THE INVERTEBRATES OF A GREAT LAKES COASTAL MARSH

By

Valerie J. Brady

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ABSTRACT

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The community structure of the invertebrates inhabiting an emergent coastal marsh in Saginaw Bay, Lake Huron, near Quanicassee, Michigan, was determined from vegetation, sediment, and aquatic dip net collected samples during 1989 and 1990. Fifty-four species of insects were collected in the vegetation community, while 16 species were found in the sediment. The macroinvertebrate community was numerically dominated by Chironomidae, _Caenis_ (Ephemeroptera: Caenidae), and Oligochaeta. Vegetation-associated macroinvertebrates reached 50,000 individuals$\cdot m^{-2}$ and 1.5 $g \cdot m^{-2}$ on December 13, 1990. Sediment macroinvertebrates reached 48,900$\cdot m^{-2}$ on July 13, 1990, and the community had a biomass of 2.3 $g \cdot m^{-2}$ on July 13, 1989. Twenty-nine species of Cladocera were present in the vegetation, and 22 species in the marsh sediment. Cladoceran abundance was generally dominated by _Chydorus sphaericus_ (O.F. Muller), while _Sida crystallina_ (O.F. Muller) dominated the biomass in the vegetation community. Ostracoda dominated the sediment zooplankton community. Vegetation zooplankton reached 250,000 individuals$\cdot m^{-3}$ and 15.1 $g \cdot m^{-3}$, while sediment zooplankton reached 356,700$\cdot m^{-3}$ and 5 $g \cdot m^{-3}$.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES - Continued

LIST OF FIGURES

INTRODUCTION

Background

Invertebrates of Great Lakes coastal wetland areas have received limited attention, especially in recent years. Most studies of the invertebrate communities were conducted many years ago (e.g. Judd 1953, Krecker 1939; summary in Tilton and Schwegler 1978), when pollution and other environmental conditions in the Great Lakes wetlands may have been very different than they are at present.

The most abundant zooplankton species in Great Lakes coastal wetlands are usually quite different from the most abundant pelagic forms (Krieger and Klarer 1991). This may also be true for other invertebrate groups. Invertebrates provide an important source of food to many fish species, including young piscivores. The Great Lakes contain about 200 species of fish; 90% of these species are directly dependent on wetlands during some part of their life, while virtually all Great Lakes fish are indirectly dependent on wetlands (Whillans 1990). Many of these species feed on the macroinvertebrates or zooplankton in the wetlands. For some, such as the yellow perch (*Perca flavescens* Mitchill), the amount of macroinvertebrate food available affects their ability to grow large enough to become piscivores (e.g. Persson 1987). Thus, knowledge of the invertebrate community structure is of great potential benefit to fishery managers.

Invertebrate community structure in coastal marshes may also provide a sensitive index to pollution inputs, since many such marshes occur near river mouths where pollution inputs are great. Several pollution indices rely on knowledge of invertebrates, for example, the Ohio Index of Biotic Integrity (Ohio EPA 1988). Before such indices can be developed, however, one must know what species may have existed in an area in the past, and what species could survive in that area if it were unimpacted.

Comparisons of coastal marsh invertebrate communities based on existing studies are difficult since many different sampling techniques were used, and only part of the community was sampled in these earlier studies. Zooplankton (Krieger and Klarer 1991) and emerging insects (Judd 1953, McLaughlin and Harris 1990) have been studied, but only Duffy and Batterson (1987) sampled meio and macro-invertebrates simultaneously in vegetation, sediment, and water column habitats of a Great Lakes coastal marsh.

Objectives

Thus, there is an obvious need for quantitative studies of coastal marshes in the Great Lakes area, and the main objective of this study was to provide such data for a coastal marsh in Saginaw Bay, Michigan. Specific objectives included the following:

1. Identify the invertebrates typical of a coastal emergent marsh community.

2. Determine the relative abundances of the major invertebrate taxa in the community.

3. Determine the seasonal trends of the major invertebrates in these wetlands.

4. Compare the invertebrate community structure of different habitats in the wetland, including water column, vegetation, and sediment associated fauna.

To accomplish the above objectives, vegetation-water column, sediment core-water column, and aquatic dip net samples were taken during 1989 and 1990 in an emergent marsh along the southeastern shore of Saginaw Bay, Lake Huron, near Quanicassee, Michigan.

STUDY AREA

Location

The study sites were located in a *Scirpus americanus* Pers. marsh along the southeastern shore of Saginaw Bay, Lake Huron, Michigan. Saginaw Bay is 82 km long and 42 km wide. The study site was part of a wetland complex that extends along the southeastern shore of the inner section of Saginaw Bay from approximately the mouth of the Quanicassee River (Tuscola County) to the Sand Point/Wildfowl Bay area (Huron County) of the thumb of Michigan. This is a coastal, or lacustrine, wetland, with no physical separation between the wetland and the waters of Saginaw Bay. The emergent vegetation extends 500 to 750 m offshore in most areas (Herdendorf et al. 1981).

The study sites were located near the town of Quanicassee, Tuscola County, Michigan. The 1989 site was located directly off Bradford Road, while the 1990 site was located near Vanderbilt Park (Figure 1). The 1989 site was chosen for its large area of emergent vegetation and its accessibility. The 1990 site was chosen to be as close as possible to the 1989 site, but with greater water depth. These sites were within about one half kilometer of each other (T. 14 N., R. 7 E., Section 21).

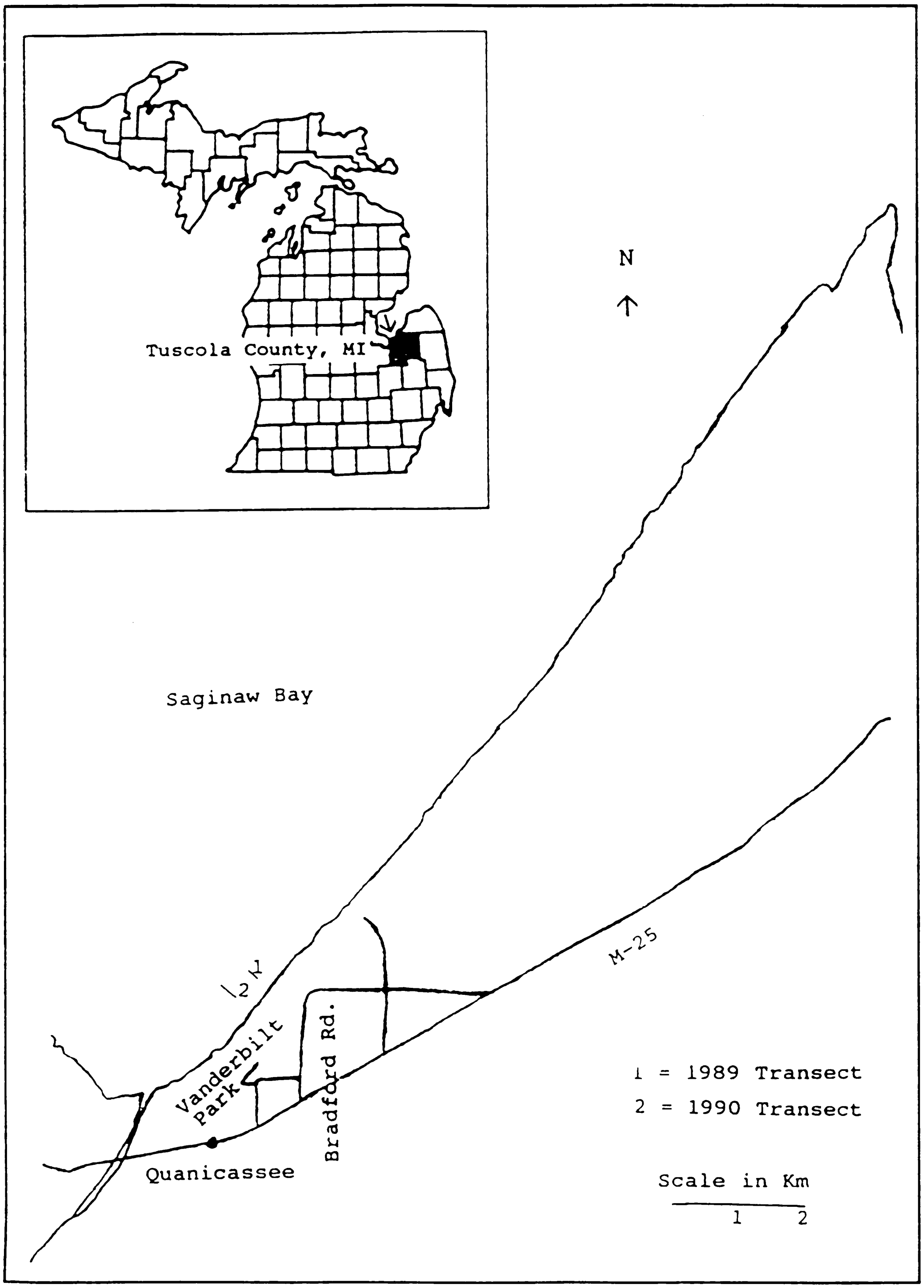


Figure 1. Location of transects at the Quanicassee coastal marsh study site on Saginaw Bay, Lake Huron, near Quanicassee, Michigan.

