calculate total number per sample. Raw data for each sample was then converted to relative catch (taxon total divided by total number of invertebrates collected per sample) and percent frequency (number of times a taxon occurred in all replicates divided by the number of total replicates per vegetation type). Invertebrates were only reported as frequent if they occurred in >50% of replicates in any of the plant community zones.

Community composition was evaluated by calculating percent relative catch of taxa, taxa richness, Shannon's diversity index (H'), Simpson's Evenness (J'), Sorensen similarity index, percent frequency of taxa, percent functional feeding group, and percent functional habitat group. Percent functional feeding group and habitat group was the total in each group of samples divided by the grand total of invertebrates for all samples per zone. Functional feeding groups were restricted to predators, gatherer-collectors, scrapers, shredders, piercers, and filterers. Functional habitat groups were restricted to sprawlers, burrowers, clingers, swimmers, climbers, and skaters.

Total number of invertebrates per sample, Shannon's diversity (H'), species richness, Simpson evenness (J'), and relative catch were determined for each marsh and vegetation zone. To determine if wetland type or vegetation type had an effect on the invertebrate community, I used a (PROC MIXED) two way analysis of variance (ANOVA) (SAS Version 9, SAS Institute Inc., Cary, NC, USA). Bonferroni t-tests were used with pair-wise comparisons to determine whether differences among the three plant community types were statistically different. A majority of data were LOG transformed to correct for variance within the data. Percent invertebrate frequency, percent functional feeding groups, and percent functional habitat groups were also used to determine whether differences occurred. Location was also tested for statistical significance using location (wetland) and plant*location (wetland) as random effects in the Proc Mixed code. Results were considered significant at $p<0.05$ but were also reported as marginally significant if $p<0.10$.

RESULTS

Water Chemistry

Because water chemistry was collected at different dates, times of day and only once per site, statistical analysis was not possible. The data were used to broadly characterize the sites where invertebrates were collected and marsh birds were feeding. Samples were collected from similar depths from all plant zones and diked and undiked marshes (29-39 cm deep in diked marshes; and 31-42 cm deep in undiked marshes). At the time of collection, water temperature ranged from 25.3-25.6°C in diked marshes and from 24.5-24.9°C for undiked marshes. Alkalinity was lower in undiked marshes ranging from 112-119 mg $CaCO_3$/L compared to diked marshes at 178-190 mg $CaCO_3$/L. Dissolved oxygen levels were higher in undiked marshes at 5.3-6.4 mg/L than in diked marshes at 3.9-4.6 mg/L. Even though water was slightly cooler, dissolved oxygen was slightly higher, and alkalinity was lower in undiked marshes than in diked marshes, differences were small compared to levels known to cause major changes in biota (for details, see Appendix C).

Invertebrate Community Parameters between Diked and Undiked Marshes

A total of 109,649 invertebrates were collected: 93,959 from diked marshes (3,758/ sample, N=25) and 15,690 from undiked marshes (541/ sample, N=29) (Figure 2). Therefore the number of invertebrates/ sample (CPUE) was 7 times greater in diked marshes than in undiked marshes. The total number of invertebrates per sample ($p=0.03$) and species richness ($p=0.05$) were significantly different between diked and undiked marshes (Table 1). These differences were consistent across all three plant zones with diked marshes consistently having a higher total number of invertebrates per sample in the three plant zones (26,121 to 40,459) compared to the total number of invertebrates/ sample three plant zones in undiked marshes (3,209 to 6,700) (Table 1). The number of species collected from the three diked plant zones was also consistently and significantly higher for the three

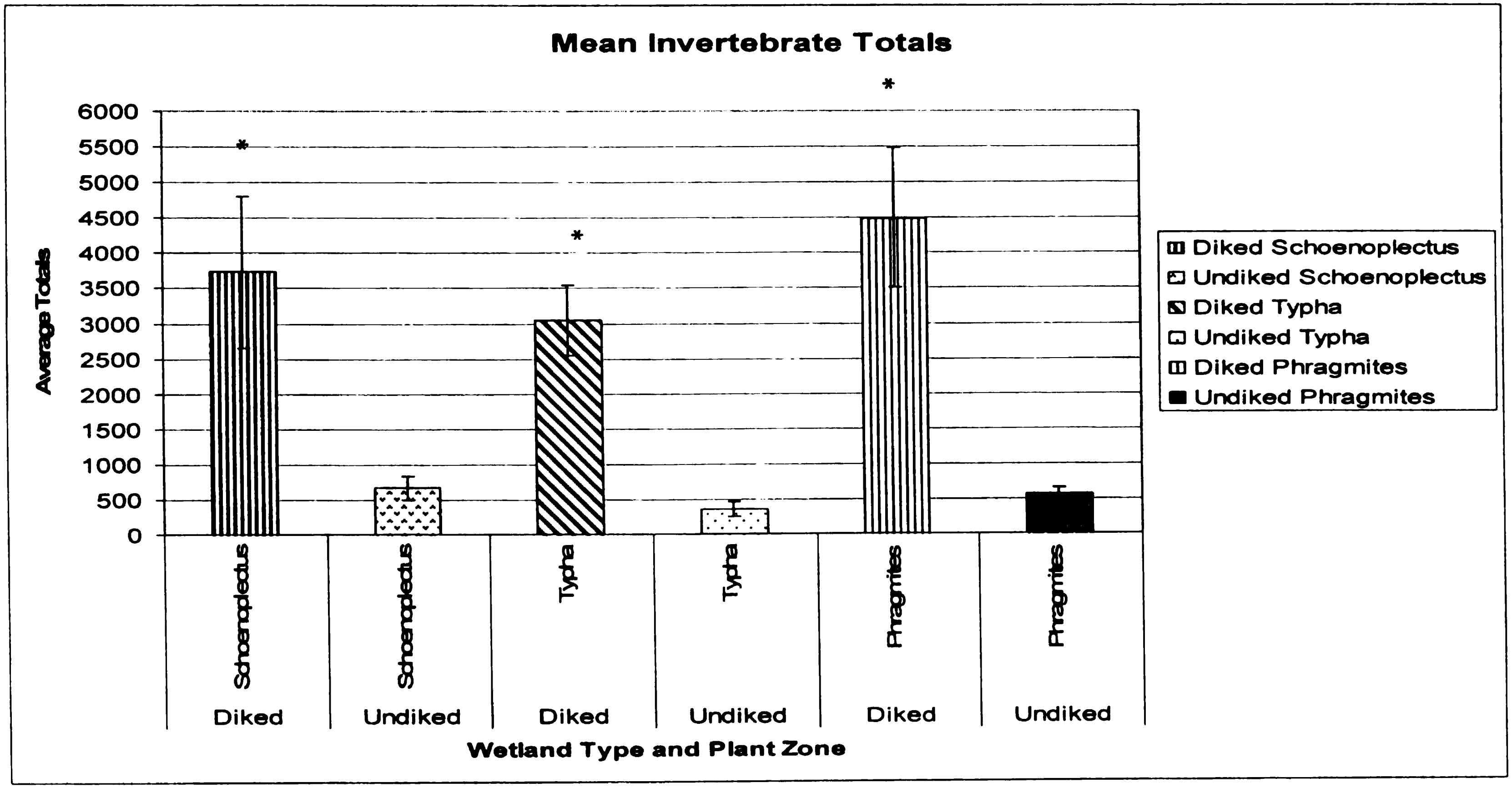

Figure 2. Mean Number per Sample (± Standard Error) in Diked and Undiked Marshes from *Schoenoplectus*, *Typha*, and *Phragmites* zones. * The total number of invertebrates per sample (p=0.03) were significantly greater in diked marshes.

plant zones in diked marshes (48 to 52 species) than for the three plant zones in undiked marshes (33 to 36 species). There were no significant differences in total number of invertebrates per sample (p=0.57) or species richness (p=0.88) among the three plant zones in either the diked or undiked marshes (Table 1). Shannon diversity (H') varied from 1.04 to 1.16 in diked and undiked marshes, and differences were not significant (p=0.78). Even though evenness (J') varied between 0.63 to 0.68 in diked marshes and from 0.73 to 0.77 in undiked marshes, these apparently consistent differences between diked and undiked marshes were not significant (p=0.20) (Table 1). Results were consistent between the two diked marshes, the East and the West Management areas, and between the two undiked marshes, Goose Bay/ Mud Lake and Little Muscamoot Bay, so location had no significant effect on results (p=.49).

Comparison of Invertebrate Community Parameters in Diked and Undiked Marshes.

A combined total of 144 taxa were collected from diked and undiked marshes (Appendix A). A total of 113 taxa were collected from undiked marshes, and 121 taxa were collected from diked marshes (Table 2). Ninety taxa were the same in both diked and undiked marshes (Appendix B). There was a 77% similarity in invertebrate communities between diked and undiked marshes based on Sorensen's similarity index (Table 2). Pairwise comparisons of invertebrate communities of the three plant zones in diked marshes showed that they shared 73-78 taxa in common (80-82% similarity) (Appendix B). In undiked marshes, the three plant zones shared 58-62 taxa in common (72-76% similarity) (Appendix B). Comparisons of diked and undiked marshes by plant zones showed that 58-67 taxa were shared in common (68-74% similarity) (Table 2,

Appendix B). Thus, the composition of invertebrate communities was similar overall as well as on a plant zone basis based on Sorenson's similarity index and the number of species shared in common.

Of the 90 taxa shared in common between diked and undiked marshes, 61 were statistically compared (Appendix B). These 61 either comprised >1% of relative catch, occurred at >50% frequency, or were taxa known to be important in diets of foraging waterfowl or wading birds (Appendix B). I also ran comparisons for the Class Gastropoda, Amphipoda, and Oligochaeta and for six Insect orders: Odonata, Hemiptera, Trichoptera, Lepidoptera, Coleoptera, and Diptera, between diked and undiked marshes and between the three plant zones in diked and undiked marshes. Of the 61 taxa compared (52 at the individual operational taxon level, plus summaries for the Class Gastropoda, Amphipoda, Oligochaeta and six insect Orders) based on total numbers of each taxon per sample, 11 taxa were significantly greater ($p < 0.05$) and 11 taxa were greater ($p < 0.10$) in diked marshes than in undiked marshes (Table 3). Eleven of 61 is 18% of all possible comparisons, more than 3 that would be expected by chance alone at the $p=0.05$ level all 11 were significantly greater ($p < 0.05$) in diked marshes compared to undiked marshes (Table 3).

More than 70% of the 7 fold average increase of 3,217 invertebrates/ sample from undiked and diked marshes was contributed by 4 taxa; *Caenis,* a mayfly, Naididae, a family of segmented worms, Gastropoda, a class of mollusks containing all snails, and *Hyallela azteca,* an amphipod crustacean (Table 1, 3, and Figures 3-6).

An additional 9.3% of the 3,217 increase in invertebrates in diked marshes (300 invertebrates) was contributed by increases in flies (Diptera) with most of this increase accounted for by increases in Chironomidae (non-biting midges) in the subfamilies, Chironomini, Tanytarsini, and Tanypodinae (e.g., see Figure 7). The remaining 19-20% of the increase was contributed by small but significant increases in *Crangonyx,* another species of Amphipoda (p=0.09, Figure 8), water mites (Hydracarina)(p=0.01), leeches (Hirudinea)(p=0.10), dragon and damselflies (Odonata)(p=0.02), especially Coenagrionidae damselflies, pygmy backswimmers and other true bugs (Hemiptera)(p=0.09), aquatic moths (Lepidoptera)(p=0.05), and aquatic beetles (Coleoptera)(p=0.02) (Tables 1, 3).

H. azteca contributed more of the increase in diked marshes compared to undiked marshes than any other taxon (Figure 3, 9, Table 3). The mean number of *H. azteca* collected from diked marshes was 1,093/ sample compared to 31/ sample from undiked marshes representing 1,062 (33%) of the mean total increase of 3,217 invertebrates/ sample in diked marshes compared to undiked marshes. The mean total number of *H. azteca*/ sample was 35 times greater in diked marshes (p=0.02) than in undiked marshes (Table 1, 3, Figure 3). The increase in *H. azteca* numbers in the bulrush (*Schoenoplectus*) zone from a mean of 38/ sample (6% of the total catch) in undiked marshes to 1717/ sample (46% of total catch) in diked marshes is especially notable but increases in the other two plant zones from 3-7% to 21% (from 11-42 mean total catch/ sample in undiked marshes to 628-942/ sample in diked marshes were also impressive (Table 3, Figures 3, 9). Two other genera of Amphipoda, *Gammarus* and *Crangonyx*, were also present (Figure 9) with *Crangonyx* increasing its dominance along with *H. azteca* in diked marshes compared to undiked marshes (Figure 8), while *Gammarus* decreased from being the dominant amphipod in undiked marshes (a mean of 59/ sample representing 10.9% of total catch) to complete absence in diked marshes (Figure 9). Overall, mean total number of Amphipoda in diked marshes was 1239/ sample compared to 101/ sample in undiked marshes. Thus, mean total increases in Amphipoda accounted for 1138 invertebrates/ sample or 35% of the total increase in invertebrates/ sample.

Mean increases in diked marshes compared to undiked marshes in *Caenis* from 41 to 444/ sample, in Naididae from 114 to 399/ sample, and in Gastropoda from 62 to 582/ sample combined accounted for 37.6% (1208) of the average increase of 3,217 invertebrates/ sample in diked marshes compared to undiked marshes (Figures 3-6). The mayfly, *Caenis,* was 11 times greater in total numbers in diked marshes compared to undiked marshes ($p=0.06$), and it was also more numerous in *Phragmites* zones compared to *Typha* or *Schoenoplectus* zones ($p=0.08$, Figures 4). *Caenis* was the only mayfly collected from most marshes, so total numbers for Ephemeroptera and *Caenis* were almost identical (Table 1). The segmented worm, Naididae, was 3.5 times greater ($p=0.06$) in diked marshes than in undiked marshes (Figure 5). The total number of snails (Gastropoda) per sample was 9 times greater in diked marshes compared to undiked marshes ($p=0.03$) (Table 1, 3, Figure 6). Three individual snail taxa increased significantly. Viviparidae snails increased from a mean of 11/ sample in undiked marshes to 147/ sample in diked marshes (Table 3). Two other snails, *Gyralus* and *Planorbella,* were also more numerous ($p=0.06$ and $p=0.08$, respectively) in diked marshes than in undiked ones.