Water Depth

Water depth in the marsh generally increased from nearshore to offshore areas, but the slope was very gradual. McNabb and coworkers (pers. comm.) measured an incline of only 7.6° in this area. The many sandbars created during seiches and the holes dug by carp (Cyprinus carpio L.) made the depth progression quite irregular.

Water depth in the marsh varies seasonally and with changing lake levels. Water levels are typically lowest in the spring, rise to a peak in July or August with the runoff from the spring snow melt and rains, and then slowly decline through the fall and winter to the spring low, following the typical water level changes of Lake Huron (Busch 1990). Monthly mean water levels for Saginaw Bay at Essexville, (approximately 10 km East of the sampling location) varied from a high of 176.54 m above sea level in October of 1989 (NOAA/NOS 1989), to a low of 176.13 m above sea level in January of 1990 (NOAA/NOS 1990). Annual water level fluctuations of 40 to 70 cm have been recorded for Saginaw Bay marshes (Cole and Weigmann 1983).

Seiches also affect water levels in the marsh. Seiches of up to one meter have been recorded for Saginaw Bay (Cole and Weigmann 1983). Seiches are short-term water level fluctuations caused by strong winds blowing across the bay. They may last a few hours or a few days. In addition smaller daily seiches occur due to the shift in wind direction from onshore during the day to offshore at night (Batterson et al. 1991).

Vegetation and Sediment

The wetland complex was dominated by the emergent bulrush, Scirpus americanus Pers., with dense beds of the cattail, Typha latifolia L., occasionally interspersed. The emergent marsh extended out to 600 m from shore in this area. Submerged and floating-leaved vegetation grew between the line of lowest water level and the offshore zone of the marsh, which began between 300 and 400 m from shore (Batterson et al. 1991). This vegetation included Chara, Ceratophyllum, Lemna, Najas, Nymphaea, Potamogeton, and Vallisneria (McNabb et al. pers. comm.). Vegetation in the areas sampled ranged from very dense, 200 to 270 S. americanus stems per square meter, to nonexistent.

The sediment in this marsh was not the organic mucks typical of many emergent wetlands. Organic mucks and detritus did build up in protected areas nearshore, but the S. americanus marsh substrate was predominantly sand. The S. americanus growth stabilizes this shifting sand substrate. Most of the sand grains in the sediment samples were large enough to be retained in a 250 μm sieve.

MATERIALS AND METHODS

Invertebrate Sampling

1. Sampling Design

All samples were collected from a fixed transect using the point-centered sampling procedure (e.g. Smith 1990). Each year a transect was laid out through the marsh perpendicular to the shore, such that depth generally increased from the nearshore end to the offshore end. The transect was chosen to intersect typical sections of S. americanus, submergent macrophytes, and open water areas in the marsh. T. latifolia islands were avoided since the vegetation samplers could not be used in them due to the density of the vegetation. The 1989 transect, located just off Bradford Road (Figure 1), began approximately 150 m from shore, and extended 150 m through the marsh along a line of 333°. The 1990 transect was located approximately 0.5 km south of the 1989 transect, in the vicinity of Vanderbilt Park (Figure 1). This transect began about 300 m from the shore, and extended approximately 300 m through the marsh along a line of 310°.

The transect was relocated in a different area of the marsh between 1989 and 1990, because low water levels during the spring of 1990 left the area of the 1989 transect dry.

Both areas were part of the same large wetland complex, but the 1990 site was farther from agricultural drainage ditches than was the 1989 transect. The transect length was also doubled during 1990 so that sampling points could be shifted closer to or farther from shore with changing water levels.

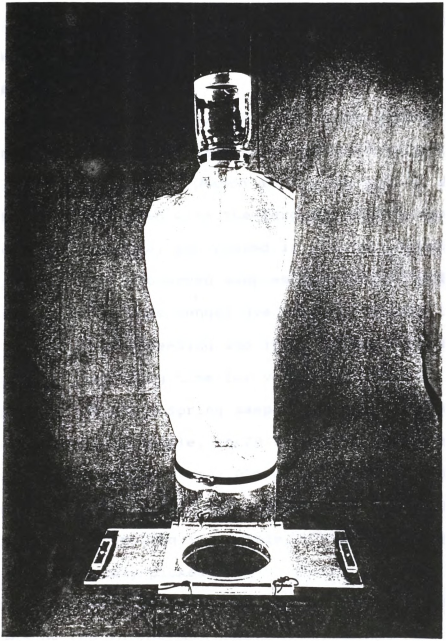
Twice a month from July through October of 1989 (except only once during July), and once a month from April through December of 1990, five vegetation and five sediment samples were taken along the transect. Each sample set was taken at a random distance and direction from a predetermined point along the transect. The five fixed points were located 20 m apart along the 1989 transect and 30 m apart along the 1990 transect. For each sample set at each point along the transect, a random direction (0° to 360° in increments of 10°) and random distance (1 m to 10 m in increments of 1 m) were obtained from a table of randomly generated numbers. This determined the exact location where each of the 5 sets of samples was to be taken. Care was taken never to sample the same direction twice from any particular fixed point, nor was any sample taken within one meter of the transect itself.

2. Vegetation Samples

Epiphytic, nektonic, and epineustic invertebrates were sampled using a Gerking sampler as modified by Mittelbach (1981). This Gerking-Mittelbach sampler consisted of a 21.5 cm diameter Plexiglas tube with 224 μm nylon netting attached to one end and sliding Plexiglas doors attached to the other end (Figure 2). The open ring top of a large mouth, 0.9 l canning jar was clamped to the top end of the net, allowing large mouth canning jars to be easily attached and exchanged.

To use the sampler, emergent vegetation in the area to be sampled was clipped at the water surface. The open sampler was lowered over the clipped vegetation until it rested on the sediment. All vegetation inside the sampler was cut at the sediment surface with a long knife. The doors of the sampler were closed, the sampler was inverted, and brought to the surface with the invertebrates and the vegetation inside. All animals and other small items were washed from the net into the attached jar, while large vegetation was removed through the sliding doors and placed in Ziplock plastic bags. The canning jar was removed, labeled, and replaced, and the sampler was rinsed between samples.

Sand frequently jammed the sampler doors so that they could not be completely closed. The sample was discarded and retaken if the doors could not be closed tightly enough to trap the vegetation. Five of these Gerking-Mittelbach samples were taken on each date, provided the water was deep enough at each sampling point along the transect (approximately 5 cm of water were required to operate the vegetation sampler). Only three Gerking-Mittelbach samples could be taken on October 27, 1989, and May 10, 1990, due to shallow water. On April 19, 1990, only three samples were



Height of sampler is one meter.

Figure 2. Gerking-Mittelbach sampler for quantitative sampling of invertebrates associated with aquatic vegetation.

taken because there was no vegetation present at the other two sampling locations. Only three Gerking-Mittelbach samples were taken on December 13, 1990, because an ice flow was blown into the sampling area just after the third sample was taken.

At the field laboratory, each sample was washed through a 250 μm sieve, then preserved in 95% ethanol containing 100 $mg \cdot l^{-1}$ Rose Bengal dye (Mason and Yevich 1967). All invertebrates associated with the large pieces of vegetation were picked the same day and placed in the appropriate sample. Later, the preserved samples were sorted under 10x magnification. The Rose Bengal dye stained protein in the samples a neon pink, speeding and increasing the accuracy of the picking. Processing time for vegetation samples ranged from one hour for early spring samples, with an average of 47 invertebrates per sample, to 20 to 30 hours per sample for fall samples, when up to 3,000 invertebrates were found in each sample. Vegetation and detritus in these samples made accurate subsampling impossible, so each vegetation sample was completely picked.

Invertebrate numbers from each sample were converted to $number \cdot m^{-2}$ by the following formula:

$$\text{Area:} \quad \pi r^2 = \pi(0.0975\ m)^2 = 2.98 \times 10^{-2}\ m^2$$

Zooplankton numbers were converted to $number \cdot m^{-3}$ by the following formula:

$$\text{Volume:} \quad \pi r^2 h = \pi(0.0975\ m)^2 \times (\text{water depth in m})$$

The five vegetation samples collected on each date were treated as five subsamples of a single sample for each date to provide means and standard errors.

3. Sediment Samples

Benthic invertebrates were sampled using a corer made of Plexiglas tube 4.5 cm in diameter and 50.5 cm in length, capped with a 4.5 cm rubber stopper. Each core included 15 cm of sediment plus the water column above it to a total depth of about 50 cm. Two cores comprised each sediment sample. No attempt was made to separate invertebrates in the water column from those residing in the sediments. One sediment sample was taken in conjunction with each vegetation sample, for a total of five sediment samples on each date.

Sediment samples were washed through a 250 μm sieve at the field laboratory, then preserved in 95% ethanol which included Rose Bengal dye. Each sediment sample was divided into sevenths before it was picked, using a subsampling device similar to that described by Waters (1969). Each subsample was floated in a sugar solution (300 g sucrose per l of water, Anderson 1959) to further speed the picking process. All floating material was sieved off and sorted under 10x magnification. Non-floating material was searched in a white enamel pan using a 10x magnifying lamp. To insure that an adequate number of organisms were obtained to characterize the sample, up to three sevenths were picked,

until at least 50 organisms were found. Once picking of a subsample was started, it was sorted completely.

The numbers of invertebrates in each sediment sample were converted to number$\cdot m^{-2}$ based on the following formula:

$$\text{Area:}\quad \pi r^2 = \pi(0.024\ \text{m})^2 \times 2 \text{ cores per sample}$$
$$= 7.24 \times 10^{-3}\ \text{m}^2$$

Zooplankton numbers were converted to number$\cdot m^{-3}$ by the following formula:

$$\text{Volume:}\quad \pi r^2 h = \pi(0.024\ \text{m})^2 \times (0.15\ \text{m} + \text{water depth to } 0.35\ \text{m maximum}) \times 2 \text{ cores per sample}$$

The five sediment samples were also treated as five subsamples of a single sample for each date.

Sediment samples were processed in this manner through July 13, 1990. No sediment samples were processed after this date due to the large amount of time required, and the low return of information for this work. The first seventh of each sediment sample required approximately five hours processing time, with about three hours required for each subsequent seventh. When completed, only 50 to 100 organisms would have been obtained.

4. Aquatic Dip Net Samples

Aquatic dip net samples were taken, beginning in September of 1989, to insure that fast-moving invertebrates were being represented if they escaped the Gerking-Mittelbach sampler. A single dip net sample of 15 to 20 sweeps through the water was taken from the middle of the transect from September, 1989, through May, 1990. Beginning in June of 1990, one dip net sample was taken in conjunction with the other two sample types, for a total of five dip net samples on each date. Each of these dip net samples consisted of 10 sweeps of the net through the water; the sweeps were 1 m apart, with the top of the net kept just below the surface of the water to standardize the depth.

All dip net samples were live-picked in a white enamel pan within 24 hours of collection, and preserved in 70% ethanol. Samples were stored at 4°C until they were picked.

5. Identification

All invertebrates were identified to Operational Taxonomic Unit (OTU's). The OTU's and the references used for identification, are shown in Table A-1. Dr. William L. Hilsenhoff of the Department of Entomology, University of Wisconsin-Madison, confirmed the identification of the Trichoptera and the odonate, _Ishnura verticalis_ Say. Identification of the Ephemeroptera, _Caenis amica_ Hagen and _C. latipennis_ Banks, was based on a reference collection identified by Mr. Arwin V. Provonsha of the Department of Entomology at Purdue University. Chironomidae larvae were identified to genus or species group for the June 30, 1989, (preliminary samples) and July 13, 1989, Gerking-Mittelbach and sediment samples (Table A-2).

Identification of the Oligochaeta as _Stylaria_, other Naididae, and Tubificidae was based on a reference collection identified by Dr. Richard Snider of the Department of Zoology, Michigan State University. The oligochaetes in the sediment samples often broke into pieces. The larger pieces of Oligochaeta were counted to provide an estimate of the numbers present. (The very small pieces (<0.2 mm) were not counted).

The crustacean zooplankton were subsampled for identification after they had been picked from the samples. All zooplankton were identified if 50 or less were present in a sample. If more than 50 zooplankton were present, one-seventh subsamples were taken. All zooplankton in each subsample were examined, until at least 50 Cladocera and 50 Copepoda had been identified. Other than those mentioned above, the identifications were not verified by experts.

6. Biomass Calculation

Biomass of the most abundant macroinvertebrate taxa was calculated for the following dates:

1989	1990
July 13	April 19
August 10	June 8
October 7	August 10
	October 6
	December 13

Average measurements for each group were obtained by measuring a subsample from each sample. At least 10 randomly chosen individuals were measured, in mm, using a calibrated ocular micrometer. Dry weight was then calculated for an "average" individual of each taxon, and was multiplied by the number of that group present. For the insect taxa, with the exception of the Ceratopogonidae, regression constants were available from the literature (Table 1).

Table 1. Regression formula and regression constants used to calculate insect biomass (Smock 1980).

Regression formula: $W=aL^b$

W = dry weight in mg
L = Length in mm
a = constant
b = constant

MACROINVERTEBRATE	CONSTANTS FOR REGRESSION FORMULA	
Chironominae	a=0.00510	b=2.32
Orthocladiinae	a=0.00510	b=2.32
Tanypodinae	a=0.00380	b=2.41
Caenidae	a=0.00660	b=2.88
Coenagrionidae	a=0.0140	b=2.78
Leptoceridae	a=0.00190	b=3.12

The dry weights of all other abundant macroinvertebrate taxa were calculated by the following formula (after Hynes and Coleman 1968):

$$W=\pi r^2 l(1\ cm^3/1000\ mm^3)(1.05\ g/cm^3)(1000\ mg/1\ g)$$

W = dry weight in mg
r = radius in mm
l = length in mm
$1.05\ g/cm^3$ = specific gravity

Regression equations were used for some of the crustacean zooplankton taxa (Table 2). For many species, however, mean dry weights from the literature were used

Table 2. Dry weights and regression constants used to estimate the biomass of the crustacean zooplankton.

ZOOPLANKTON	DRY WEIGHT (μg) OR CONSTANTS FOR REGRESSION FORMULA	SOURCE
CLADOCERA		
Acroperus harpae Baird	6.00	Hall et al. 1970
Alona quadrangularis (O.F. Muller)	a=0.087 b=2.02	Vuille 1991
Bosmina longirostris (O.F. Muller)	1.80	Hall et al. 1970
Camptocercus rectirostris Schodler	5.00	Hall et al. 1970
Ceriodaphnia	4.20	Hall et al. 1970
Chydorus sphaericus (O.F. Muller)	2.00	Hall et al. 1970
Daphnia	35.00	Hall et al. 1970
Diaphanosoma brachyurum Lieven	7.00	Hall et al. 1970
Eurycercus lamellatus (O.F. Muller)	80.00	Hall et al. 1970
Ilyocryptus	a=0.0404 b=2.71	Vuille 1991
Latona setifera (O.F. Muller)	a=0.128 b=2.189	McCauley 1984
Leydigia acanthocercoides Fischer	6.00	Hall et al. 1970
Leydigia quadrangularis	6.00	Hall et al. 1970
Macrothrix laticornis Jurine	2.00	Hall et al. 1970
Macrothrix rosea Jurine	2.00	Hall et al. 1970
Pleuroxus procurvus Birge	4.00	Hall et al. 1970
Scapholeberis kingi Sars	a=0.0566 b=3.079	McCauley 1984
Sida crystallina (O.F. Muller)	a=0.128 b=2.189	McCauley 1984
Simocephalus	50.00	Hall et al. 1970
COPEPODA		
Acanthocyclops vernalis Fischer	8.60	Hall et al. 1970
Eucyclops agilis Koch	8.00	Hall et al. 1970
Eurytemora affinis Poppe	a=0.00697 b=2.154	Culver et al. 1985
Harpactacoida	5.10	Vuille 1991
OSTRACODA	22.00	Nalepa and Quigley 1983

(Table 2). This allowed calculation of the crustacean zooplankton biomass on all sample dates.

7. Depth-Abundance Relationships

The relationship between invertebrate abundance and the depth or distance from shore at which these vegetation samples were taken was investigated for several of the most abundant macroinvertebrate and zooplankton groups. Abundance of each group was plotted against water depth or against distance from shore in an xy scatter plot to show any obvious relationships.

Characterization of Site

Physical, chemical, and nutrient data were collected on each date to characterize the water within the marsh. These samples were taken from the offshore end of the transect during 1989 (300 m from shore), and from the center of the 1990 transect (450 m from shore), areas that appeared "typical" of the study site.

Water and air temperatures were measured to the nearest 0.5°C using a hand-held mercury thermometer. Water temperatures were taken just above the sediment surface. Water samples for pH, alkalinity, and chloride were collected in polyethylene bottles and placed on ice during transport back to the field laboratory. The pH and alkalinity were measured within two hours of the time of collection, while the chloride sample was frozen upon arrival at the field laboratory. pH was measured using an

Orion Research model 701A Ionalyzer. Alkalinity was measured by titration with sulfuric acid, as specified in Standard Methods (APHA 1980).

One 250 ml dissolved oxygen sample, collected with the other water quality samples, was immediately fixed, and was analyzed at the field laboratory within two hours of collection using the Rapid Winkler-Azide modification (APHA 1980). The dissolved oxygen values were then converted to percent saturation of dissolved oxygen. Chloride was analyzed with a Technicon® AutoAnalyzer II using the automated ferricyanide method (U.S.E.P.A. 1979). Means and standard errors were calculated for all parameters each year, and for both years together.

Water depth was measured with a meter stick where each series of samples was taken. Depth was measured to the nearest 0.5 cm, and estimated when wave action made an exact reading impossible. The water depths on July 13, 1989, were estimated from the depths measured on August 10, 1989.

RESULTS

Vegetation Invertebrate Community Composition

1. Macroinvertebrates

Non-insectan macroinvertebrates were represented by 11 orders, with 16 identified genera, in the vegetation community of the Quanicassee marsh (Table 3). Oligochaeta, aquatic mites, Amphipoda, Gastropoda, *Hydra*, and Nematoda were present in 50% or more of the Gerking-Mittelbach samples. Only Oligochaeta, Amphipoda, and Gastropoda were collected by aquatic dip net at least 50% of the time (Table 3).