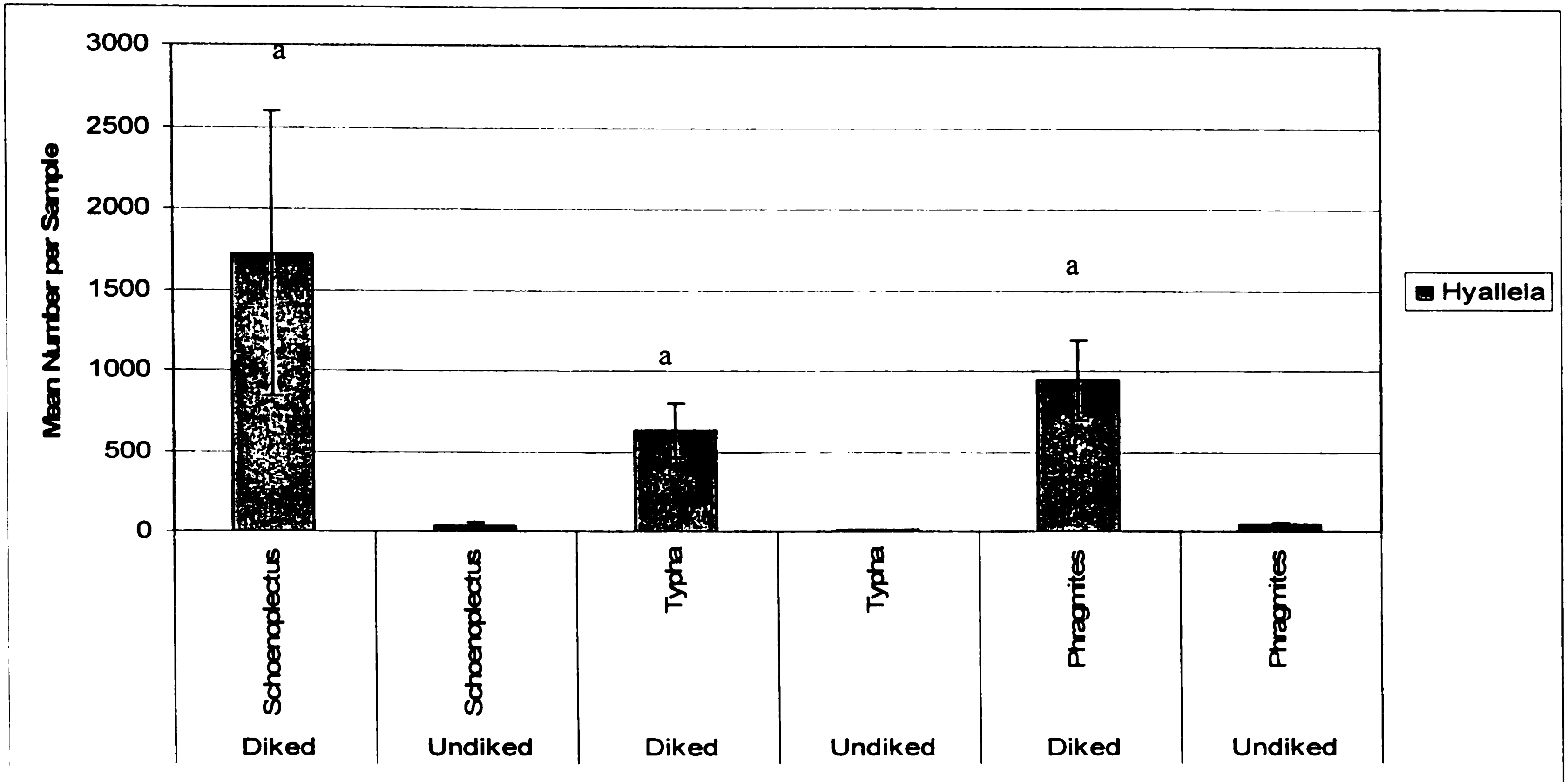

Figure 3. *Hyallela* total number per sample (± standard error) in diked and undiked *Schoenoplectus, Typha,* and *Phragmites* zones. [a] Total number per sample was significantly greater (p=0.02) in diked marshes compared to undiked marshes

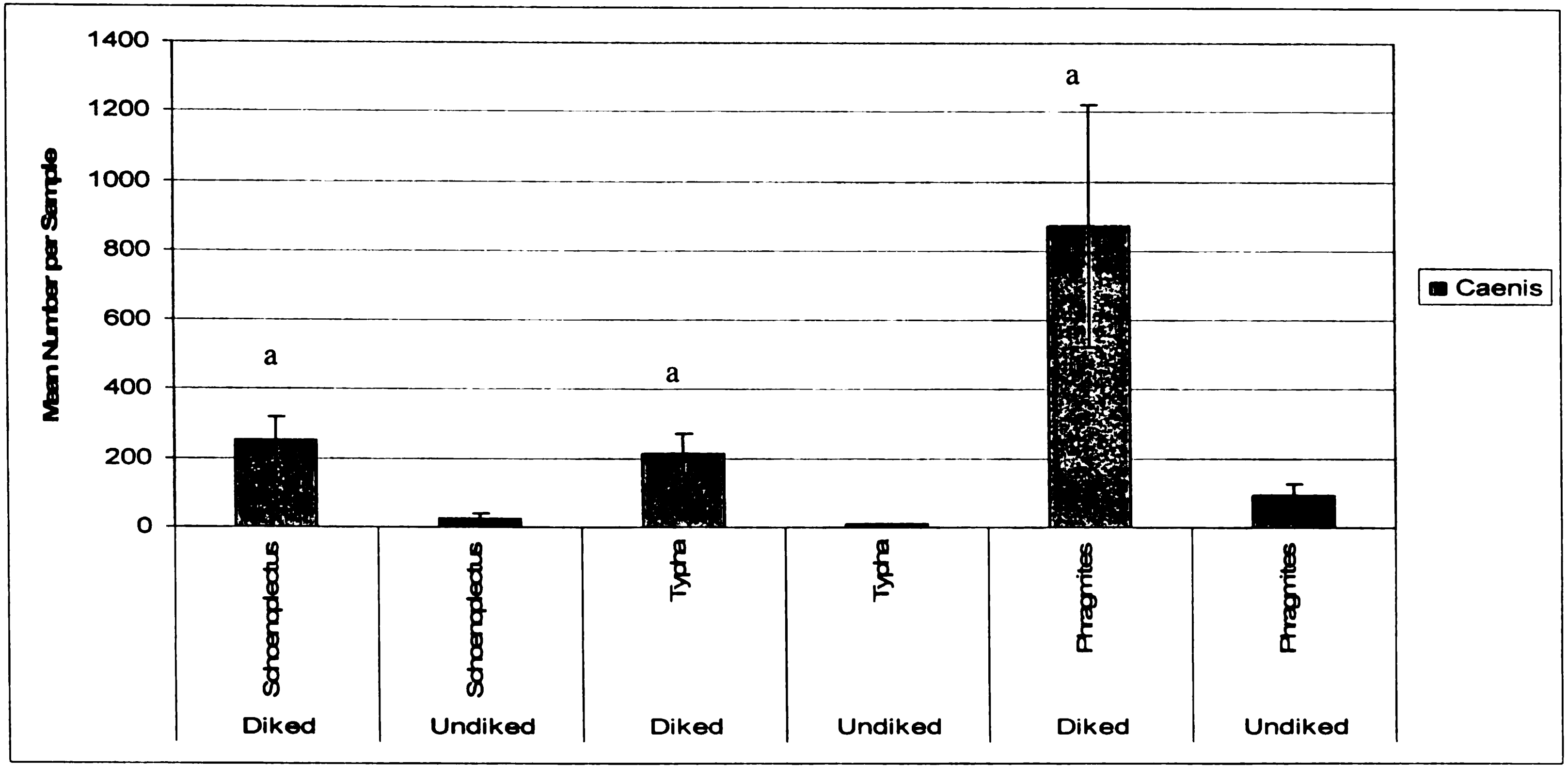

Figure 4. *Caenis* total number per sample (± standard error) in diked and undiked *Schoenoplectus, Typha,* and *Phragmites* zones. [a] *Caenis* total number per sample was greater (p=0.06) in diked marshes compared to undiked

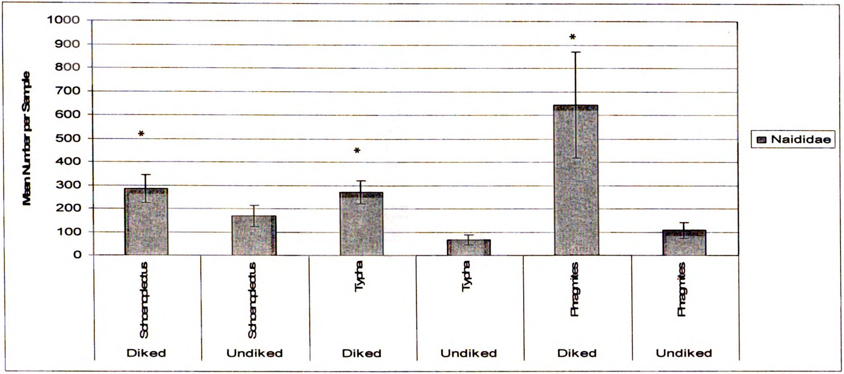

Figure 5. Naididae total number per sample (± standard error) from diked and undiked *Schoenoplectus, Typha,* and *Phragmites* zones. * Naididae total number per sample was greater (p=0.06) in diked marshes compared to undiked marshes.

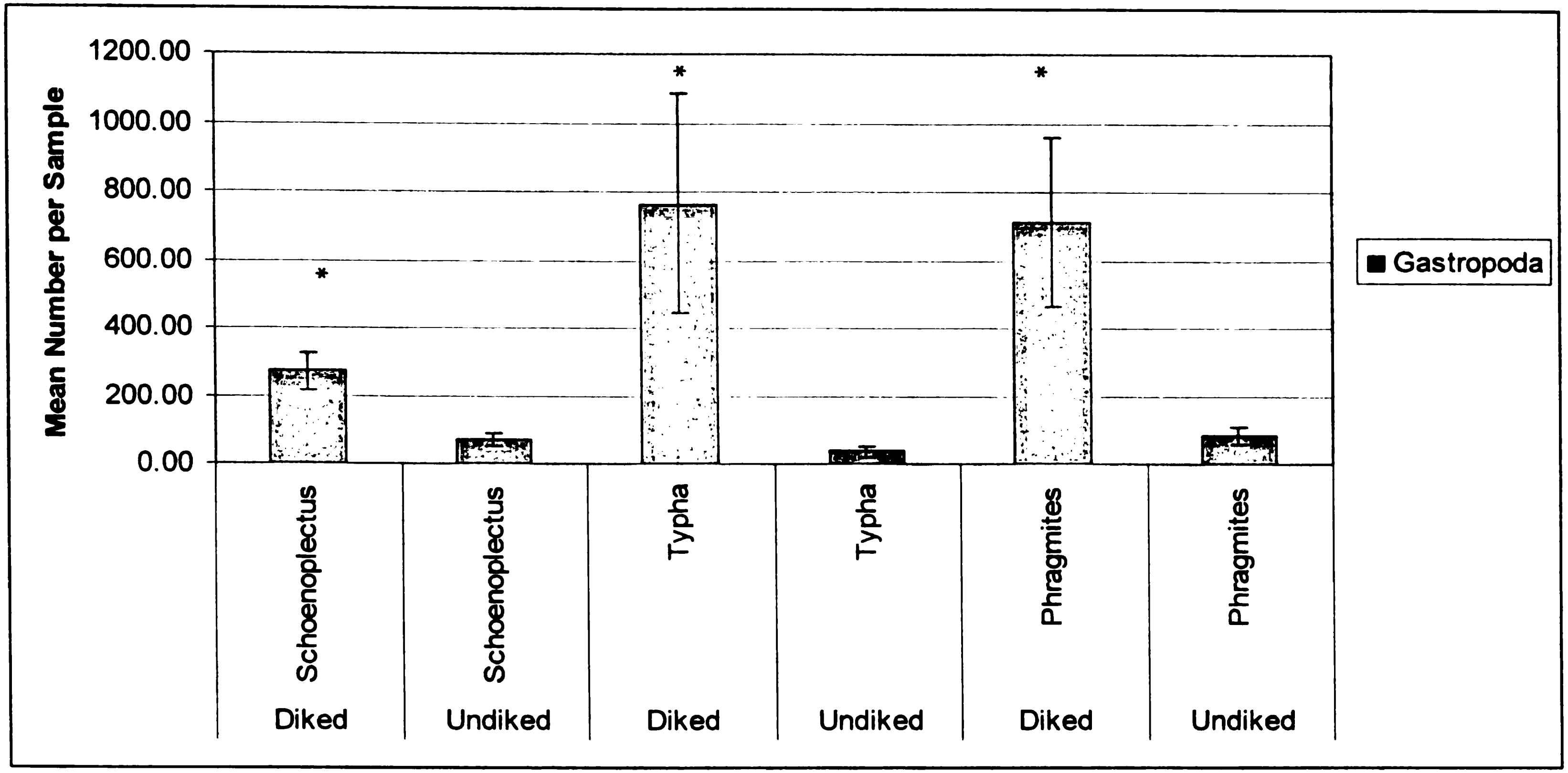

Figure 6. Gastropoda total number per sample (±standard error) in diked and undiked *Schoenoplectus, Typha,* and *Phragmites* zones. * Total number per sample was significantly greater (p=0.03) in diked marshes compared to undiked ones.

The remaining increases in total invertebrates in diked marshes compared to undiked marshes were contributed by relatively small increases in Hydracarina (aquatic mites), Hirudinea (leeches), and 5 insect orders: Odonata, Hemiptera, Lepidoptera, Diptera, and Coleoptera (Tables 1, 3). The mean number of water mites, *Hydracarina*, per sample varied from 65 to 147/ sample in the plant zones in diked marshes compared to 5-10/ plant zone in undiked marshes. Overall, water mites were 15 times greater in diked marshes than in undiked marshes ($p=0.01$) (Table 3). There were four times more leeches, *Hirudinea,* per sample in diked marshes than in undiked ones ($p=0.10$)

The mean total number of Odonata/ sample (dragon and damselflies) was 9 timer greater in diked marshes (168/ sample) than in undiked marshes (18/ sample, $p=0.02$) with increases in Coenagrionidae damselflies from 7/ sample to 53/ sample being part of this increase. Mean Coenagrionidae/ sample was 7.5 times greater in diked marshes than in undiked marshes ($p=0.07$). Odonata richness ($p=0.02$) was also significantly greater in diked marshes (20 taxa) compared to undiked marshes (9 taxa).

Hemiptera increased from 42/ sample to 125/ sample, a 3 fold increase in diked marshes compared to undiked marshes (Table 1, Table 3). The family of Hemiptera with the greatest increase in total numbers per sample in diked marshes compared to undiked marshes was the pygmy backswimmer family, Pleidae, from 3/ sample in undiked marshes to 48/sample in diked marshes ($p=0.05$)(Table 1, Table 3). Interaction effects between marsh type (diked and undiked) and vegetation type (*Schoenoplectus, Typha,* or *Phragmites*) were significant for total numbers of Hemiptera ($p=0.09$) and for the Hemipteran, *Mesovelia* ($p=0.08$). *Mesovelia* made up nearly 4% of total catch in undiked marshes but was rare in diked marshes. Thus, this genus of Hemiptera actually responded in the opposite direction to the response of all Hemiptera combined and to Pleidae.

Lepidoptera total numbers increased from 1.2 to 20.6/ sample (p=0.05) in diked marshes compared to undiked marshes (Table 1, Table 3). Lepidoptera diversity (H') (p=0.07) and evenness (J') (p=0.10) also slightly increased in diked marshes compared to undiked ones. The only two taxa that were common enough to be tested statistically were *Acentria* and *Paraponyx.* Taxa richness was 6 in diked marshes and 7 in undiked ones (Appendix B).

The mean total number of aquatic beetles, Coleoptera increased from 10/ sample in undiked marshes to 53/ sample in diked marshes (p=0.02, Table 1, Table 3). Coleoptera richness (18 species) also increased in diked marshes compared to undiked marshes (13 species) (p=0.06). Coleoptera diversity (H')(p=0.10) and evenness (J') (p=0.07) showed significant interaction effects between marsh type (diked and undiked) and plant zone (*Schoenoplectus, Typha,* or *Phragmites*). Coleoptera diversity (H') was significantly greater (p=0.03) in diked *Typha* and *Phragmites,* compared to diked and undiked *Schoenoplectus,* and undiked *Typha.* Coleoptera evenness (J') was slightly greater (p=0.06) in diked *Typha* and *Phragmites,* compared to diked and undiked *Schoenoplectus* and undiked *Typha.*

The total number of flies, Diptera, was six times greater in diked marshes than in undiked ones increasing from a mean of 66/ sample in undiked marshes to 366/ sample in diked marshes (p=0.03, Table 1, Table 3). Diptera accounted for 300 or 9.3% of the total increase of 3,217 invertebrates in diked marshes compared to undiked marshes. Three of the Chironomidae midge subfamilies increase in diked marshes compared to undiked ones (Table 1). *Chironomini* (p=0.02), *Tanypodinae* (p=0.02), and *Tanytarsini* (p=0.04) were significantly greater in diked marshes compared to undiked marshes (Table 1, Table 3). Combined mean numbers/ sample for the three midge subfamilies increased from 43/ sample in undiked marshes to 298/ sample in diked marshes, a 255 invertebrate increase representing 7.9% of the total invertebrate increase in diked marshes compared to undiked ones. The mean total number/ sample of *Orthocladinae* was not significantly different between diked and undiked marshes (Table 1).