The vegetation macroinvertebrate community in the Quanicassee marsh was dominated, both numerically and by weight, by aquatic insects, oligochaetes, and snails (Figures 3 and 4). Macroinvertebrates were generally more abundant and had greater biomass in 1990 than during 1989 (Figure 5). Macroinvertebrates reached their peak abundance in the vegetation community at the 1989 site on September 22, with a mean of $12{,}800 \cdot m^{-2}$ (Figure 5A), nearly 75% of which was aquatic insects (Figure 3). Macroinvertebrate mean dry weight was greatest on October 7, 1989, with $720\ mg \cdot m^{-2}$ (Figure 5B), and again, over 70% of this was aquatic insects (Figure 4).

Table 3. The macroinvertebrate taxa (excluding insects) in the vegetation of a Saginaw Bay, Lake Huron, coastal marsh: Percent occurrence, maximum mean number per m2, and maximum mean dry weight (mg/m2) for selected taxa.

FAMILY	OPERATIONAL TAXONOMIC UNIT		GERKING- MITTELBACH % OCCUR	MAX MEAN NUM/M2 ± SE	MAX MEAN WT ± SE (mg/m2)	DIP NETa % OCCUR	MAX NUM
ANNELIDA							
OLIGOCHAETA*			VC	15,400 ± 5,200		VC	147
Naididae	Stylaria			8,800 ± 2,800	515 ± 175		
	Others			13,900 ± 2,900	540 ± 160		
Tubificidae				5,900 ± 2,600	580 ± 260		
Others				1,500 ± 320	50 ± 20		
HIRUDINAE			S	60 ± 60		U	2
AQUATIC MITES*			VC	1,100 ± 560	60 ± 14	S	22
CRUSTACEA							
AMPHIPODA							
Gammaridae	Gammarus fasciatus Say		U	10 ± 10		U	2
	Gammarus pseudolimmnaeus Bousfield*		C	750 ± 410	580 ± 210	C	39
Hyalellidae	Hyalella azteca Saussure	b	U	30 ± 30		C	8
GASTROPODA							
Ancylidae	Ferrissia parallela Haldeman*		C	320 ± 130	100 ± 25	S	2
Lymnaeidae	Fossaria humilis Say		S	70 ± 70		U	6
	Pseudosuccinea columella Say	c,d	U	7 ± 7		N	0
	Stagnicola catascopium Say	b,d	U	7 ± 7		N	0
Physidae	Physa heterostropha Say		C	260 ± 220	30 ± 7	C	45
Planorbidae	Gyraulus parvus Say*		C	680 ± 390	110 ± 10	C	52

Table 3 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT		GERKING- MITTELBACH % OCCUR	GERKING- MITTELBACH MAX MEAN NUM/M2 ±SE	GERKING- MITTELBACH MAX MEAN WT±SE (mg/m2)	DIP NETa % OCCUR	DIP NETa MAX NUM
ISOPODA							
Asellidae	Asellus forbesi Williams*	c	U	310±310		N	0
PELECYPODA							
Dreissinidae	Dreissina polymorpha Pallas	b,d	1 found in Gerking-Mittelbach sample, October 6, 1990				
OTHERS							
HYDROZOA							
Hydridae	Hydra*		C	990±560		S	9
NEMATODA*			C	4,100±3,700	27±12	U	3
TARDIGRADA*		c	S	24,800±24,400	20±11	N	0
TURBELLARIA			U	100±60		U	14

Percent Occurrence:
VC = very common, present in 80% or more of vegetation samples.
C = Common, present in 50 - 79% of vegetation samples.
S = Scarce, present in 20 - 49% of vegetation samples.
U = Uncommon, present in less than 20% of vegetation samples.
N = None, not found in that sample type.
a = Number present in sample.
b = Present only in 1989 vegetation samples.
c = Present only in 1990 vegetation samples.
d = Found only in one sample on one date.
* = Made up at least 1% of vegetation macroinvertebrate community on at least one date.

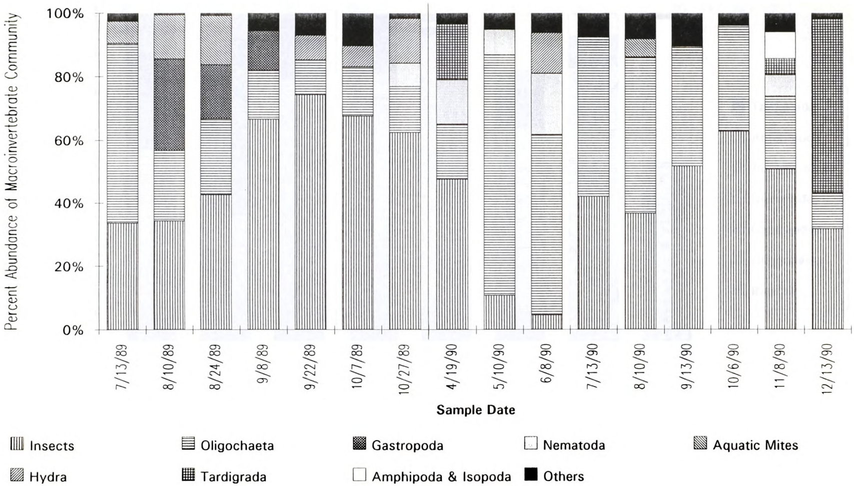


Figure 3. Composition of the vegetation macroinvertebrate community of a Saginaw Bay coastal marsh, based on abundance.

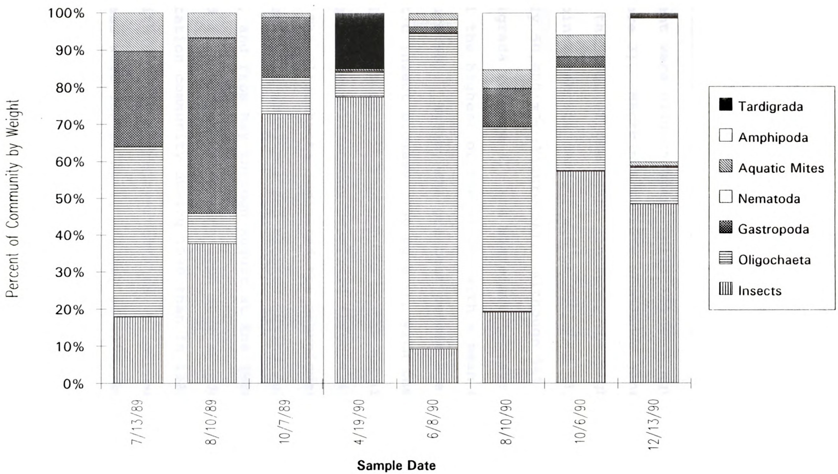
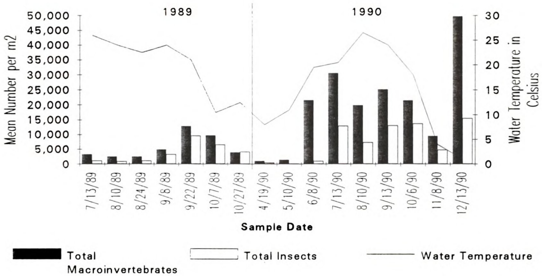


Figure 4. Composition of the vegetation macroinvertebrate community of a Saginaw Bay coastal marsh, based on dry weight.

At the 1990 site, macroinvertebrate mean abundance was very low in April and May, only $1,000 \cdot m^{-2}$ and $2,000 \cdot m^{-2}$, respectively (Figure 5A). But the macroinvertebrate community had reached an average of 30,550 macroinvertebrates$\cdot m^{-2}$ by July 13, 1990 (Figure 5A). Fifty percent were oligochaetes, while 42% were aquatic insects (Figure 3). Macroinvertebrate abundance generally remained high the rest of the year. In fact, the highest macroinvertebrate density was on December 13, 1990, with nearly $50,000 \cdot m^{-2}$ (Figure 5A). Although 54% were the tiny Tardigrada (Figure 3), the macroinvertebrate biomass was still the highest of the study, with a mean of $1,500\ mg \cdot m^{-2}$ (Figure 5B). Again, the greatest percentage of this was aquatic insect biomass ($730\ mg \cdot m^{-2}$), with the next largest portion ($580\ mg \cdot m^{-2}$) represented by the amphipod species, Gammarus pseudolimmnaeus Bousfield (Figure 4).

The Oligochaeta dominated the macroinvertebrate community in abundance and biomass during July at the 1989 site, and from May through August at the 1990 site (Figures 3 and 4). Oligochaetes were much more abundant in the vegetation community during 1990 than in 1989 (Figure 6A). As with all the macroinvertebrates, oligochaete numbers and biomass were low in April and May of 1990, but they had greatly increased by June (Figure 6A). Oligochaeta reached their maximum mean abundance of $15,400 \cdot m^{-2}$ on July 13, 1990 (Figure 6A, Table 3).

A.



B.

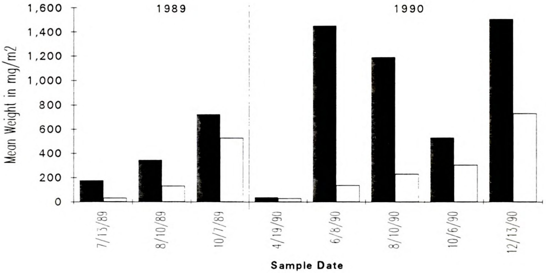
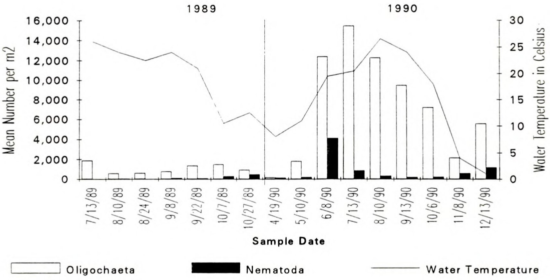


Figure 5. A. Abundance trends, and B. Mean weight of the macroinvertebrates and insects in the vegetation community of a Saginaw Bay emergent marsh. In both graphs, the macroinvertebrate series includes the insects.

A.



B.

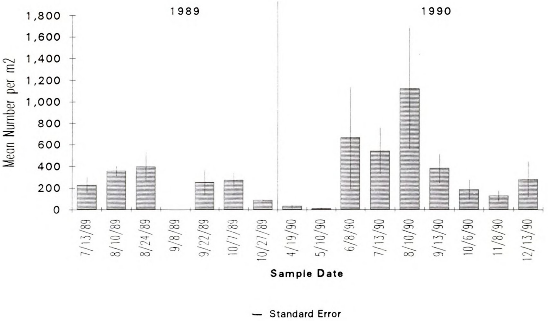


Figure 6. Abundance trends of A. Oligochaeta (Annelida) and Nematoda, and B. aquatic mites in the vegetation community of a Saginaw Bay, Lake Huron, coastal marsh near Quanicassee, Michigan.

Most of the oligochaetes associated with the vegetation were in the family Naididae, with the genus Stylaria making up a large percentage of the numbers on many dates (Figure 7). Stylaria was the most abundant oligochaete group in August at both sites (Figure 7). On August 10, 1990, there was an average of 8,800 Stylaria$\cdot m^{-2}$, with a mean biomass of 515 $mg \cdot m^{-2}$ dry weight (Table 3). Tubificidae were also found in association with the vegetation. Tubificidae made up nearly 50% of the 15,400 oligochaetes$\cdot m^{-2}$ in the vegetation community on June 6, 1990 (Figures 6A and 7). The oligochaetes, especially the Naididae, were often found inside the cells of senescent Scirpus americanus Pers., with the number inside the cells increasing with increasing decomposition of the vegetation.

Nematoda were also found inside the cells of senescent bulrush vegetation. Nematodes made up a greater percentage of the macroinvertebrate community, and were more abundant, at the 1990 site than at the 1989 site (Figures 3 and 6A). The Nematoda reached their maximum mean abundance and biomass on June 8, 1990 (Table 3, Figure 6A).

Aquatic mites were also commonly found in the vegetation samples. Although they made up a larger proportion of the macroinvertebrate community during July and August at the 1989 site (Figures 3 and 4), aquatic mites reached greater mean abundances at the 1990 site (Figure 6B). There were 1,100 aquatic mites$\cdot m^{-2}$ with a mean biomass of 60 $mg \cdot m^{-2}$ on August 10, 1990 (Table 3). Aquatic mite

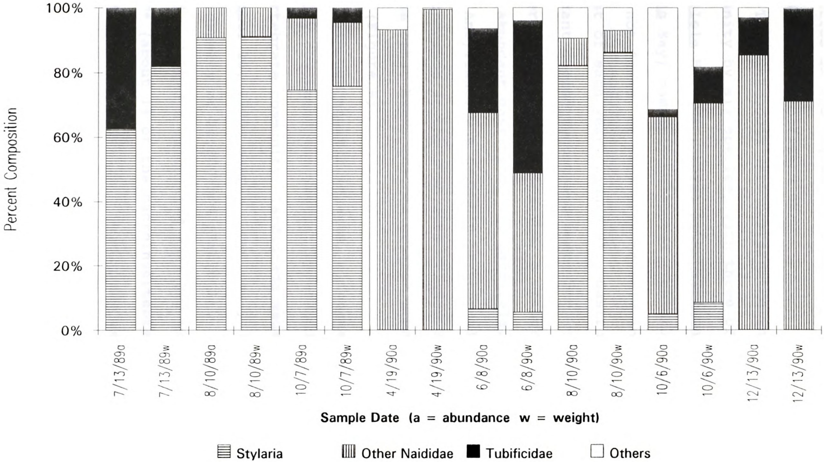


Figure 7. Composition of the Oligochaeta community in the vegetation of a Saginaw Bay coastal marsh, based on abundance and dry weight.

densities in the vegetation community were lower after August 10, 1990 (Figure 6B).

The Gastropoda were represented in the vegetation community by six species, with three of these (Ferrissia parallela Haldeman, Physa heterostropha Say, and Gyraulus parvus Say) commonly collected (Table 3). The Gastropoda were not found, or were present only in low numbers, until August of each year (Figure 8). Gastropoda were more abundant during August and September, then declined into the winter (Figure 8). G. parvus, a planorbid, was often the most abundant gastropod. F. parallela, one of the limpet-like Ancylidae, was commonly present along the 1989 site, but uncommon at the 1990 site (Figure 8). P. heterostropha, on the other hand, reached greater abundances at the 1990 site (Figure 8).

Although aquatic insects, oligochaetes, and snails usually dominated the vegetation-associated macroinvertebrate community, Tardigrada made up 54% of the December 13, 1990, sample numerically (Figure 3), with a mean density of $24{,}800 \cdot m^{-2}$ (Table 3). However, these Tardigrada had a calculated mean dry weight of only 21.5 $mg \cdot m^{-2}$ (about 1% of the macroinvertebrate biomass, Figure 4) due to their small size. Tardigrada were present from April through June, and October through December, of 1990.

The most common amphipod was Gammarus pseudolimmnaeus Bousfield. G. pseudolimmnaeus first appeared in the vegetation samples at the 1990 site in June, rose to peak

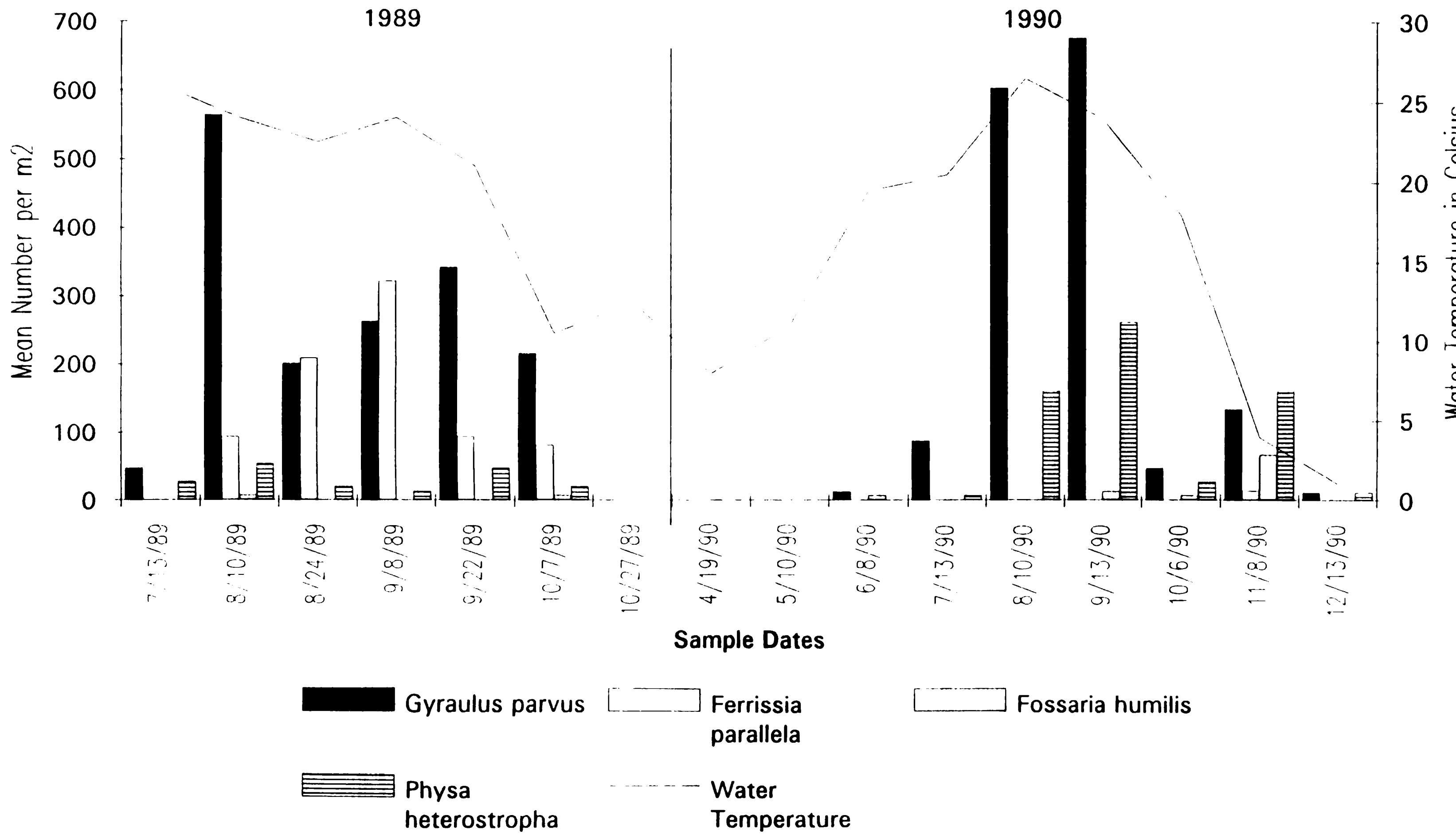


Figure 8. Abundance trends of selected Gastropoda in the vegetation community of a Saginaw Bay coastal marsh.

mean densities of $750 \cdot m^{-2}$ in September, then declined in abundance through the end of sampling in December, 1990. Hyalella azteca Saussure (Hyalellidae) was present only at the 1989 site, although the Gammaridae were more abundant at the 1990 site (Table 3). The isopod Asellus forbesi Williams was found only at the 1990 site (Table 3).