The total number of *Caecidotea,* an Isopod, was three times greater in diked marshes than in undiked ones (p=0.10). The total number of caddisflies, Trichoptera, also increased by four fold in diked marshes compared to undiked ones (p=0.07).

The relative contribution to community composition as a mean percent of total catch of common taxa are illustrated in Figure 9. Taxa that made up a greater percentage of the community in diked marshes than in undiked marshes included the amphipod, *H. azteca.* This illustrates that not only did their numbers increase 35 fold as discussed above for *H. azteca* and all Amphipoda combined, but their dominance of the community overall also increased substantially to 21-46% of total catch in diked vegetation zones (p=0.02) compared to the 3-7% in undiked plant zones (Figures 3, 9, Table 3). In contrast, the amphipod, *Gammarus,* was the most common amphipod in undiked marshes contributing 10.9% of total catch/ sample on average (Table 5), but did not occur in diked marshes (Figure 9) suggesting that it had been displaced from the community by *H. azteca* and, perhaps to a lesser extent, by *Crangonyx.* In contrast, the relative contribution of Naididae to community composition in diked marshes decreased compared to undiked marshes (Table 5) even though its actual numbers increased 3.5 fold as discussed above.

Thus, its contribution to community composition decreased from undiked marshes (21% of total catch) to diked marshes (12% of total catch) (Figure 9). The Order Hemiptera (true bugs) made up a greater percentage of total catch in undiked marshes than in diked marshes (Table 5). This was especially true of *Mesovelia* (Figure 9) which made up (4%) of total catch in undiked marshes compared to (<1%) in diked marshes (Table 5, p=0.01). However, the exception to this trend was Pleidae (Table 5, Figure 5) which increased in total catch/ sample in diked marshes compared to undiked marshes (Figure 9). The Gastropod, *Physa,* relative catch was greater (p=0.07) in diked *Typha* (4%) and diked *Phragmites* (3%) compared to diked *Schoenoplectus* (1%) (Table 4). The total number of the Odonata, *Enallagma,* was statistically the same for diked and undiked marshes (Table 3). *Tanytarsini* relative catch slightly increased (p=0.09) in diked marshes and between diked vegetation zones (p=0.08). These increases were in diked *Typha* (3%) and *Phragmites* (6%) zones compared to undiked *Schoenoplectus* (1%) and *Typha* (1%) zones. *Caenis* relative catch increased (p=0.08) in *Phragmites* dominated zones in diked (16%) and undiked (13%) marshes (Table 4) compared to diked and undiked *Schoenoplectus* (9% and 3%, respectively) and *Typha* (6% and 3%, respectively) (Table 4). There were three times more Trichoptera, *Oxyethira,* in diked marshes but relative catch was greater (p=0.08) in undiked marshes (Table 3, Table 5).

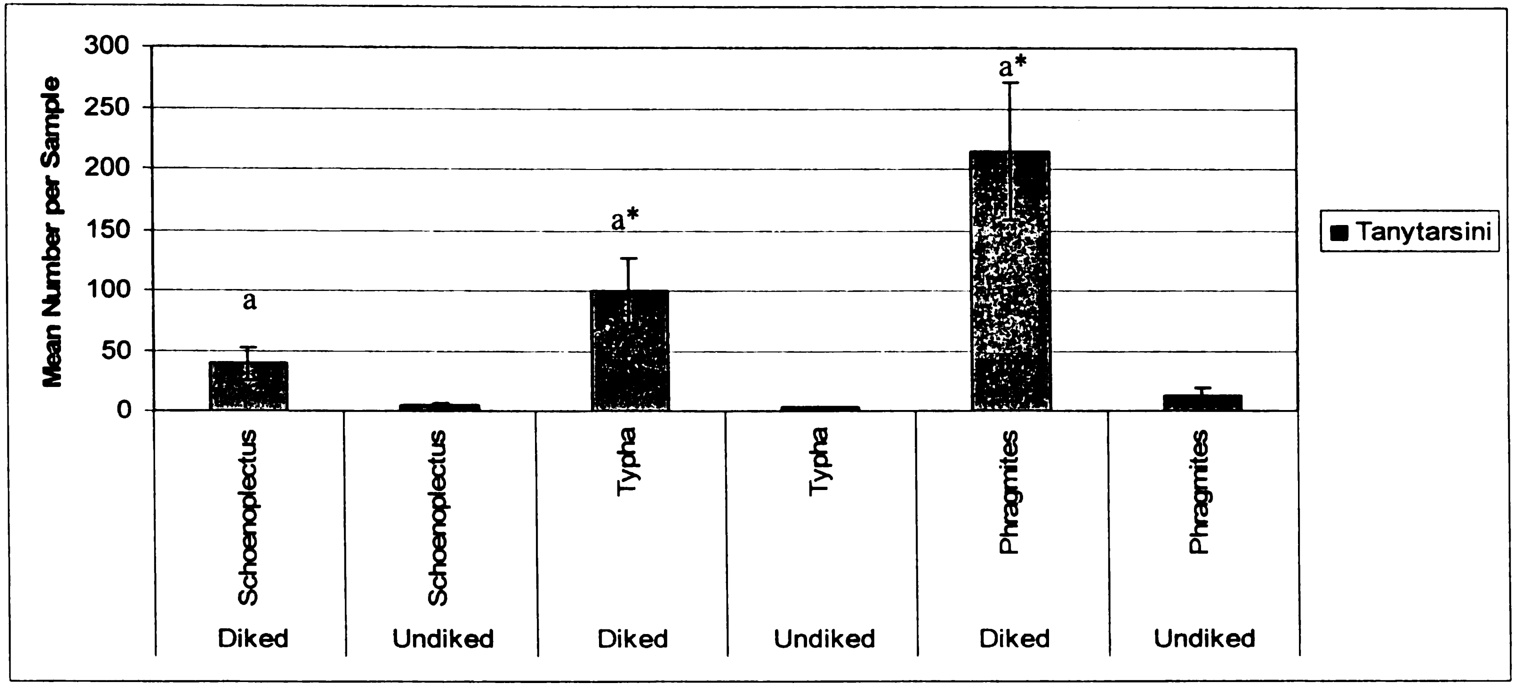

Figure 7. *Tanytarsini* total number per sample (± standard error) in diked and undiked *Schoenoplectus, Typha,* and *Phragmites* zones. Total number per sample significantly increased (p=0.04) in diked marshes compared to undiked marshes. [a] Percent relative catch increased (p=0.09) in diked marshes compared to undiked marshes. * Percent relative catch increased (p=0.08) in diked *Typha* and diked *Phragmites* zones, compared to undiked *Schoenoplectus* and *Typha* zones.

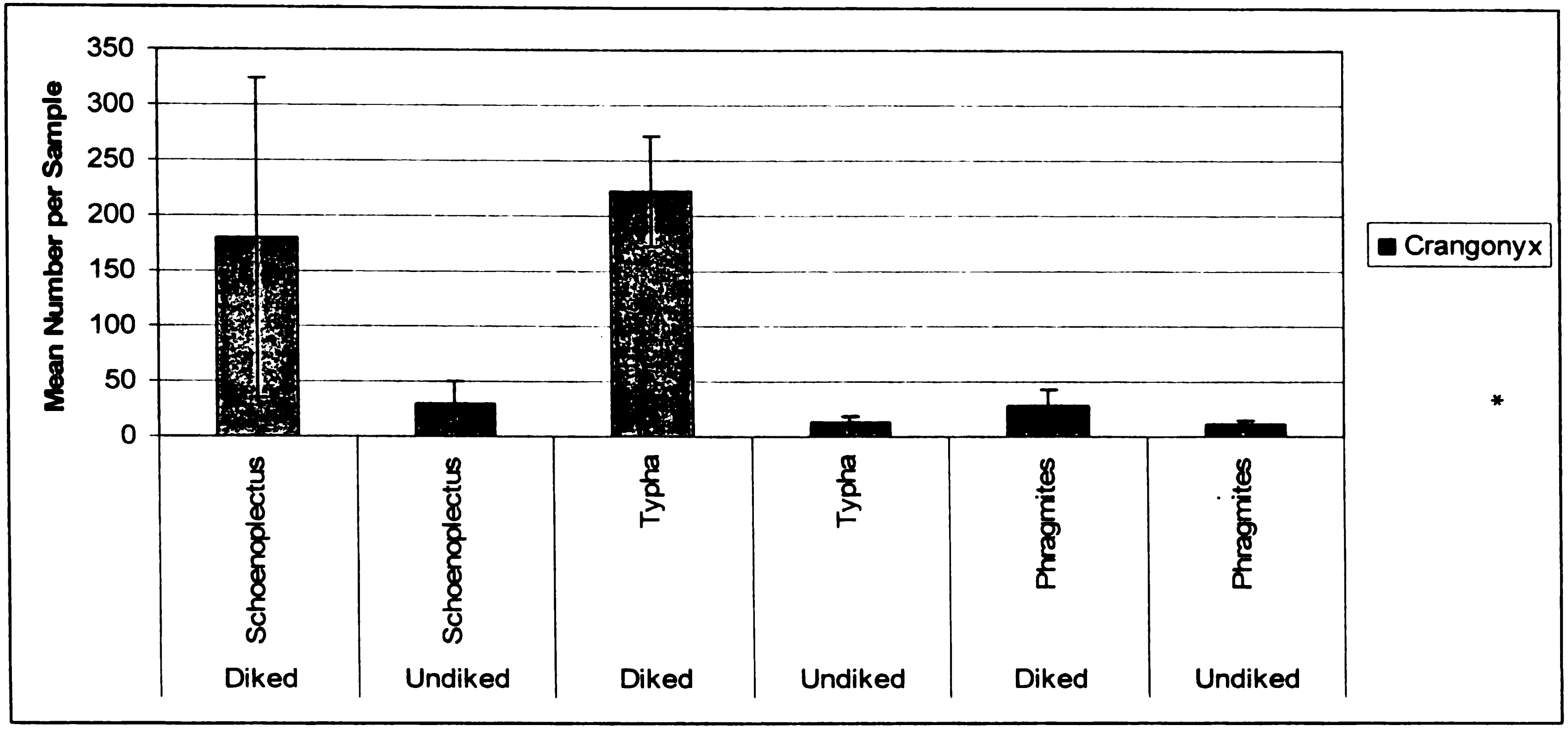

Figure 8. *Crangonyx* total number per sample (± standard error) in diked and undiked *Schoenoplectus, Typha,* and *Phragmites* zones. * *Crangonyx* percent relative catch is slightly greater (p=0.09) in diked *Typha* compared to diked *Phragmites.*

Table 1. Summary Table of Mean (±Standard Error) Invertebrate Community Characteristics from Diked and Undiked Marshes and *Schoenoplectus, Typha, and Phragmites* Zones. Values for all taxa are mean number/ sample. *= P <0.05, **= P <0.10..

Marsh Type			Diked				Undiked	
Plant Zone	All Diked	*Schoenoplectus*	*Typha*	*Phragmites*	All Undiked	*Schoenoplectus*	*Typha*	*Phragmites*
N	25	7	9	9	29	10	9	10
Total #	93,959	26,121	27,379	40,459	15,690	6,700	3,209	5,781
Mean #/ Sample	3,758.36 ±493.91*	3,731.57 ±1079.42	3, 042 ±499.86	4, 495.44 ±985.51	541.03 ±74.30	670.00 ±172.18	356.56 ±99.35	578.10 ±336.03
Diversity (H')	1.12 ±0.03	1.04 ±0.07	1.16 ±0.04	1.14 ±0.04	1.13 ±0.02	1.11 ±0.03	1.16 ±0.03	1.13 ±0.05
Richness	50.36 ±2.16*	47.71 ±4.89	51.89 ±3.86	50.89 ±3.02	34.52 ±1.28	34.80 ±2.61	33.00 ±2.35	35.6 ±1.77
Evenness (J')	0.66 ±0.02	0.63 ±0.05	0.68 ±0.02	0.67 ±0.03	0.74 ±0.02	0.73 ±0.02	0.77 ±0.02	0.73 ±0.04
Hirudinea	17.68 ±3.88	15.29 ±5.91	22.56 ±9.42	14.67 ±3.44	4.17 ±1.32	3.60 ±1.76	2.33 ±0.83	6.40 ±3.35
Oligochaeta	414.72 ±89.54	295.57 ±60.20	274.33 ±47.54	647.78 ±227.61	120.00 ±21.64	175.20 ±45.56	70.56 ±22.81	109.30 ±33.75
Naididae	408.48 ±89.06	285.00 ±59.81	269.89 ±49.35	643.11 ±225.43	115.69 ±21.27	168.60 ±44.83	65.89 ±21.28	107.60 ±33.82
Gastropoda	606.52 ±147.23	270.00 ±56.91	765.00 ±318.10	709.78 ±249.19	62.79 ±12.50	68.40 ±20.55	35.00 ±14.13	82.20 ±26.57
Viviparidae	153.28 ±57.89	69.00 ±33.81	126.22 ±65.85	245.89 ±145.15	11.41 ±4.79	20.50 ±12.87	7.11 ±5.53	6.20 ±1.79

Table 1. Cont.

Gyralus	182.96 ±53.27	68.57 ±15.43	269.89 ±137.31	185.00 ±49.41	18.57 ±3.76	21.20 ±6.46	10.44 ±4.64	23.30 ±7.65
Planorbella	59.84 ±12.55	46.14 ±22.11	54.22 ±14.81	76.11 ±27.43	3.76 ±1.64	4.00 ±1.66	0.78 ±0.55	6.20 ±4.43
Amphipoda	1186.36 ±265.74	1896.86 ±856.04	849.67 ±170.98	970.44 ±250.44	102.55 ±20.65	139.60 ±48.62	60.89 ±19.62	103.00 ±29.16
Hyalella	1045.88 ±269.10	1717.29 ±874.21	627.67 ±168.64	941.89 ±249.35	31.17 ±8.83	38.00 ±19.75	10.89 ±5.00	42.60 ±15.23
Crangonyx	140.48 ±45.62	179.57 ±143.76	222.00 ±50.50	28.56 ±13.95	18.03 ±6.92	30.10 ±19.11	13.33 ±5.20	10.20 ±4.48
Isopoda	45.32 ±9.23	32.57 ±16.39	55.56 ±15.43	45.00 ±16.92	16.34 ±9.84	36.70 ±28.16	7.67 ±2.03	3.80 ±2.39
Caecidotea	36.64 ±9.00	25.43 ±17.13	43.11 ±14.13	38.89 ±16.92	11.62 ±6.16	25.40 ±17.38	6.00 ±1.62	2.90 ±2.38
Hydracarina	109.48 ±19.01	147.00 ±48.01	65.44 ±20.53	124.33 ±28.94	7.83 ±1.43	10.00 ±2.50	4.56 ±1.55	7.38 ±1.33
Ephemeroptera	461.56 ±138.98	254.71 ±66.59	212.89 ±58.55	871.11 ±349.43	43.76 ±14.12	24.50 ±14.65	10.11 ±2.71	93.30 ±33.92
Caenis	459.84 ±139.03	251.14 ±66.52	211.78 ±58.78	870.22 ±349.38	42.69 ±14.12	23.20 ±14.53	9.22 ±2.75	92.30 ±33.85
Odonata	160.76 ±36.80	268.43 ±110.64	87.44 ±19.42	150.33 ±44.24	18.62 ±5.04	30.30 ±12.93	9.11 ±3.43	15.50 ±5.24
Coenagrionidae	49.52 ±15.76	101.14 ±51.30	19.56 ±7.05	39.33 ±10.03	6.83 ±2.76	13.00 ±7.58	2.22 ±0.85	4.80 ±1.99

Table 1. Cont.

Hemiptera	120.88 ±15.95	172.43 ±26.63	72.78 ±17.06	128.89 ±29.31	41.55 ±6.08	30.90 ±9.22	50.56 ±15.06	44.10 ±6.79
Mesovelia	6.36 ±2.05	16.57 ±5.80	2.78 ±0.55	2.00 ±0.93	13.72 ±3.78	9.70 ±3.27	26.11 ±10.68	6.60 ±2.11
Pleidae	66.64 ±12.49	89.29 ±32.58	38.11 ±11.38	77.56 ±19.62	2.93 ±1.44	0.30 ±0.21	2.67 ±2.06	5.80 ±3.69
Trichoptera	95.48 ±20.35	84.43 ±17.58	45.56 ±13.34	154.00 ±48.38	24.79 ±5.93	35.10 ±13.23	10.56 ±5.65	27.30 ±9.15
Lepidoptera	21.12 ±4.46	13.57 ±5.44	31.67 ±10.35	16.44 ±4.36	1.55 ±0.49	1.00 ±0.47	1.11 ±0.54	2.50 ±1.24
Coleoptera	55.16 ±11.58	26.57 ±8.08	80.33 ±29.76	52.22 ±5.83	10.17 ±1.76	9.90 ±3.33	5.78 ±1.93	14.40 ±3.13
Diptera	380.44 ±49.05	191.00 ±29.59	365.33 ±72.40	542.89 ±86.47	66.34 ±10.67	82.20 ±24.11	51.33 ±16.92	64.00 ±12.84
Chironomini	109.28±19.40	67.00 ±15.22	92.78 ±19.71	158.67 ±45.84	14.17 ±3.06	20.50 ±6.58	7.67 ±3.77	13.70 ±4.60
Tanytarsini	124.36 ±26.60	39.14 ±13.24	100.00 ±27.40	215.00 ±56.90	7.00 ±2.40	4.80 ±1.86	2.44 ±0.99	13.30 ±6.38
Tanypodinae	76.00 ±19.30	48.29 ±13.47	90.11 ±48.73	83.44 ±22.75	8.93 ±1.87	13.50 ±4.55	7.33 ±2.54	5.80 ±1.40

Table 2. Sorensen Similarity Index with Number of similar taxa (% similarity) for Diked and Undiked Marshes from *Schoenoplectus, Typha,* and *Phragmites* zones.

# of Taxa	Type	# of Taxa	Type	# Shared Taxa (Similarity %)
121	Diked	113	Undiked	90 (77%)
87	Diked Schoenoplectus	76	Undiked Schoenoplectus	58 (71%)
101	Diked Typha	77	Undiked Typha	64 (72%)
90	Diked Phragmites	86	Undiked Phragmites	65 (74%)

Table 3. Total Number per Sample (% Percent Total) of Dominant taxa in Diked and Undiked Marshes in *Schoenoplectus*, *Typha* and *Phragmites* Zones.

			Wetland Type	Diked			Undiked		
			Plant Zone	*Schoenoplectus*	*Typha*	*Phragmites*	*Schoenoplectus*	*Typha*	*Phragmites*
			Mean #/ Sample	3, 731.57	3, 042.11	4, 495.44	670.00	356.56	578.10
Mollusca	Gastropoda	Viviparidae		69.00 (2%)	126.22 (4%)	245.89 (5%)	20.50 (3%)	7.11 (2%)	6.20 (1%)
	Amphipoda	Hyalella	*Hyalella*	1, 717.29 (46%)	627.67 (21%)	941.89 (21%)	38.00 (6%)	10.89 (3%)	42.60 (7%)
Annalida	Oligochaeta	Naididae		285.00 (8%)	269.89 (9%)	643.11 (14%)	168.60 (25%)	65.89 (18%)	107.60 (19%)
Arachnida	Hydracarina			147.00 (4%)	65.44 (2%)	124.33 (3%)	10.00 (1%)	4.56 (1%)	8.60 (1%)
Insecta	Odonata			268.43 (7%)	87.44 (3%)	150.33 (3%)	30.30 (5%)	9.11 (3%)	15.50 (3%)
		Coenagrionidae	*Imm.*	101.14 (3%)	19.56 (1%)	39.33 (1%)	13.00 (2%)	2.22 (1%)	4.80 (1%)
	Hemiptera			172.43 (5%)	72.78 (2%)	128.89 (3%)	30.90 (5%)	50.56 (14%)	44.10 (8%)
		Pleidae		89.29 (2%)	38.11 (1%)	77.56 (2%)	0.30 (<1%)	2.67 (1%)	5.80 (1%)
	Lepidoptera			13.57 (<1%)	31.67 (1%)	16.44 (<1%)	1.00 (<1%)	1.11 (<1%)	2.50 (<1%)
	Coleoptera			26.57 (1%)	80.33 (3%)	52.22 (1%)	9.90 (1%)	5.78 (2%)	14.40 (2%)
		Noteridae	*Hydrocanthus*	18.29 (<1%)	10.56 (<1%)	12.00 (<1%)	1.90 (<1%)	1.00 (<1%)	2.10 (<1%)
	Diptera	Chironomidae	*Tanytarsini*	39.14 (1%)	100.00 (3%)	215.00 (5%)	4.80 (1%)	2.44 (1%)	13.30 (2%)
			Chironomini	67.00 (2%)	92.78 (3%)	158.67 (4%)	20.50 (3%)	7.67 (2%)	13.70 (2%)
			Tanypodinae	48.29 (1%)	90.11 (3%)	83.44 (2%)	13.50 (2%)	10.20 (2%)	5.80 (1%)

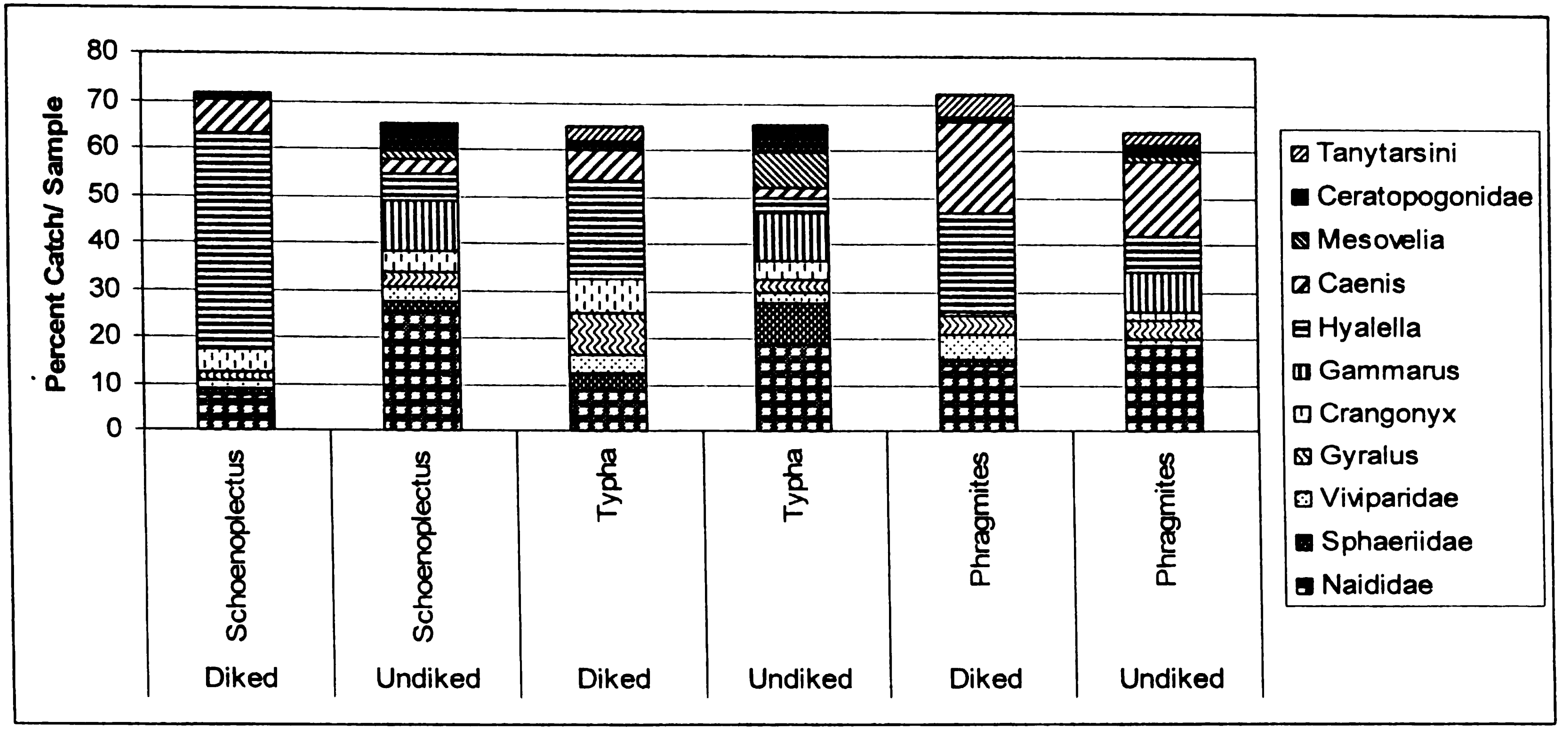

Figure 9. Percent relative catch per sample (>5%) of invertebrates in each of the three vegetation zones in diked and undiked marshes.

Effects of Plant zonation on Invertebrate Community Parameters

Several taxa were commonly collected from all plant zones in diked and undiked marshes (Figure 9). The dominant groups included the segmented worm, Naididae, the Amphipods, *Hyalella* and *Crangonyx,* and the Ephemeropteran, *Caenis* (Figure 9).

Major differences related to plant zone often involved difference between responses in the *Schoenoplectus* (bulrush) zone compared to either the *Typha* (cattail) or *Phragmites* (common reed) zones. For example, *H. azteca* made up 46% of total catch in the diked *Schoenoplectus* zone but only 21% in the other two plant zones in diked marshes (Figure 9, Table 3). Four taxa were typically more abundant in the *Schoenoplectus* zones of diked and undiked marshes than in the other two zones. Water mites were frequently collected across all plant zones in diked and undiked marshes (Table 6), but total number per sample showed a slightly significant (p=0.09) difference between diked *Schoenoplectus* and diked and undiked *Typha, Phragmites,* and undiked *Schoenoplectus* (Table 3). The grass shrimp, *Palaemonetes kadiakensis,* comprised 0.5% relative catch in diked marshes and 0.7% in undiked marshes (Table 4) and was collected in 67% of the replicates in diked marshes (Table 6) and 37% of replicates in undiked marshes. Four times more shrimp/ sample were collected in diked marshes than in undiked marshes. While grass shrimp were collected more frequently in *Schoenoplectus* zones, it was also collected in *Typha* (30% of replicates in diked marshes, 4% in undiked marshes) and *Phragmites* (26% of replicates in diked marshes, 3% in undiked marshes) replicates. There were ten times more Corixidae, Hemiptera, which were collected in 71% of diked *Schoenoplectus* replicates compared to 30% of undiked *Schoenoplectus* replicates (Table 6). Corixidae made up 2.2% of the diked *Schoenoplectus* zone and was <0.5% in the diked *Typha* and diked *Phragmites* zone (Table 4). The burrowing water beetle, *Hydrocanthus*, comprised 0.8% relative catch in diked marshes and 1.1% in undiked marshes (Table 4), but less than 1% total number per sample in both diked and undiked marshes (Table 3). There were eight times more *Hydrocanthus* in diked marshes and it was collected in 62% of diked replicates, compared to 17% of undiked replicates (Table 3). *Hydrocanthus* was collected in less than 50% of diked and undiked *Typha* (41% and 15% respectively) and *Phragmites* (37% and 32% respectively) replicates.

In the *Typha* zone, differences occurred between the taxa in diked and undiked marshes. In undiked marshes, the damselfly, *Ischnura,* the fishfly, *Chauliodes,* and the soldierfly Family, Stratiomyidae, each comprised 1% total number per sample of the invertebrate community but less than 1% of the diked community (Table 4). There were four times the number of Odonata, *Ischnura,* three times *Chauliodes,* and twice the number of Stratiomyidae in diked marshes compared to undiked wetlands. *Ischnura* and *Chauliodes* were infrequently collected in undiked replicates (3-16% and 13-26% respectively) and diked replicates (11-48% and 19-43% respectively). Stratiomyidae was similarly infrequently collected in undiked replicates (19-33%) but was collected in 70% of the diked *Typha* replicates compared to diked *Schoenoplectus* (24%) and *Phragmites* (26%).

In diked *Typha* marshes, the snail, *Gyraulus crista*, the caddisfly, *Polycentropus,* and the moth, *Parapoynx,* each comprised 1% total number of the invertebrate community but less than 1% in undiked marshes. *G. crista* was not found in undiked marshes but was collected in 14% of *Schoenoplectus,* 52% of *Typha,* and 56% of

Phragmites diked replicates. There were 57 times more *Polycentropus* and 15 times more *Parapoynx* in diked marshes compared to undiked marshes. *Polycentropus* and *Parapoynx* were rarely collected in undiked replicates (3-7% and 3-19%, respectively), but in diked replicates they were frequently collected (48-76% and 52-63%, respectively) (Table 6).

In the *Phragmites* zone, differences also occurred between taxa of diked and undiked marshes. In undiked *Phragmites*, the water-striders, Gerridae, the velvet water bug, Hebridae, the minute moss beetle, Hydraenidae, and dixid midges, Dixidae, each comprised 1% total number of the invertebrate community. There were eight times the number of Hebridae, and ten times the number of Dixidae in undiked marshes compared to diked marshes but there was twice the number of Hydraenidae in diked marshes compared to undiked marshes. The number of Gerridae was the same for diked and undiked wetlands. Generally, all four of these taxa were rarely collected (<25%) in either diked or undiked replicates. The only exception was Hydraenidae which was collected in 41% of diked *Phragmites* replicates.

In diked *Phragmites,* total number of the limpet, Ancylidae, was seven times greater, the immature dragonfly, Libellulidae was 374 times greater, and the caddisfly, *Leptocerus* was 131 times greater, compared to undiked marshes. Each of these taxa comprised 1% of the diked invertebrate community but <1% in undiked marsh community. Ancylidae was collected in 32-37% of undiked replicates and increased to 37-81% of diked replicates (Table 6). Immature Libellulidae were rarely collected in undiked marshes (0-4%), but were frequently collected in diked replicates (76-89%). Immature Leptoceridae and *Leptocerus* were rarely collected in undiked (0-6% and 0-7%, (0-6% and 0-7%, respectively) replicates and generally were infrequent in diked (0-33% and 4-22%, respectively) replicates.

Table 4. Mean Invertebrate Relative Catch >0.5% (±Standard Error) in Diked and Undiked Marshes.