Hydra was present in vegetation samples from June through December, and was sometimes quite abundant. There were 2,700 Hydra$\cdot m^{-2}$ (mean density) in June, the first date in 1990 that they were collected. Mean density of Hydra was less than $500 \cdot m^{-2}$ during the rest of 1990. The only member of the Pelecypoda found in the marsh was the invading Dreissina polymorpha Pallas. One small mussel was found in an October 6, 1990, vegetation sample (Table 3).

2. Insects

Insects were more abundant in the Quanicassee marsh vegetation in 1990 than 1989, but the difference was not as great as was the difference in macroinvertebrate abundance between 1989 and 1990 (Figure 5A). Aquatic insects reached their greatest mean abundance during 1989 on September 22, with 9,500 insects$\cdot m^{-2}$ (Figure 5A). Greatest aquatic insect biomass was on October 7, 1989, with 530 $mg \cdot m^{-2}$ (Figure 5B). Aquatic insect densities were low in the spring of 1990 (Figure 5A), but they did make up the largest proportion of macroinvertebrates present (Figures 3 and 4). Aquatic insects were much more abundant by September and October of 1990 (Figure 5A), when they made up over 50% of the numbers and biomass of the macroinvertebrate community (Figures 3 and 4). Aquatic insects had their maximum mean abundance and biomass on December 13, 1990, with 15,500 insects$\cdot m^{-2}$ (Figure 5A) and 730 mg$\cdot m^{-2}$ mean dry weight (Figure 5B).

More than 54 species of aquatic insects, representing 28 families, were associated with the vegetation in the marsh, but only seven groups were found in 50% or more of the Gerking-Mittelbach samples (Table 4). These groups included the dipteran families Ceratopogonidae and Chironomidae, three species of Ephemeroptera, the Odonata, *Ishnura verticalis* Say, and two Trichoptera species. The Chironomidae and two species of Ephemeroptera, *Caenis amica* Hagen and *Caenis latipennis* Banks, were the most abundant insect taxa present in the vegetation community (Figure 9). Thirty-three of the 54 species of aquatic insects collected from the marsh vegetation community were found in aquatic dip net samples, while the Gerking-Mittelbach sampler collected 47 of the 54 species (Table 4).

From 14% to 93% of the insect community in the Quanicassee marsh vegetation was chironomid larvae (Figures 9 and 10). The Chironomidae made up a larger percentage of the insect community, and were more abundant, at the 1990 site than at the 1989 site (Figures 9 and 11A). At the 1990 site, low spring and early summer densities rapidly increased to a maximum mean abundance of 12,000 Chironomidae$\cdot m^{-2}$ on July 13 (Figure 11A). Chironomid abundance remained high through the end of sampling in

Table 4. The insect taxa in the vegetation of a Saginaw Bay, Lake Huron, coastal marsh: Percent occurrence, maximum mean number per m2, and maximum mean dry weight (mg/m2) for selected taxa.

FAMILY	OPERATIONAL TAXONOMIC UNIT		LIFE STAGE	GERKING-MITTELBACH % OCCUR	GERKING-MITTELBACH MAX MEAN NUM/M2 ±SE	GERKING-MITTELBACH MAX MEAN WT ± SE (mg/m2)	DIP NETa % OCCUR	DIP NETa MAX NUM
COLEOPTERA								
Dytiscidae	Copelatus gyphicus Say		L	U	7 ± 7		N	0
	Hygrotus or Hydroporus	b	L	U	7 ± 7		U	1
Elmidae	Dubiraphia	b,d	L	U	7 ± 7		N	0
	Stenelmis		A	U	7 ± 7		U	1
Gyrinidae	Gyrinus	b	L	U	7 ± 7		N	0
Staphylinidae	Phloeonomus	b,d	A	U	7 ± 7		N	0
COLLEMBOLA								
Isotomidae	Isotomurus tricolor Packard			U	150 ± 110		N	0
Sminthuridae	Bourletiella	b,d		U	7 ± 7		N	0
	Pseudobourletiella spinata MacGillivray			U	15 ± 15		U	2
DIPTERA								
Ceratopogonidae*			L, P, A	C	710 ± 490	30 ± 14	S	39
Chironomidae*			L, P, A	VC	12,000 ± 4,000		VC	59
Chironominae	Chironomini		L		4,400 ± 660	1,000 ± 150		
	Tanytarsini		L		5,200 ± 1,100	100 ± 20		
Orthocladiinae	Corynoneura		L		660 ± 190	16 ± 4		
	Others		L		1,300 ± 220	50 ± 9		
Tanypodinae			L		1,700 ± 530	580 ± 350		

Table 4 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT		LIFE STAGE	GERKING- MITTELBACH % OCCUR	MAX MEAN NUM/M2 ±SE	MAX MEAN WT ± SE (mg/m2)	DIP NETa % OCCUR	MAX NUM
Diptera (cont'd)								
Ephydridae	Ilythea	b	A	U	15 ± 15		N	0
	Notiphila	b,d	A	U	7 ± 7		U	1
Muscidae		b	L	U	7 ± 7		N	0
Stratiomyidae	Hedriodiscus	b,c	L	U	7 ± 7		N	0
EPHEMEROPTERA								
Baetidae	Baetis levitans McDunnough		L	C	150 ± 80		S	6
Caenidae	Brachycercus		L	U	15 ± 8		N	0
	Caenis amica Hagen*		L	VC	4,200 ± 2,500	210 ± 67	S	60
	Caenis latipennis Banks*		L	VC	5,900 ± 3,200	90 ± 20	VC	110
HEMIPTERA								
Corixidae	Trichocorixa naias Kirkaldy		L, A	S	640 ± 460		S	1
	Sigara decorata Abbott	c,d	A	U	7 ± 7		N	0
Gerridae	Trepobates	b,d	L	U	7 ± 7		N	0
Hebridae	Merragata hebroides White		L, A	U	7 ± 7		U	3
	Merragata brunnea Drake	c,d	L	N	0		U	1
Mesoveliidae	Mesovelia mulsanti White		L, A	U	75 ± 35		S	6
Notonectidae	Buenoa	c,d	L	N	0		U	1
	Notonecta lunata Hungerford	c,d	A	N	0		U	1
Veliidae	Microvelia	c,d	L	N	0		U	2

Table 4 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT		LIFE STAGE	GERKING- % OCCUR	MITTELBACH MAX MEAN NUM/M2 ± SE	MAX MEAN WT ± SE (mg/m2)	DIP NETa % OCCUR	MAX NUM
HYMENOPTERA		b	A	U	7 ± 7		U	1
LEPIDOPTERA								
Noctuidae	Bellura*		L	U	20 ± 20		N	0
Pyralidae	Acentria niveus Olivier		L	U	35 ± 35		U	7
	Parapoynx		L	U	7 ± 7		U	1
	Petrophila	c,d	P	N	0		U	1
ODONATA								
Coenagrionidae	Enallagma antennatum Say		L	U	7 ± 7		U	1
	Enallagma hageni Walsh	b	L	S	15 ± 8		U	1
	Enallagma signatum Hagen	b	L	N	0		U	2
	Enallagma species x		L	U	7 ± 7		U	1
	Ishnura verticalis Say*		L	VC	800 ± 75	380 ± 65	C	65
Gomphidae	Gomphus	c,d	L	U	7 ± 7		U	1
Libellulidae	Erythemis	b,d	L	N	0		U	1
TRICHOPTERA								
Hydroptilidae	Agraylea multipunctata Curtis		L, P, A	C	200 ± 70		S	4
	Hydroptila	c,d	L, P	U	7 ± 7		N	0
	Orthotrichia		L	U	7 ± 7		N	0
	Oxyethira		L	S	55 ± 15		U	3

Table 4 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT	LIFE STAGE	GERKING-MITTELBACH % OCCUR	GERKING-MITTELBACH MAX MEAN NUM/M2 ±SE	GERKING-MITTELBACH MAX MEAN WT ± SE (mg/m2)	DIP NET[a] % OCCUR	DIP NET[a] MAX NUM
Trichoptera (cont'd)							
Leptoceridae	Nectopsyche diarina Ross [c]	L	U	20 ± 15		U	3
	Oecetis cinerascens Hagen	L	S	75 ± 25		U	5
	Oecetis species x*	L	C	250 ± 180	1 ± 0.3	U	2
	Oecetis species y [c]	L	U	55 ± 35		N	0
Phryganeidae	Agrypnia vestita Walker	L	U	35 ± 25		U	3

Percent Occurrence:
VC = very common, present in 80% or more of vegetation samples.
C = Common, present in 50 - 79% of vegetation samples.
S = Scarce, present in 20 - 49% of vegetation samples.
U = Uncommon, present in less than 20% of vegetation samples.
N = None, not found in that sample type.

a = Number present in sample.
b = Present in 1989 vegetation samples only.
c = Present in 1990 vegetation samples only.
d = Found in vegetation samples on only one date.
* = Made up at least 1% of vegetation macroinvertebrate community on at least one date.