Taxa			Undiked	Diked
Oligochaeta	Naididae		21.3±2.79	11.7±1.52
	Tubificidae		1.4±0.69	
Mollusca	Sphaeriidae		1.6±1.05	2.2±0.47
Gastropoda	Viviparidae		2.5±0.96	3.1±0.82
	Lymnaeidae	*Stagnicola*	1.5±0.58	0.6±0.33
	Physidae	*Physa*	1.9±0.36	2.8±0.51
	Planorbidae	*Gyraulus*	3.0±0.44	5.0±1.07
		Planorbella	0.7±0.23	1.6±0.30
Arachnida	Hydracarina		1.8±0.30	3.0±0.36
Amphipoda	Crangonyctidae	*Crangonyx*	2.7±0.61	5.3±1.78
	Gammaridae	*Gammarus*	10.9±2.06	
	Talitridae	*Hyalella*	5.5±1.51	25.1**±2.79
Isopoda	Asellidae	*Caecidotea*	1.8±0.59	1.4±0.40
Ephemeroptera	Caenis	*Caenis*	6.3±1.76	10.3±1.73
Odonata	Coenagrionidae	*Imm.*	1.2±0.27	1.1±0.21
		Enallagma	1.8**±0.41	
	Libellulidae	*Imm.*		1.6±0.31
Hemiptera	Belostomatidae	*Belostoma*	1.4±0.29	
	Mesovelidae	*Mesovelia*	3.8***±0.87	
	Nepidae	*Ranatra*	1.1±0.21	
	Pleidae		0.5±0.24	2.0±0.33
Homoptera			1.0±0.31	
Trichoptera	Hydroptilidae	*Oxyethira*	1.1*±0.32	0.7±0.23
	Leptoceridae	*Cercalea*	1.3±0.35	
Diptera	Ceratopogonidae		4.2±1.00	1.1±0.23
	Chironomidae	*Chironomini*	2.5±0.43	3.2±0.45
		Tanytarsini	1.0±0.27	3.9*±0.89
		Orthocladinae	1.7±0.39	
		Tanypodinae	1.6±0.21	2.0±0.36

*** Significant at ($p<0.01$)
** Significant at ($p<0.05$)
* Significant at ($p<0.10$)

Functional Feeding Groups

Gatherer-collectors comprised approximately 60% of invertebrates collected in diked and undiked marshes while predators made up approximately 20% and scrapers approximately 10% (Figure 9). Comparisons between diked and undiked vegetation zones showed similar trends with gatherer-collectors (49 to 70% in diked vegetation zones and 52-62% in undiked vegetation zones) being the most dominant functional group (Figure 9). Gatherer-collectors, which feed mainly on decomposing fine particulate organic material (Merritt and Cummins 1996), have been reported to dominate coastal marshes that are vegetated and accumulate detritus (Merritt et al. 2002) which generally characterize the diked and undiked marshes I was sampling.

Except for diked *Typha* and *Phragmites* zones, in which scrapers made up a greater percentage (25% and 16% respectively) than predators (15% and 13% respectively) (Figure 9), predators were more abundant than scrapers between diked and undiked vegetation zones (Figure 9).

Functional Habitat Groups

There were only minor differences in the percentages of habitat groups between diked and undiked marshes (Figure 10). In undiked marshes, burrowers comprised 28% of the invertebrate community and dominated the *Schoenoplectus* zone (35%) (Figure 10). In diked wetlands, swimmers comprised the greatest percentage of invertebrates (40%) and also dominated the *Schoenoplectus* zone (60%) (Figure 10). Climbers made up a greater percentage of the undiked community (11%) compared to the diked community (4%) (Figure 10).

Sprawlers increased in the *Phragmites* zones of diked and undiked marshes (24% and 26%) compared to the diked and undiked *Schoenoplectus* (13% and 14%, respectively) and *Typha* zones (15% and 13%, respectively) (Figure 10). This difference reflects the fact that *Caenis* contributed a substantial portion of the invertebrate community of *Phragmites* zones (Table 1, Table 3, and Figure 8).

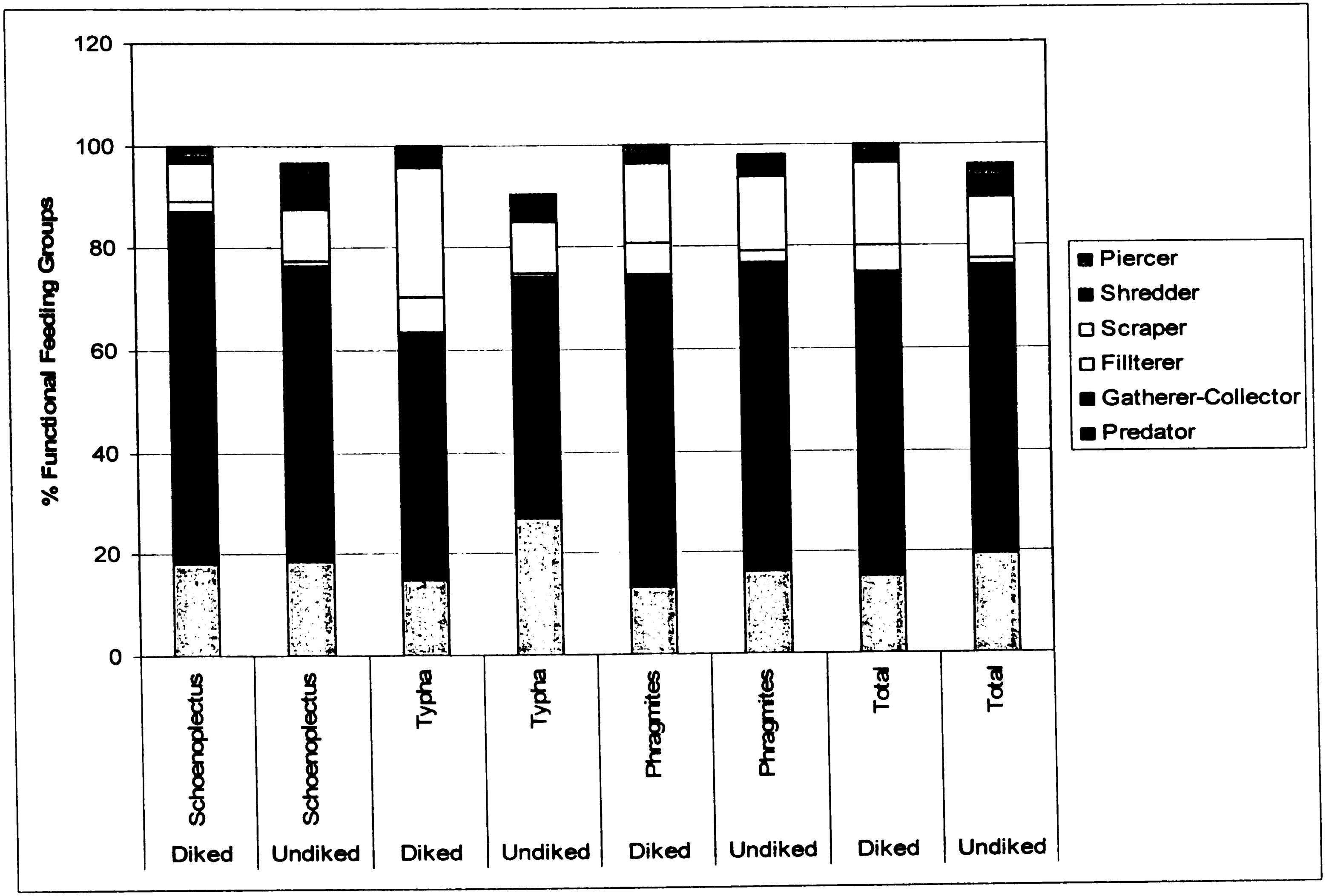

Figure 10. Percent functional feeding groups from diked and undiked *Schoenoplectus*, *Typha*, and *Phragmites* zones.

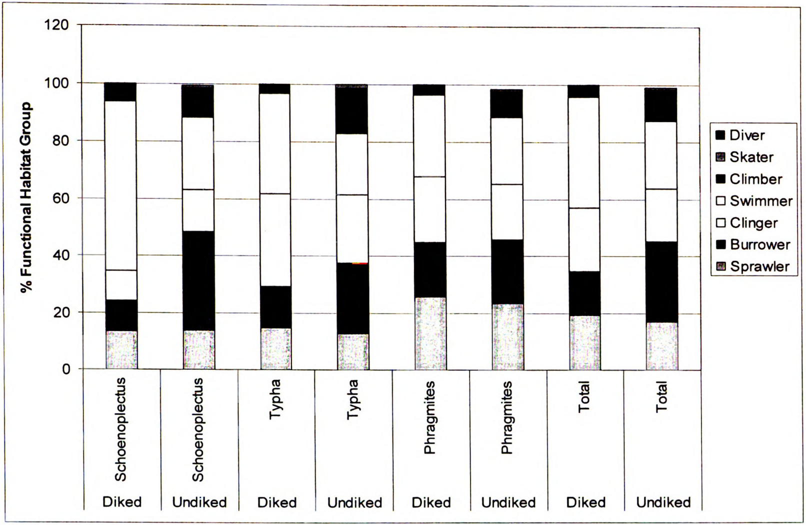

Figure 11. Percent functional habitat groups from diked and undiked *Schoenoplectus, Typha,* and *Phragmities* zones.

Invertebrate Frequency

Naididae was the most frequently observed invertebrate (>90%) collected in diked and undiked marshes (Table 6). In undiked marshes, Amphipoda was the second most frequently found taxa but *Gammarus* was the only Amphipod to be frequently caught in all three vegetation zones (77-89%) (Table 6). Hydracarina was also frequently found in all three vegetation zones (67-70%). Four Gastropods were frequently found in the *Schoenoplectus* zone while three were found in the *Phragmites* zone and only one (*Gyraulus*) was found in the *Typha* zone. There were five Dipterans that were found in *Phragmites*, four in *Typha,* and three in *Schoenoplectus* (Table 6). *Mesovelia* was only frequent in *Schoenoplectus* (73%) and *Typha* (81%) zones. *Caenis* was only frequent in *Typha* (52%) and *Phragmites* (77%) zones. *Schoenoplectus* was unique from the other zones in that immature Coenagrionidae (53%), *Enallagma* (70%), and *Oxyethira* (50%) were only caught in that zone at a frequency >50% (Table 6). *Typha* had three unique taxa: *Crangonyx* (59%), *Caecidotea* (56%), and *Belostoma* (59%) (Table 6). *Phragmites* had two unique taxa: *Ranatra* (68%) and Homoptera (58%) (Table 6).

In diked marshes, *Gyraulus* (95-100%), *Hyalella* (100%), *Caenis* (100%), Chironomidae pupae (100%), and *Tanypodinae* (90-100%) were all found at >90% frequency (Table 6). Hydracarina was found at 100% of replicates collected from *Schoenoplectus* and *Phragmites*, but only at 89% in *Typha*. Hirudinea was frequently found in all three vegetations but was most frequently found in *Schoenoplectus* (81%). *Parapoynx* was also frequently found in all three zones (52-63%). Seven Gastropods were frequently found in *Schoenoplectus* and *Phragmites* marshes and five were found in *Typha*.

Table 5. Percent Invertebrate Frequency (>50%) from Diked and Undiked Marshes in *Schoenoplectus*, *Typha*, and *Phragmites* Zones.

Wetland Type				**Diked**			**Undiked**	
Taxa			***Schoenoplectus***	***Typha***	***Phragmites***	***Schoenoplectus***	***Typha***	***Phragmites***
Hirudineidae	Hirudinea		81	63	67			
Oligochaeta	Naididae		100	96	100	93	96	97
Mollusca	Sphaeriidae		62	89	89			
Gastropoda	Ancylidae		52		81			
	Viviparidae		67		70	60		52
	Lymnaeidae	*Stagnicola*	67					55
	Physidae	*Physa*	86	93	93	67		74
	Planorbidae	*Gyraulus*	95	96	100	77	59	84
		G. crista		52	56			
		Planorbella	76	70	85			
Arachnida	Hydracarina		100	89	100	70	67	68
Amphipoda	Crangonyctidae	*Crangonyx*	67	93			59	
	Gammaridae	*Gammarus*				83	89	77
	Talitridae	*Hyalella*	100	100	100	53		84
Decapoda	Palaemonidae	*Palaemonetes*	67					
Isopoda	Asellidae	*Caecidotea*		81	56		56	
		Lirceus	57					
Ephemeroptera	Caenidae	*Caenis*	100	100	100		52	77
Odonata	Coenagrionidae	*Imm.*	90	63	93	53		
		Enallagma	67			70		
	Libellulidae		76	89	81			
	Courduliidae				56			
Hemiptera	Belostomatidae	*Belostoma*					59	
	Corixidae		71		59			

Table 5. Cont.

	Mesovelidae	*Mesovelia*	76			73	81	
	Nepidae	*Ranatra*						68
	Notonectidae		62	52	56			
	Pleidae		90	74	93			
	Veliidae		52					
Homoptera								58
Trichoptera	Hydroptilidae	*Oxyethira*	71		59	50		
	Leptoceridae	*Setodes*	76	52	59			
	Polycentropodidae	*Polycentropus*	76		70			
Lepidoptera	Pyralidae	*Parapoynx*	52	63	52			
Coleoptera	Noteridae	*Hydrocanthus*	62					
Diptera	Ceratopogonidae		67	70	81	80	59	65
	Chironomidae	*Pupae*	100	100	100			
		Chironomini		59		67	52	71
		Tanytarsini	71	93	100			55
		Tanypodinae	90	93	100	80	52	58
		Orthocladinae			52		52	52
	Stratiomyidae			70				

Ancylidae and Viviparidae were found in *Schoenoplectus* (52%) and *Phragmites* (81%) zones and *Gyraulus crista* was found in *Typha* (52%) and *Phragmites* (56%) zones. Amphipods were found in all three zones but *Crangonyx* was only frequent in *Schoenoplectus* (67%) and *Typha* (93%) zones. There were three Odonata frequently caught in *Schoenoplectus* and *Phragmites* zones but only two in *Typha*. Most Hemiptera that were frequently caught were from the *Schoenoplectus* zone. Three Trichoptera were frequent in *Schoenoplectus* and *Phragmites* zones but only *Setodes* (52%) was in *Typha*. Each zone had five Dipterans frequently found. *Schoenoplectus* had six unique taxa: *Stagnicola* (67%), *Palaemonetes* (67%), *Lirceus* (57%), *Enallagma* (67%), *Mesovelia* (76%), Veliidae (52%), and *Hydrocanthus* (62%) (Table 6). *Typha* had two unique taxa: *Chironomini* (59%) and Stratiomyidae (70%) (Table 6). *Phragmites* had two unique taxa: Corduliidae (56%) and *Orthocladinae* (52%) (Table 6).

DISCUSSION

My hypothesis that invertebrate community species composition, total catch/ sample, richness, and evenness would differ significantly between diked and undiked coastal marshes was partially supported. The total number of invertebrates per sample and taxa richness significantly increased in diked marshes compared to undiked marshes. The number of invertebrate/ sample was seven times higher in diked marshes than in undiked marshes increasing from a mean of 541/ sample in undiked marshes to 3,748/ sample in diked marshes. Eighty percent of this unexpectedly large increase was the result of increases in five taxa that are known to be important in waterfowl and wading bird diets. They included Amphipoda, especially *H. azteca,* Naididae worms, *Caenis* mayflies, snails (Gastropoda), and non-biting midges (Chironomidae). Marshes have traditionally been diked for waterfowl management in Great Lakes coastal marshes, and my findings suggest that diking is effective in producing more food for breeding waterfowl, especially when accompanied by maintenance of channels for hunter access. I sampled near the edge of each of the three plant zones, so invertebrates were likely a combination of taxa characteristic of the emergent zone and the adjacent open water channel dominated by submergent, floating and floating-leafed plants. Each area sampled was located in habitat where waterfowl or other water birds had been observed. These results suggest that waterfowl and wading birds feeding in the outer edge of the three plant zones have substantially greater access to invertebrate food resources in diked marshes than they do in undiked marshes.

Taxa richness increased from 33-36 taxa in undiked marshes to 48-52 taxa in diked marshes (Table 1). There were no significant differences in invertebrate diversity (H') or evenness (J') between diked and undiked marshes. Invertebrate communities in diked and undiked marshes shared 90 taxa in common out of a total of 144 taxa collected from Lake St. Clair marshes. Sorenson's percent similarity between diked and undiked communities and among communities in the three dominant plant zones was >70% for most comparisons. Thus, changes in community composition between diked and undiked marshes generally involved less than 30% of the taxa present in both. Of particular note was the substantial increase in dominance by *H. azteca* in diked marshes and its apparent displacement of *Gammarus* as the dominant amphipod in diked marshes compared to undiked marshes.

Dominant taxa were similar between diked and undiked marshes at the family or Order level with minimal differences among the three dominant plant zones present

(*Schoenoplectus, Typha,* and *Phragmites*). Dominant taxa included segmented worms, Naididae, side-swimmers or scuds, *Hyalella* and *Crangonyx*, the mayfly, *Caenis,* and snails, Gastropoda (Figure 9). These dominant groups are consistent with other researcher's findings for Lake St. Clair and the St. Clair River invertebrate communities (Davis et al. 1991, Ciborowski and Corkum 1988, French III 1988, Herdendorf et al. 1986). Additionally, other researchers have described these taxa as being dominant in Lake Ontario (Barton 1986), Lake Erie (De Szalay and Cassidy 2001, Herdendorf 1987) and Lake Huron coastal wetlands (Burton et al. 2002, Stricker et al. 2001, Barton and Griffiths 1984).

My findings differ from results found by McLaughlin and Harris (1990) for marshes in Green Bay, Wisconsin. They did not find significant differences in total number of invertebrates in diked marshes compared to undiked marshes but suggested that there were more invertebrates in diked marshes than undiked marshes. A possible reason that they failed to find significant differences was that they only sampled emerging insects. This would have excluded Naididae and Amphipoda, which dominated the invertebrate community in diked and undiked marshes in Lake St. Clair marshes (Figure 9).

My second hypothesis was that the invertebrate parameters listed above would be affected by plant zonation in diked and undiked marshes. I did not find significant differences in total number per sample, taxa richness, diversity, or evenness among plant zones in diked or undiked marshes. There were significant differences between the Coleoptera community of diked vegetation zones, and marginally significant differences in the Hemiptera community. Plant zone was marginally significant for seven taxa in diked marshes, and was marginally significant for the mayfly, *Caenis*, in undiked marshes.

In other studies of Great Lake coastal marshes, vegetation type was correlated with the type of macroinvertebrate community present (Burton et al. 2004, 2002, French III 1988). McLaughlin and Harris (1990) and De Szalay and Cassidy (2001), showed that the largest numbers of invertebrates were found in sparse emergent zones within diked marshes but neither study found a significant difference between emergent vegetation zones and open water zones in diked marshes. Thus, my results are consistent with their studies.

Additionally, Fell et al. (2003) and Kulesza et al (2008) failed to find significant differences between the macroinvertebrate communities in *Typha* and *Phragmites* dominated marshes. I detected marginally significant differences between *Crangonyx* relative catch, *Caenis* total number and *Caenis* relative catch between *Phragmites* dominated zones compared to *Typha,* and *Schoenoplectus* zones but generally the invertebrate community was the most similar between *Typha* and *Phragmites*.

Like De Szalay and Cassidy (2001), the invertebrate community was dominated by invertebrates classified as gatherer-collectors (60%) which included the Oligochaetes, the Amphipods, and mayflies. Scrapers and Predators were abundant in diked and undiked marshes (>10%) and were mainly comprised of snails and mostly Odonates, Hemipterans, ceratopogonids, and chironomids. While De Szalay and Cassidy (2001) failed to collect any Filterers or Shredders, I did find a few but they made up <5% of the invertebrate community.

I documented differences in the three plant zones common to diked and undiked marshes in order to document changes in the potential prey base of avian fauna of diked and undiked Great Lake coastal marshes. Primarily, marsh birds eat immature and adult insects, snails, and crustaceans (Mazak et al. 1997, Kaminski and Prince 1981, Swanson et al. 1974, Krull 1970). Each avian species selectively forages for particular invertebrates, and favors intermediate to large-sized invertebrate families (Mazak et al. 1997, Kaminski and Prince 1981, Swanson et al. 1979, Swanson et al. 1974). I frequently (>50% replicates) caught more large organisms, such as Lepidoptera and Odonata, in diked marshes than in undiked marshes (Table 6). In fact, there were 13 times more Lepidoptera and 9 times more Odonates in diked marshes (Table 3). The Gastropods, Viviparidae, *Gyraulus,* and *Planorbella* significantly increased in diked marshes and there were between 8-13 times more in diked marshes. The largest significant increase in diked marshes compared to undiked marshes was the very large 35 fold increase in the amphipod crustaceans, *Hyallela* and *Crangonyx.* Amphipods are among the important prey for waterfowl and fish in the Midwest (Anteau and Afton 2008) and are known to reach very high densities in submersed aquatic vegetation. Submersed aquatic vegetation was common in the hunter access channels adjacent to the emergent zones that I sampled in the diked marshes.

Krull (1970) suggested that the vegetation zone-invertebrate interaction is important for foraging avian species. He showed that plants that were poor waterfowl food, typically harbored more invertebrates and that these plants would be indirectly important for waterfowl. Examples of invertebrates which showed changes between plant zone and which may be important to birds in diked and undiked marshes include: the grass shrimp in *Schoenoplectus* zones of diked and undiked (Table 3, Table 4) marshes: the moth, *Parapoynx* in diked (Table 3, Table 4), and damselfly, *Ischnura* in undiked *Typha* zones (Table 3, Table 4); and the mayfly, *Caenis*, which is found in the highest relative catch in the *Phragmites* zones in diked and undiked marshes (Table 3, Table 4).

Just as McLaughlin and Harris (1990) suggested, diked marshes would seem to be a preferred habitat for foraging marsh birds because of the significant increase in aquatic invertebrates. Preliminary examination of data from bird surveys at randomly selected open water areas at St. Clair Flats indicate higher densities of Canada goose (*Branta canadensis*), wood duck (*Aix sponsa*), and black tern (*Chlidonias niger*) in diked compared to undiked marshes; however, black terns were only observed nesting in undiked marshes and densities varied by site and year (M. Monfils pers. comm.). In undiked coastal marshes, mallard (*Anas platyrhynchos),* American coot (*Fulica americana*), pied-billed grebe (*Podilymbus podiceps*), and Forster's tern (*Sterna forsteri*) were recorded at higher overall densities compared to diked areas, although densities also varied by site and year (M. Monfils pers. comm.) Many of the above avian species eat large amounts of invertebrates during the breeding season (Herdendorf et al. 1986, Kaminski and Prince 1981, Krull 1970)

Conclusion

The St. Clair River delta marshes are highly productive Great Lakes coastal marshes that exhibit high habitat and species diversity (Albert 2003, French III 1988, Herdendorf et al. 1986). Some notable examples of threatened and endangered species include: the king rail (*Rallus elegans*), the spotted turtle (*Clemmys guttata*), and the eastern fox snake (*Elaphe gloydi*) (personal observations). These marshes also support great numbers of avian fauna that utilize these marshes as important resting and/or breeding areas (Prince et al. 1992, Herdendorf et al. 1986, personal observations). While there is extensive literature on the feeding ecology of waterfowl (Mazak et al. 1997, Prince et al. 1992, Kaminski and Prince 1981, Swanson et al. 1979, Swanson et al. 1974), few studies have looked at the invertebrate community within diked Great Lakes coastal marshes which are managed for waterfowl production (De Szalay and Cassidy 2001, McLaughlin and Harris 1990, Herdendorf et al. 1986)

Studies have demonstrated that diking coastal marshes leads to changes in the aquatic invertebrate, fish and plant communities (Herrick and Wolf 2005, Thiet 2002, Jude and Pappas 1992, McLaughlin and Harris 1990). These studies have shown mixed results as to whether these diked marshes are beneficial or harmful. In general, dikes cutoff water fluctuations that naturally occur in coastal marshes, harbor greater number of invasive plants, and are generally nutrient enriched (Herrick and Wolf 2005, Thiet 2002, McLaughlin and Harris 1990, Herdendorf et al. 1986).

While diked marshes were more productive for the overall invertebrate community, it should not be concluded that diking coastal marshes is beneficial. In fact, diked marshes harbored more invertebrates that are typically collected in inland marshes, such as mosquitoes which were collected in 10-19% of diked replicates compared to 0-4% of undiked replicates. Additionally, there appeared to be taxa that were sensitive to diked marshes, such as the marsh treader, *Mesovelia,* which total number typically was greater in undiked marshes, and the damselfly, *Enallagma,* which uncharacteristically, of the other Odonates, did not increase in total number in diked marshes. The amphipod, *Gammarus*, was a dominant invertebrate in undiked marshes but was absent from diked marshes.

I did not find significant effects caused by vegetation zone but I did find seven taxa in diked marshes and one taxon in undiked marshes that were marginally significant between plant zones. This was not surprising due to the fact that I limited sampling to the edges of vegetation zones where marsh birds predominately feed. In other coastal marshes, plant zone and water level fluctuations are important covarying factors that structures invertebrate communities (Burton et al. 2004, 2002, Stricker et al. 2003, Merritt et al. 2002, Cardinale et al. 1998). Future studies of the invertebrate community of the St. Clair deltaic coastal marshes should focus on sampling areas that are further into vegetation zones so as to exclude edge effects if the goal is to describe differences among plant zones. I was more interested in documenting the differences in habitat use at the edge of the three plant zones, since this is where most aquatic birds concentrate their feeding, and in documenting differences between diked and undiked marshes.

Phragmites appears to be expanding its dominance of coastal wetland plant communities throughout the Great Lakes region and may potentially cause significant changes to invertebrate and vertebrate communities in other Great Lake coastal marshes. While my study results may be useful for trying to determine the effects of the *Phragmites* spread, it should be used with caution. By sampling the edge of *Phragmites* dominated marshes, I sampled areas that were potentially the newest growth in which the invertebrate community would not have had enough time to redistribute itself. Also, invertebrates from the adjacent channels were likely included in the areas that I sampled. To truly test the effects that the invasion of *Phragmites* has on marsh invertebrate communities, samples would have to be collected in mature stands and far enough into the vegetation stand to exclude edge effects.

Appendix A. List of Macroinvertebrate taxa identified from Lake St. Clair Delta Marshes (Little Muscamoot Bay, Dickinson Island, East Marsh, and West Marsh) in July 2006.

Class	**Order**	**Family**	**Taxa**		**Feeding Group**	**Habitat Group**
Annelida	Hirudinea				Predator	Sprawler
Oligochaeta		Naididae			Gatherer-collector	Burrower
		Tubificidae			Gatherer-collector	Burrower
Bivalvia		Sphaeriidae			Filterer	Clinger
		Unionidae	*Dreissena*	*polymorpha*	Filterer	Clinger
Gastropoda		Ancylidae			Scraper	Clinger
		Hyrobiidae	*Somatogyrus*		Scraper	Clinger
		Lymnaeidae	*Acella*	*haldermani*	Scraper	Clinger
			Fossaria		Scraper	Clinger
			Pseudosuccinea		Scraper	Clinger
			Stagnicola		Scraper	Clinger
		Physidae	*Aplexa*		Scraper	Clinger
			Physa		Scraper	Clinger
			Physella		Scraper	Clinger
		Planorbidae	*Gyraulus*	*crista*	Scraper	Clinger
			Menetus		Scraper	Clinger
			Planorbella	*exacuous*	Scraper	Clinger
			Promenetus		Scraper	Clinger
		Viviparidae	*Campeloma*		Scraper	Clinger
			Cipangopaludina	*japonious*	Scraper	Clinger
		Valvatidae	*Pleurocera*		Scraper	Clinger
			Valata		Scraper	Clinger
Arachnida	Hydracarina				Predator	Swimmer
	Amphipoda	Crangonycitidae	*Crangonyx*		Gatherer-collector	Swimmer
		Gammaridae	*Gammarus*		Gatherer-	Swimmer

					collector	
		Talitridae	*Hyalella*	*azteca*	Gatherer-collector	Swimmer
	Decapoda		*Crayfish*		Shredder	Burrower
		Palaemonidae	*Palaemonetes*	*kadiakensis*	Gatherer-collector	Swimmer
	Isopoda	Asellidae	*Caecidotea*		Shredder	Burrower
			Lirceus		Shredder	Burrower
Insecta	Collembola				Gatherer-collector	Clinger
	Ephemeroptera	Baetidae	*Baetis*		Gatherer-collector	Swimmer
			Procloeon		Gatherer-collector	Swimmer
			Pseudocentroptiloides		Gatherer-collector	Swimmer
		Caenidae	*Caenis*		Gatherer-collector	Sprawler
		Ephemeridae			Gatherer-collector	Burrower
	Odonata	Aeshnidae	*Aeshna*		Predator	Climber
			Boyeria		Predator	Climber
			Basiaeschna		Predator	Climber
		Coenagrionidae	*Enallagma*		Predator	Climber
			Ischnura		Predator	Climber
		Courduliidae	*Cordulia*		Predator	Sprawler
			Didymops		Predator	Sprawler
			Epitheca		Predator	Sprawler
			Neurocordulia		Predator	Sprawler
			Somatochlora		Predator	Sprawler
		Gomphidae			Predator	Burrower
		Libellulidae	*Erythemis*		Predator	Sprawler

		Ladona	Predator	Sprawler
		Libellula	Predator	Sprawler
		Macrothemis	Predator	Sprawler
		Sympetrum	Predator	Sprawler
		Tramea	Predator	Sprawler
	Lestidae		Predator	
Hemiptera	Belostomatidae	*Belostoma*	Predator	Climber
	Corixidae		Piercer	Swimmer
	Gerridae		Predator	Skater
	Hebridae		Predator	Climber
	Hydrometridae	*Hydrometra*	Predator	Skater
	Mesovelidae	*Mesovelia*	Predator	Climber
	Naucoridae		Predator	Clinger
	Nepidae	*Ranatra*	Predator	Climber
	Notonectidae		Predator	Swimmer
	Pleidae		Predator	Swimmer
	Saldidae		Predator	Climber
	Veliidae		Predator	Skater
Homoptera				
Megaloptera	Corydalidae	*Chauliodes*	Predator	Clinger
Neuroptera	Sisyridae	*Climacia*	Predator	Climber
Trichoptera	Helicopsychidae	*Helicopsyche*	Scrapper	Clinger
	Hydropsychidae	*Chematopsyche*	Filterer	Clinger
	Hydroptilidae	*Agraylea*	Piercer	Climber
		Dibusa	Scraper	
		Hydroptila	Piercer	Clinger
		Orthothrichia	Gatherer-collector	
		Oxyethira	Piercer	Climber
	Leptoceridae	*Ceraclea*	Gatherer-collector	Sprawler

		Leptocerus	Shredder	Swimmer
		Mystacides	Gatherer-collector	Sprawler
		Nectopsyche	Shredder	Climber
		Oecetis	Predator	Clinger
		Setodes	Gatherer-collector	Sprawler
		Trianodes	Shredder	Swimmer
	Limnephilidae	*Limnephilus*	Shredder	Climber
	Molannidae	*Molanna*	Scraper	Sprawler
	Phryganeidae	*Fabria*	Shredder	Climber
	Polycentropodidae	*Neuroclipsis*	Filterer	Clinger
		Polycentropus	Predator	Clinger
Lepidoptera	Arctiidae	*Estigmene*	Shredder	Burrower
	Nepticulidae		Shredder	Burrower
	Noctuidae	*Simyra*	Shredder	Burrower
	Pyralidae	*(Nymphulinae)*	Shredder	Climber
		Acentria	Shredder	Climber
		Crambus	Shredder	Climber
		Parapoynx	Shredder	Climber
		Petrophila	Shredder	Climber
	Tortricidae	*Archips*	Shredder	Burrower
Coleoptera	Carabidae		Predator	Clinger
	Chrysomelidae		Shredder	Clinger
	Curculionidae		Shredder	Clinger
	Dytiscidae	*Agabetes*	Predator	Swimmer
		Agabus	Predator	Swimmer
		Celina	Predator	Swimmer
		Cybister	Predator	Swimmer
		Desmopachria	Predator	Swimmer
		Hydroporus	Predator	Swimmer

		Hydrovatus	Predator	Swimmer
		Hygrotus	Predator	Swimmer
		Illybius	Predator	Swimmer
		Laccophilus	Predator	Swimmer
		Laccornis	Predator	Swimmer
		Matus	Predator	Swimmer
	Gyrinidae	*Dineutus*	Predator	Swimmer
		Gyrinus	Predator	Swimmer
	Haliplidae	*Haliplus*	Piercer	Swimmer
		Peltodytes	Piercer	Swimmer
	Hydraenidae		Scrapper	Cinger
	Hydrochidae	*Hydrochus*	Shredder	
	Hydrophilidae	*Berosus*	Piercer	Swimmer
		Enochrus	Gatherer-collector	Burrower
		Hydrophilus	Predator	
		Laccobius	Piercer	
		Tropisternus	Predator	Climber
	Lampyridae			
	Lutrochidae	*Lutrochus*		Clinger
	Noteridae	*Hydrocanthus*	Predator	Climber
	Scirtidae	*Cyphon*	Scrapper	Climber
	Staphylinidae		Predator	Clinger
Diptera	Ceratopogonidae		Predator	Sprawler
	Chaoboridae		Predator	
	Chironomidae	*pupae*	Gatherer-collector	Swimmer
		Chironomini	Gatherer-collector	Burrower
		Orthocladinae	Gatherer-collector	Clinger
		Tanypodinae	Predator	Sprawler

	Tanytarsini	Filterer	Clinger
Culicidae		Filterer	Swimmer
Dixidae		Gatherer-collector	Swimmer
Ephydridae		Gatherer-collector	
Sciomyzidae		Predator	Burrower
Stratiomyidae		Gatherer-collector	Sprawler
Tabanidae	*Tabanus*	Predator	Sprawler
Tipulidae		Shredder	Burrower

Appendix B. List of Taxa found in Diked and Undiked Marshes from the Three Plant Zones. (X) Denotes Taxa Present and (*) is for taxa used for statistical comparisons.