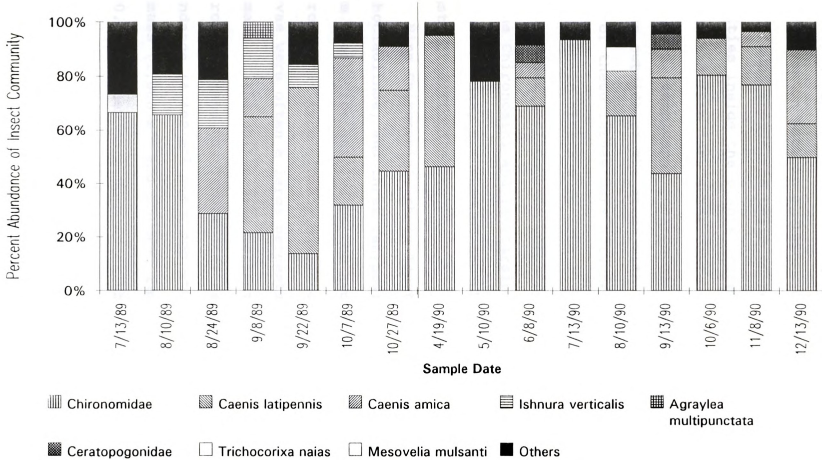


Figure 9. Composition of the vegetation insect community of a Saginaw Bay coastal marsh, based on abundance.

December (Figure 11A). Their greatest mean biomass (1,100 $mg \cdot m^{-2}$) was on October 6, 1990. Chironomid larvae were often found inside the cells of senscent S. americanus, with densities inside the plants increasing as decomposition progressed from late summer into winter. On actively growing S. americanus, chironomid larvae were usually found on the outside of the stems with the periphyton community. Some of these larvae were attached to the stems by fixed cases, while others were free living. Free-living Chironomidae included the Corynoneura, Tanypodinae, and some of the Chironomini and Tanytarsini. Most of the other Orthocladiinae, and some of the Chironomini and Tanytarsini, constructed fixed cases.

Nine Chironomini, three Tanytarsini, seven Orthocladiinae, and three Tanypodinae taxa were identified from vegetation samples on the two dates on which the Chironomidae were closely examined (Table A-2). Chironomini larvae were often a large percentage of the abundance and biomass of the chironomids collected (Figure 12). Both the Chironomini and the Tanytarsini reached their maximum mean abundance ($4{,}400 \cdot m^{-2}$ and $5{,}200 \cdot m^{-2}$, respectively) and biomass ($1{,}000 \cdot m^{-2}$ and $100 \cdot m^{-2}$, respectively) on October 6, 1990, when they made up most of the Chironomidae in the vegetation community (Figure 12).

The free-living Corynoneura never dominated the chironomid community. Corynoneura did reach a maximum mean abundance of 660 $larvae \cdot m^{-2}$ on August 10, 1990 (Table 4).

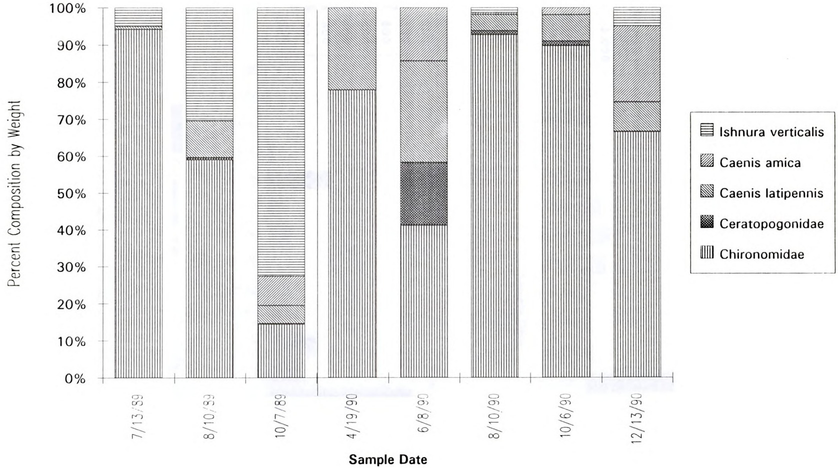


Figure 10. Composition of the vegetation insect community of a Saginaw Bay coastal marsh, based on dry weight.

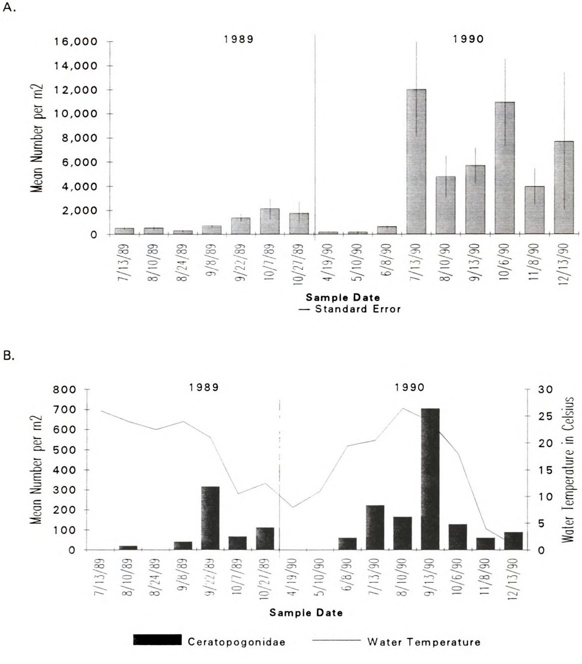


Figure 11. Abundance trends of the Diptera, A. Chironomidae, and B. Ceratopogonidae, in the vegetation community of a Saginaw Bay, Lake Huron, coastal marsh.

Its greatest mean biomass (16 $mg \cdot m^{-2}$) was on October 7 at the 1989 site, however (Figure 12). The other Orthocladiinae also reached their greatest mean abundance ($1,300 \cdot m^{-2}$) on August 10, 1990, and had their maximum mean biomass (50 $mg \cdot m^{-2}$) on this date (Table 4). The Tanypodinae reached their greatest abundance at the end of the sampling period each year. The Tanypodinae had a mean density of $1,700 \cdot m^{-2}$ on December 13, 1990, and dominated the chironomids by weight, with 580 $mg \cdot m^{-2}$ (Figure 12).

The only other dipteran family commonly present and abundant in the vegetation was the Ceratopogonidae (Table 4). The Ceratopogonidae generally had abundances of 50 to 200 $larvae \cdot m^{-2}$ during the summer, fall, and winter (Figure 11B). They reached their greatest density in September of both years (Figure 11B), but they never made up a large percentage of the insect community (Figures 9 and 10). The Diptera families Ephydridae, Muscidae, and Stratiomyidae were occasionally collected at the 1989 site, but were never abundant (Table 4).

The only odonate commonly present in vegetation samples was the coenagrionid damselfly, _Ishnura_ _verticalis_ Say, although adult dragonflies were routinely seen flying through the marsh during the summer months (Table 4). _I._ _verticalis_ reached its maximum abundance in September of both years, but it was much more abundant at the 1989 site (Figure 13). During 1989, _I._ _verticalis_ abundance increased to a September 22 peak of 800 $nymphs \cdot m^{-2}$ (Figure 13). The

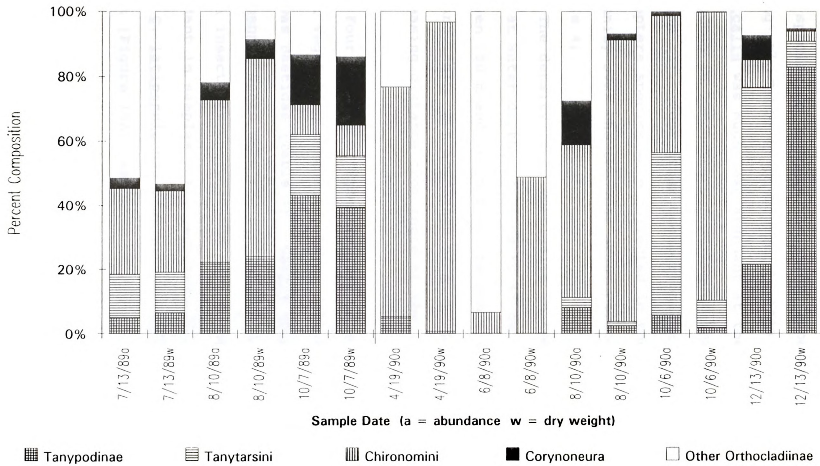


Figure 12. Composition of the Chironomidae community in the vegetation of a Saginaw Bay coastal marsh, based on abundance and dry weight.

large individual biomass of the later instar nymphs allowed this species to dominate the insect biomass (with 380 mg·m^{-2}, Table 4) on October 7, 1989 (Figure 10). I. verticalis was much less abundant at the 1990 site, but was collected in low numbers from August through December (Figure 13). Four other Coenagrionidae species and two Anisoptera species were collected in the vegetation community over the two-year study period, but were uncommon (Table 4).