				Diked			Undiked		
				Schoenoplectus	Typha	Phragmites	Schoenoplectus	Typha	Phragmites
Order	**Family**	**Taxa**							
Hirudinea*				X	X	X	X	X	X
	Naididae*			X	X	X	X	x	X
	Tubificidae*			X	X	X	X	X	X
	Sphaeriidae*			X	X	X	X	X	X
	Unionidae	*Dreissena*	*polymorpha*						X
Gastropoda*	Ancylidae*			X	X	X	X	X	X
	Hyrobiidae	*Somatogyrus*				X			
	Lymnaeidae	*Acella*	*haldermani*				X	X	X
		Fossaria							X
		Pseudosuccinea		X	X	X		X	X
		*Stagnicola**		X	X	X	X	X	X
	Physidae	*Aplexa*		X	X				
		*Physa**		X	X	X	X	X	X
		Physella			X				
	Planorbidae	*Gyraulus**		X	X	X	X	X	X
		Gyraulus	*crista**	X	X	X			
		Menetus		X	X	X	X		
		*Planorbella**		X	X	X	X	X	X
		Promenetus	*exacuous*	X	X	X	X	X	
	Viviparidae*	*Campeloma*		X					
		Cipangopaludina	*japonious*			X			

	Valvatidae	*Pleurocera*						X	
		Valata		X			X		
Hydracarina*				X	X	X	X	X	X
Amphipoda	Crangonycitidae	*Crangonyx**		X	X	X	X	X	X
	Gammaridae	*Gammarus*					X	X	X
	Talitridae	*Hyalella**		X	X	X	X	X	X
Appendix B Cont.									
Decapoda		*Crayfish**		X	X	X		X	X
	Palaemonidae	*Palaemonetes*	*kadiakensis**	X	X	X	X	X	X
Isopoda	Asellidae	*Caecidotea**		X	X	X	X	X	X
		*Lirceus**		X	X	X	X	X	X
Collebola					X	X	X	X	X
Ephemeroptera	Baetidae	*Baetis*						X	
		Procloeon							X
		Pseudocentroptiloides		X	X			X	
	Caenidae	*Caenis**		X	X	X	X	X	X
	Ephemeridae						X		
Odonata*	Aeshnidae	*Aeshna*		X	X	X	X		
		Boyeria		X	X		X	X	X
		Basiaeschna			X				
	Coenagrionidae	*Enallagma**		X	X	X	X	X	X
		*Ischnura**		X	X	X	X	X	X
		*Imm**		X	X	X	X	X	X
	Courduliidae	*Cordulia*				X			
		Imm		X	X	X			
		Didymops		X					
		Epitheca				X			
		Neurocordulia			X	X			
		Somatochlora				X	X		
	Gomphidae								X

	Libellulidae	*Imm**	X	X	X		X	X
		Erythemis		X				
		Ladona		X				
		Libellula	X	X	X			X
		Macrothemis	X					
		Sympetrum	X	X	X	X	X	
		Tramea	X	X	X			X
	Lestidae			X				
Hemiptera*	Belostomatidae	*Belostoma**	X	X	X	X	X	X
	Corixidae*		X	X	X	X	X	X
	Gerridae		X	X	X	X	X	X
	Hebridae		X				X	X
	Hydrometridae	*Hydrometra*						X
	Mesovelidae	*Mesovelia**	X	X	X	X	X	X
	Naucoridae		X		X	X	X	
	Nepidae	*Ranatra**	X	X	X	X	X	X
	Notonectidae*		X	X	X	X	X	X
	Pleidae*		X	X	X	X	X	X
	Saldidae					X		X
	Veliidae*		X	X	X	X	X	X
Homoptera			X		X	X	X	X
Megaloptera	Corydalidae	*Chauliodes**	X	X	X	X	X	X
Neuroptera	Sisyridae	*Climacia**	X	X	X		X	
Trichoptera*	Helicopsychidae	*Helicopsyche*					X	
	Hydropsychidae	*Chematopsyche*				X		
	Hydroptilidae	*Agraylea*	X	X	X	X	X	X
		Dibusa	X					
		Hydroptila					X	X
		Orthothrichia	X		X			
		*Oxyethira**	X	X	X	X	X	X
	Leptoceridae	*Ceraclea**	X	X	X	X	X	X

		Leptocerus	X	X	X	X		
		Mystacides		X		X	X	X
		Nectopsyche					X	X
		Oecetis				X	X	
		*Setodes**	X	X	X	X		X
		Trianodes	X			X		X
	Limnephilidae	*Limnephilus*		X		X	X	X
	Molannidae	*Molanna*				X	X	
	Phryganeidae	*Fabria*		X	X			X
	Polycentropodidae	*Neuroclipsis*				X		
		*Polycentropus**	X	X	X	X	X	X
Lepidoptera*	Arctiidae	*Estigmene*				X		
	Nepticulidae			X		X		
	Noctuidae	*Simyra*		X				X
	Pyralidae	*(Nymphulinae)*						X
		*Acentria**	X	X	X	X	X	X
		Crambus	X	X	X	X		
		*Parapoynx**	X	X	X	X	X	X
		Petrophila		X				
	Tortricidae	*Archips*		X			X	
Coleoptera*	Carabidae							X
	Chrysomelidae				X			
	Curculionidae			X		X	X	X
	Dytiscidae*	*Agabetes*			X	X		X
		Agabus		X				
		Celina	X	X	X			
		Cybister		X				
		Desmopachria		X	X	X		X
		Hydroporus	X	X	X	X	X	
		*Hydrovatus**	X	X	X	X	X	X
		Hygrotus	X	X	X			

		Illybius		X	X			X
		Laccophilus		X				
		Laccornis			X			
		*Matus**	X	X	X			X
	Gerinidae	*Dineutus*	X	X	X			X
		Gyrinus	X	X	X	X		X
	Haliplidae	*Haliplus*	X	X	X			
		Peltodytes		X	X			
	Hydraenidae		X	X	X			X
	Hydrochidae	*Hydrochus*	X					
	Hydrophilidae	*Berosus*		X	X		X	X
		Enochrus						X
		Hydrophilus	X	X				
		Laccobius		X			X	
		*Tropisternus**	X	X	X		X	X
	Lampyridae			X			X	
	Lutrochidae	*Lutrochus*						X
	Noteridae	*Hydrocanthus**	X	X	X	X	X	X
	Scirtidae	*Cyphon*		X				
	Staphylinidae			X	X		X	X
Diptera*	Ceratopogonidae*		X	X	X	X	X	X
	Chaoboridae		X					
	Chironomidae	*pupae*	X	X	X	X	X	X
		*Chironomini**	X	X	X	X	X	X
		*Orthocladinae**	X	X	X	X	X	X
		*Tanypodinae**	X	X	X	X	X	X
		*Tanytarsini**	X	X	X	X	X	X
	Culicidae		X	X	X		X	
	Dixidae				X		X	X
	Ephydridae		X	X				
	Sciomyzidae		X	X	X			X

Stratiomyidae*		X	X	X	X	X	X
Tabanidae	*Tabanus*				X		
Tipulidae*		X	X	X	X	X	X

Appendix C. Mean (±Standard Error) Water Chemistry for Diked and Undiked Marshes in *Schoenoplectus, Typha* and *Phragmites.*

Wetland Type		Diked			Undiked	
Plant Zone	*Schoenoplectus*	*Typha*	*Phragmites*	*Schoenoplectus*	*Typha*	*Phragmites*
N	12	29	15	29		18
Depth (cm)	36.38 ±6.99	29.71 ±4.00	38.50 ±5.94	39.10 ±3.86	41.73 ±7.56	30.69 ±3.61
Temperature (°C)	25.45 ±1.10	25.63 ±0.82	25.25 ±1.13	24.46 ±0.73	24.50 ±0.65	24.85 ±1.12
pH	7.38 ±0.26	7.41 ±0.12	7.33 ±0.26	7.95 ±0.14	8.10 ±0.17	7.73 ±0.25
Dissolved Oxygen (mg/L)	4.63 ±1.18	3.85 ±0.86	3.97 ±1.00	6.25 ±0.46	6.40 ±0.64	5.32 ±0.61
Salinity (PPT)	0.10 ±0.03	0.06 ±0.02	0.09 ±0.03	0.03 ±0.01	0.06 ±0.02	0.05 ±0.02
Turbidity (NTU)	7.88 ±4.36	20.12 ±7.92	7.13 ±3.93	4.92 ±1.45	6.99 ±2.33	5.30 ±1.27

Specific Conductivity (SpC) (mS/L)	0.20 ±0.06	0.11 ±0.04	0.18 ±0.06	0.05 ±0.02	0.12 ±0.04	0.10 ±0.04
Alkalinity (mg/L)	175.00 ±9.44	190.00 ±9.58	178.00 ±12.36	119.23 ±3.31	112.00 ±4.78	118.75 ±5.14

Appendix D. Mean Hemiptera Shannon's Diversity (*H'*), Taxa Richness, Evenness (*J'*) for Diked and Undiked Marshes, from *Schoenoplectus, Typha,* and *Phragmites* Zones.

Marsh Type	**Vegetation Zone**	**Diversity (*H'*)**	**Richness**	**Evenness (*J'*)**
Undiked		0.60±0.03	5.97±0.36	0.81±0.02
	Schoenoplectus	0.57±0.04	5.4±0.65	0.81±0.03
	Typha	0.60±0.07	6.33±0.69	0.77±0.04
	Phragmites	0.65±0.04	6.20±0.55	0.84±0.02
Dike		0.51±0.03	5.56±0.39	0.72±0.04
	Schoenoplectus	0.50±0.06	6.29±0.84	0.66±0.08
	Typha	0.56±0.05	5.11±0.45	0.83±0.05
	Phragmites	0.46±0.06	5.44±0.75	0.66±0.05

Appendix E. Mean Odonata Shannon's Diversity (*H'*), Taxa Richness, and Evenness (*J'*) for Diked and Undiked from *Schoenoplectus, Typha,* and *Phragmites* Zones.

Marsh Type	Vegetation Zone	Diversity (*H'*)	Richness	Evenness (*J'*)
Undiked		0.27±0.04	2.31±0.24	0.62±0.07
	Schoenoplectus	0.29±0.06	2.60±0.48	0.67±0.12
	Typha	0.26±0.07	2.11±0.42	0.61±0.15
	Phragmites	0.26±0.06	2.20±0.39	0.57±0.13
Diked		0.57±0.04	6.28±0.47	0.76±0.02
	Schoenoplectus	0.52±0.06	5.71±0.84	0.73±0.05
	Typha	0.64±0.06	6.78±0.72	0.81±0.03
	Phragmites	0.55±0.06	6.22±0.92	0.74±0.05

Appendix F. Mean Trichoptera Shannon's Diversity (*H'*), Taxa Richness, Evenness (*J'*) for Diked and Undiked Marshes from *Schoenoplectus, Typha*, and *Phragmites* Zones.

Marsh Type	Vegetation Zone	Diversity (*H'*)	Richness	Evenness (*J'*)
Undiked		0.34±0.04	3.17±0.41	0.61±0.07
	Schoenoplectus	0.31±0.08	3.70±0.91	0.55±0.09
	Typha	0.31±0.10	2.44±0.82	0.57±0.19
	Phragmites	0.38±0.06	3.30±0.60	0.72±0.09
Diked		0.46±0.03	4.28±0.34	0.77±0.04
	Schoenoplectus	0.48±0.06	4.57±0.72	0.77±0.06
	Typha	0.41±0.06	3.56±0.58	0.76±0.10
	Phragmites	0.50±0.05	4.78±0.49	0.77±0.05

Appendix G. Mean Lepidoptera Shannon's Diversity (*H'*), Taxa Richness, Evenness (*J'*) for Diked and Undiked Marshes from *Schoenoplectus, Typha,* and *Phragmites* Zones.

Marsh Type	Vegetation Zone	Diversity (*H'*)	Richness	Evenness (*J'*)
Undiked		0.03±0.02	0.59±0.13	0.10±0.06
	Schoenoplectus	0.03±0.03	0.50±0.22	0.10±0.10
	Typha	0.03±0.03	0.67±0.24	0.11±0.11
	Phragmites	0.03±0.03	0.60±0.22	0.09±0.09
Diked		0.18±0.03	1.84±0.19	0.46±0.08
	Schoenoplectus	0.23±0.06	1.86±0.40	0.63±0.17
	Typha	0.15±0.05	1.89±0.35	0.39±0.13
	Phragmites	0.17±0.05	1.78±0.28	0.39±0.14

Appendix H. Mean Coleoptera Shannon's Diversity (*H'*), Taxa Richness, Evenness (*J'*) for Diked and Undiked Marshes from *Schoenoplectus, Typha,* and *Phragmites* Zones.

Marsh Type	Vegetation Zone	Diversity (*H'*)	Richness	Evenness (*J'*)
Undiked		0.37±0.04	3.10±0.32	0.67±0.07
	Schoenoplectus	0.31±0.07	2.70±0.45	0.66±0.12
	Typha	0.29±0.10	2.33±0.62	0.52±0.16
	Phragmites	0.51±0.05	4.20±0.44	0.83±0.04
Diked		0.57±0.07	6.48±0.91	0.70±0.06
	Schoenoplectus	0.23±0.12	3.14±1.14	0.32±0.14
	Typha	0.71±0.10	8.56±2.03	0.86±0.02
	Phragmites	0.71±0.06	7.00±0.67	0.84±0.04

Appendix I. Mean Gastropoda Shannon's Diversity (*H'*), Taxa Richness, and Evenness (*J'*) for Diked and Undiked Marsh from *Schoenoplectus, Typha,* and *Phragmites* Zones.

Marsh Type	Vegetation Zone	Diversity (*H'*)	Richness	Evenness (*J'*)
Undiked		0.52±0.03	5.10±0.36	0.75±0.03
	Schoenoplectus	0.56±0.03	5.80±0.55	0.78±0.04
	Typha	0.45±0.08	4.22±0.74	0.69±0.09
	Phragmites	0.54±0.04	5.20±0.51	0.77±0.02
Diked		0.61±0.03	7.28±0.38	0.72±0.02
	Schoenoplectus	0.66±0.06	7.57±0.92	0.77±0.05
	Typha	0.56±0.05	6.89±0.63	0.68±0.05
	Phragmites	0.63±0.03	7.44±0.50	0.73±0.02

Literature Cited

Albert, D. A. 2003. Between land and lake: Michigan's Great Lakes coastal wetlands. Michigan Natural Features Inventory, Michigan State University Extension, East Lansing, Mich.: Extension Bulletin E-2902. 96p.

Albert, D. A. 2001. Natural community abstract for Great Lakes marsh. Michigan Natural Features Inventory. Lansing, MI. 11 pp.

Angradi, T.R., S.M. Hagan, and K.W. Able. 2001. Vegetation type and the intertidal macroinvertebrate fauna of a brackish marsh: *Phragmities* vs. *Spartina. Wetlands.* 21: 75-92.

Anteau, M. J. and A. D. Afton. 2008. Amphipod densities and indices of water quality across the Midwest, USA. *Wetlands.* 28(1):184-196.

Barton D. R. 1986. Nearshore benthic invertebrates of the Ontario waters of Lake Ontario. *J. Great Lakes Res.* 12(4):270-280.

Barton D. R. and M. Griffiths. 1984. Benthic invertebrates of the nearshore zone of Eastern Lake Huron, Georgian Bay, and North Channel. *J. Great Lakes Res.* 10(4): 407-416.

Bedford, K.W. 1992. The physical effects of the Great Lakes on tributaries and wetlands. *J. Great Lakes Res.* 18(4):571-589.

Bricker, K.S., F. J. Bricker and J. E. Gannon. 1976. Distribution and abundance of zooplankton in the U. S. waters of Lake St. Clair, 1973. *J. Great Lakes Res.* 2(2): 256-271.

Burch, J.B. 1982. North American freshwater snails: Identification keys, generic synonymy, supplemental notes, glossary, references, index. *Walkerana.* 1(4):217-365.

Burch, J.B. and J.L. Tottenham. 1980. North American freshwater snails: Species list, ranges, and illustrations. *Walkerana.* 1(3):81-215.

Burdick, D.M. and R.A. Konisky. 2003. Determinants of the expansion for *Phragmites australis*, common reed, in natural and impacted coastal marshes. *Estuaries.* 26(2B):407-416.

Burton, T.M., C.A. Stricker, and D.G. Uzarski. 2002. Effects of plant community composition and exposure to wave action on invertebrate habitat use of Lake Huron coastal wetlands. *Lakes & Reservoirs: Research and Management.* 7:255-269.

Burton, T.M., D.G. Uzarski, and J.A. Genet. 2004. Invertebrate habitat use in relation to fetch and plant zonation in northern Lake Huron coastal wetlands. *Aquatic Ecosystem Health & Management.* 7(2):249-267.

Burton, T.M., D.G. Uzarski, J.P. Gathman, J.A. Genet, B.E. Keas, and C.A. Stricker. 1999. Development of a preliminary invertebrate index of biotic integrity for Lake Huron coastal wetlands. *Wetlands.* 19(4): 869-882.

Cardinale, B.J., V.J. Brady, and T.M. Burton. 1998. Changes in the abundance and diversity of coastal wetlands fauna from the open water/ macrophyte edge towards shore. *Wetlands Ecology and Management.* 6:59-68.

Chadde, S. W. 2002. A Great Lakes Wetland Flora: A complete guide to the aquatic and wetland plants of the upper Midwest. 2nd Ed. PocketFlora Press. Laurium, MI.

Ciborowski, J. J. H. and L. D. Corkum. 1988. Organic contaminants in adult aquatic insects of the St. Clair and Detroit Rivers, Ontario, Canada. *J. Great Lakes Res.* 14(2): 148-156.

Clifford, H.F. 1991. Aquatic Invertebrates of Alberta. University of Alberta. Edmonton, Alberta.

Davis, B. M., P. L. Hudson and B. J. Armitage. 1991. Distribution and abundance of caddisflies (Trichoptera) in the St. Clair-Detroit River system. *J. Great Lakes Res.* 17(4): 522-535.

Derecki, J. A. 1985. Effect of channel changes in the St. Clair River during the present century. *J. Great Lakes Res.* 11(3): 201-207.

De Szalay, F.A. and W. Cassidy. Effects of muskrat (*Ondatra zibethicus*) lodge construction on invertebrate communities in a Great Lakes coastal wetland. *Am. Midl. Nat.* 146:300-310.

Edsall, T. A., R. C. Haas, and J. V. Adams. 2001. Annual production of burrowing mayfly nymphs (*Hexagenia* spp.) in U.S. waters of Lake St. Clair. *J. Great Lakes Res.* 27(4): 449-456.

Edsall, T.A., B.A. Manny, and C.N. Raphael. 1988. The St. Clair River and Lake St. Clair, Michigan: an ecological profile. U.S. Fish and Wildlife Service, Biological Report 85(7.3).

Fell, P.E., R.S. Warren, J.K. Light, R.L. Rawson, Jr., and S.M. Fairley. 2003. Comparison of fish and macroinvertebrate use of *Typha angustifolia*, *Phragmites australis*, and treated *Phragmites* marshes along the lower Connecticut River. *Estuaries.* 26(2B):534-551.

French III, J. R. Effect of submersed aquatic macrophytes on resource partitioning in yearling rock bass (*Ambloplites rupestris*) and pumpkinseeds (*Lepomis gibbosus*) in Lake St. Clair. *J. Great Lakes Res.* 14(3): 291-300.

Gathman, J.P., T.M. Burton, and B.H. Armitage. 1999. Coastal wetlands of the upper Great Lakes: distribution of invertebrate communities in response to environmental variation. p. 949-94. *In* D.P. Batzer, R.B. Rader, and S.A. Wissinger (eds.) Invertebrates in Freshwater Wetlands of North America. John Wiley & Sons, Inc, New York, NY, USA.

Grothues, T.M., and K.W. Able. 2003. Response of juvenile fish assemblages in tidal salt marsh creeks treated for *Phragmites* removal. *Estuaries.* 26(2B):563-573.

Havens, K.J., H. Berquist, and W. I. Priest, III. 2003. Common reed grass, *Phragmites australis*, expansion into constructed wetlands: Are we mortgaging our wetland future? *Estuaries*. 26(2B):417-422.

Herdendorf, C.E., C. N. Raphael, and E. Jaworski. 1986. The ecology of Lake St. Clair wetlands: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.7). 187p.

Herdendorf, C.E. 1987. The ecology of the coastal marshes of western Lake Erie: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.9). 171p.

Herrick, B.M., and A.T. Wolf. 2005. Invasive plant species in diked vs. undiked Great Lakes wetlands. *J. Great Lakes Res.* 31:277-287.

Jivoff, P.R. and K.W. Able. Blue crab, *Callinectes sapidus*, response to the invasive common reed, *Phragmites australis*: abundance, size, sex ratio, and molting frequency. *Estuaries*. 26(2B):587-595.

Jude, D.J. and J. Pappas. 1992. Fish utilization of Great Lakes coastal wetlands. *J. Great Lakes Res.* 18(4):651-672.

Kaminski, R.M. and H. H. Prince. 1981. Dabbling duck activity and foraging response to aquatic macroinvertebrates. *The Auk.* 98(1): 115-126.

Krieger, K.A. 1992. The ecology of invertebrates in Great Lakes coastal wetlands: current knowledge and research needs. *J. Great Lakes Res.* 18(4):634-650.

Krull, J. N. 1970. Aquatic plant-macroinvertebrate associations and waterfowl. *J. Wildlife Management.* 34(4): 707-718.

Kulesza, A.E., J.R. Holomuzki, and D.M. Klarer. 2008. Benthic community structure in stands of *Typha angustifolia,* and herbicide-treated and untreated *Phragmites australis. Wetlands.* 28(1): 40-56.

Kulesza, A.E. and J.R. Holomuzki. 2006. Amphipod performance responses to decaying leaf litter of *Phragmites australis* and *Typha angustifolia* from a Lake Erie coastal marsh. *Wetlands.* 26(4):1079-1088.

Leach, J.H. 1980. Limnological sampling intensity in Lake St. Clair in relation to distribution of water masses. *J. Great Lakes Res.* 6(2): 141-145.

MacKenzie, R.A., J.L. Kaster, and J.V. Klump. 2004. The ecological patterns of benthic invertebrates in a Great Lakes coastal wetland. *J. Great Lakes Res.* 30(1):58-69.

Mazak, E. J., H. J. MacIsaac, M. R. Servos, and R. Hesslein. 1997. Influence of feeding habits on organochlorine contaminant accumulation in waterfowl of the Great Lakes. *Ecological Applications.* 7(4): 1133-1143.

McCullough, G.B. 1985. Wetland threats and losses in Lake St. Clair. *Coastal Wetlands.* Proc. First Great Lakes Coastal Wetlands Coll. Nov. 5-7, 1984. East Lansing, MI. Prince, H.H. and F. M. D'Itri, ed. Pp. 201-208.

McLaughlin, D.B. and H.J. Harris. 1990. Aquatic insect emergence in two Great Lakes marshes. *Wetlands Ecology and Management.* 1(2):111-121.

Merritt, R. W. M. E. Benbow and P. L. Hudson. 2002. Wetland macroinvertebrates of Prentiss Bay, Lake Huron, Michigan: diversity and functional group composition. *The Great Lakes Entomologist.* 35(2): 149-160.

Merritt, R.W. and K.W. Cummins. (eds). 1996. An introduction to the aquatic insects of North America, 3rd ed. Dubuque, IA: Kendall/Hunt Publishing Co.

Mitch, W.J. and J.G. Gosselink. 2000. Wetlands, third edition. John Wiley& Sons, Inc., New York, NY, USA.

Nalepa, T. F. and J. M. Gauvin. 1988. Distribution, abundance, and biomass of freshwater mussels (Bivalvia: Unionidae) in Lake St. Clair. *J. Great Lakes Res.* 14(4): 411-419.

Parsons, K.C. 2003. Reproductive success of wading birds using *Phragmites* marsh and upland nesting habitats. *Estuaries.* 26(2B): 596-601.

Peckarsky, B.L., P.R. Fraissinet, M.A. Penton, and D.J. Conklin, Jr. 1990. Freshwater Marcoinvertebrates of Northeastern North America. Comstock Publishing Associates. Cornell University Press. Ithaca, NY.

Prince, H.H., P.I. Padding, and R.W. Knapton. 1992. Waterfowl use of the Laurentian Great Lakes. *J. Great Lakes Res.* 18(4):673-699.

Quinn, F. H. 1985. Temporal effects of St. Clair River dredging on Lakes St. Clair and Erie water levels and connecting channel flow. *J. Great Lakes Res.* 11(3):400-403.

Quinn, F. H. 1980. Note: Wind stress effects on Detroit River discharges. *J. Great Lakes Res.* 6(2): 172-175.

Raichel, D.L., K.W. Able, and J.M. Hartman. 2003. The influence of *Phragmites* (common reed) on the distribution, abundance, and potential prey of a resident marsh fish in the Hackensack Meadowlands, New Jersey. *Estuaries.* 26(2B):511-521.

Rooth, J.E., J.C. Stevenson, and J.C. Cornwell. 2003. Increased sediment accretion rates following invasion by *Phragmites australis*: the role of litter. *Estuaries.* 26(2B):475-483.

Ruiz, G.M., P. Fofonoff, A.H. Hines, and E.D. Grosholz. 1999. Non-indigenous species as stressors in estuarine and marine communities: Assessing invasion impacts and interactions. *Limnol. Oceanogr.* 44(3, part 2):950-972.

Saltonstall, K., P.M. Peterson, and R.J. Soreng. 2004. Recognition of *Phragmites australis subsp. Americanus (Poaceae: Arundinoideae)* in North America: evidence from morphological and genetic analysis. *SIDA.* 21(2):683-692.

SAS Institute Inc. 2006. Version 9.1. Cary, NC, USA.

Schloesser, D.W. 1988. Zonation of mayfly nymphs and caddisfly larvae in the St. Marys River. *J. Great Lakes Res.* 14(2): 227-233.

State Of the Lakes Ecosystem Conference (SOLEC). 2004. Environment Canada and U.S. Environmental Protection Agency. ISBN 0-662-42425-5. EPA 905-R-06-001.

Stricker, C.A. 2003. The influence of water level fluctuations on water chemistry and invertebrate community composition in a Great Lakes coastal wetland. Dissertation, Michigan State University. 160p.

Stricker, C.A., T.M. Burton, V.J. Brady, B.J. Cardinale, and J.P. Gathman. 2001. Invertebrate communities of Great Lakes' coastal wetlands, Saginaw Bay, Lake Huron. *Verh. Internat. Verein. Limnol.* 27:3440-3443.

Swanson, G.A., G. L. Krapu, and J. R. Serie. 1979. Foods of laying female dabbling ducks on the breeding grounds. *Waterfowl and Wetlands: An Integrated Review.* Proc. 1977 Symp., Madison, WI, NC Sect., The Wildlife Society, T.A. Brookhout, ed. Pp 47-55.

Swanson, G.A., M. I. Meyer, and J. R. Serie. 1974. Feeding ecology of breeding blue-winged teals. *J. Wildlife Management.* 38(3): 396-407.

Tsanis, I. K., H. Shen, and S. Venkatesh. 1996. Water currents in the St. Clair and Detroit Rivers. *J. Great Lakes Res.* 22(2): 213-223.

Thiet, R.K. 2002. Diversity comparisons between diked and undiked coastal freshwater marshes on Lake Erie during a high-water year. *J. Great Lakes Res.* 28(2):285-298.

Thomas, R. L. M. D. Christensen, E. Szalinska and M. Scarlat. 2006. Formation of the St. Clair River delta in the Laurentian Great Lakes system. *J. Great Lakes Res.* 32: 738-748.

Thornley, S. 1985. Macrozoobenthos of the Detroit and St. Clair Rivers with comparisons to neighbouring waters. *J. Great Lakes Res.* 11(3): 290-296.

Thorp, J.H. and A.P. Covich. 1991. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc. San Diego, Ca.

Uzarski, D.G., T.M. Burton, and J.A. Genet. 2004. Validation and performance of an invertebrate index of biotic integrity for Lakes Huron and Michigan fringing wetlands during a period of lake level decline. *Aquatic Ecosystem Health and Management.* 7(2): 269-288.

Wainright, S.C., M.P. Weinstein, K.W. Able, and C.A. Currin. 2000. Relative importance of benthic microalgae, phytoplankton and the dentritus of smooth cordgrass *Spartina alterniflora* and the common reed *Phragmites australis* to brackish-marsh food webs. *Mar. Ecol. Prog. Ser.* 200:77-91.

Weinstein, M.P. and J.H. Balletto. 1999. Does the common reed, *Phragmites australis*, affect essential fish habitat? *Estuaries*. 22(3B):793-802.

Weinstein, M.P., J.R. Keough, G.R. Guntenspergen, and S.Y. Litvin. 2003. Preface. *Phragmites australis:* A sheep in wolfs clothing? *Estuaries*. 26(2B):397.

Wiggins, G.B. 1977. Larvae of the North American Caddisfly Genera (Trichoptera). University of Toronto Press. Toronto, Canada.

Wilcox, K.L., S.A. Petrie, L.A. Maynard, and S.W. Meyer. 2003. Historical distribution and abundance of *Phragmites australis* at Long Point, Lake Erie, Ontario. *J. Great Lakes Res.* 29(4):664-680.

Windham, L. and R.G. Lathrop, Jr. 1999. Effects of *Phragmites australis* (common reed) invasion on aboveground biomass and soil properties in brackish tidal marsh of the Mullica river, New Jersey. *Estuaries*. 22(4):927-935.

Windham, L., J.S. Weis, and P. Weis. 2001. Patterns and processes of mercury release from leaves of two dominant salt marsh macrophytes, *Phragmites australis* and *Spartina alterniflora. Estuaries*. 24(6A):787-795.

Zanatta, D. T., G. L. Mackie, J. L. Metcalf-Smith, and D. A. Woolnough. 2002. Note: A refuge for native freshwater mussels (Bivalvia: Unionidae) from impacts of the exotic zebra mussel (Dressena polymorpha). *J. Great Lakes Res*. 28(3): 479-489.

Zar, J.H. 1999. Biostatistical Analysis. 4th Edition. Prentice-Hall, Englewood Cliff, New Jersey.