The density of I. verticalis in the marsh reached a peak at water depths of 25 cm to 45 cm (Figure 14A), and between 150 m and 300 m from the shore at the 1989 site (Figure 14B). But abundance of I. verticalis decreased with increasing distance from shore at the 1990 site (Figure 14B).

Four species of Ephemeroptera were collected in the marsh vegetation community; three species were Caenidae and one was Baetidae (Table 4). Caenis amica Hagen and Caenis latipennis Banks were the most abundant Ephemeroptera in the marsh insect community (Table 4). Neither species was abundant in samples until September of each year.

C. latipennis had peak abundances in September of both years (Figure 15A), and made up 62% of the insect community on September 22, 1989 (Figure 9). C. latipennis densities declined after September to 1,000·m^{-2} to 2,000·m^{-2} through the end of sampling each year (Figure 15A). C. amica

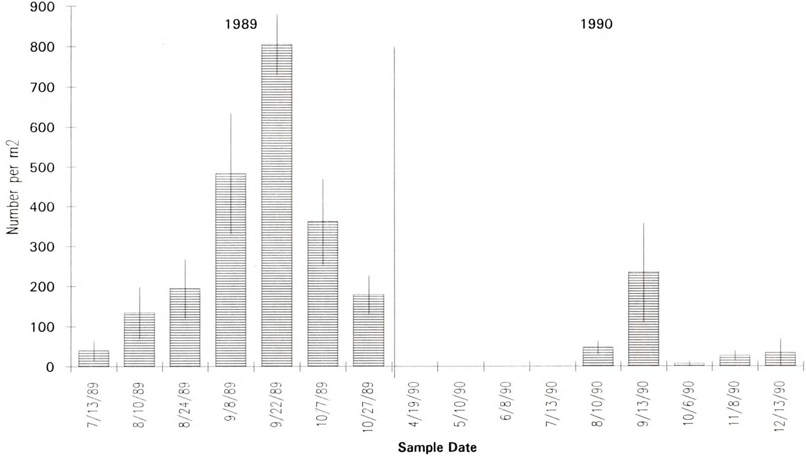


Figure 13. Abundance trends, including standard error, of Ishnura verticalis Say (Odonata: Coenagrionidae) in a Saginaw Bay coastal marsh.

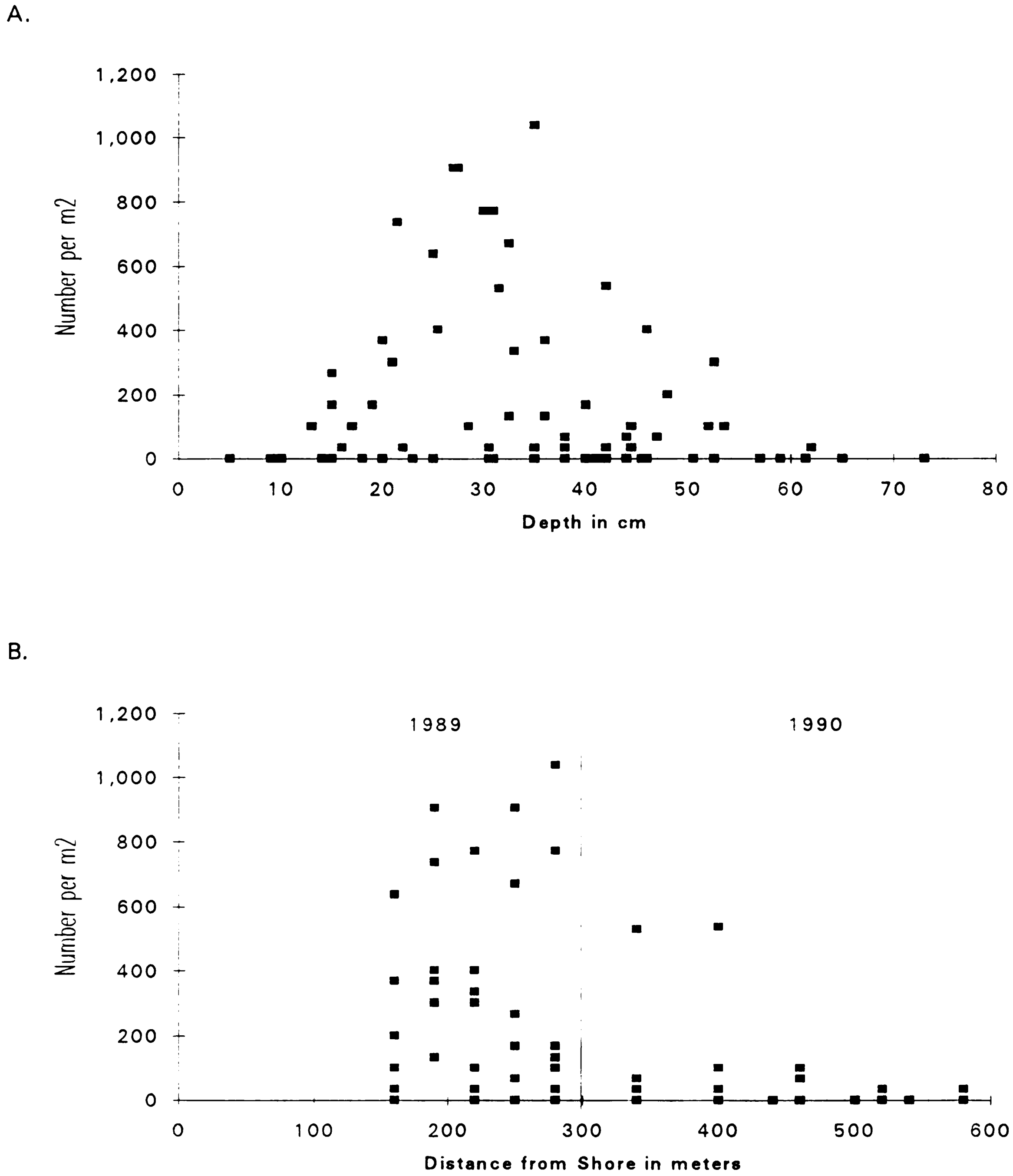


Figure 14. Relationship between abundance and A. water depth, or B. distance from shore for Ishnura verticalis Say (Odonata: Coenagrionidae) in the vegetation community of a coastal marsh, Saginaw Bay, Lake Huron.

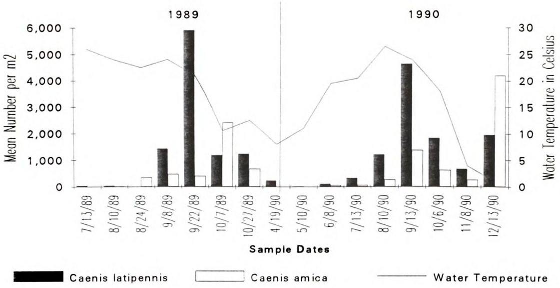
reached peak abundances of 2,400$\cdot m^{-2}$ on October 7, 1989, and 4,200$\cdot m^{-2}$ on December 13, 1990 (Figure 15A).

The higher abundances of both Caenis species consisted largely of early instar nymphs; thus, they rarely made up much of the insect community biomass (Figure 10). Densities of Caenis also seemed to be related to water depth (Figure 15B). Greater abundances of Caenis were generally collected from depths less than about 40 cm (Figure 15B). However, no relationship was found between abundance and distance from shore.

Nymphs of another Ephemeroptera species, Baetis levitans McDunnough (Baetidae), were consistently collected in Gerking-Mittelbach samples in low numbers from July through early October of 1989 (Table 4). Greatest mean abundance for B. levitans was 150 nymphs$\cdot m^{-2}$ on September 22, 1989 (Table 4). B. levitans was only present in the August and September samples at the 1990 site, and at low densities.

The Trichoptera were represented by four species each in the families Hydroptilidae and Leptoceridae, and by one species of Phryganeidae, Agrypnia vestita Walker (Table 4). Most Trichoptera were more abundant at the 1989 site than at the 1990 site. The exceptions were Hydroptila and an unknown Oecetis species ("species y"), which were only occasionally collected from the 1990 site (Table 4, Figure 16B). The caddisfly larvae usually reached their highest

A.



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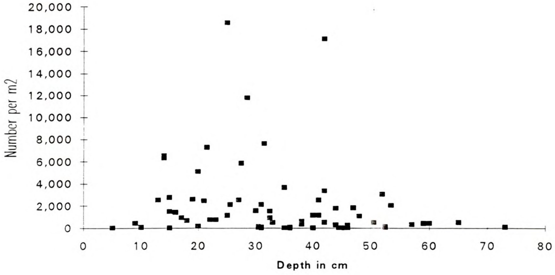


Figure 15. A. Abundance trends of Caenis nymphs, and B. Relationship between water depth and Caenis abundance, in the vegetation community of a Saginaw Bay, Lake Huron, coastal marsh near Quanicassee, Michigan.

densities in the vegetation community in September, especially during 1989 (Figure 16).

The Hydroptilidae, Agraylea multipunctata Curtis, and another unidentified Oecetis species ("species x") were the most abundant, and the most common, Trichoptera species at both sites. Both species reached mean abundances of 200 to 250 larvae$\cdot m^{-2}$ during September of 1989 (Table 4, Figure 16). Oecetis species x was slightly more abundant in December than in September during 1990, however (Figure 16B).

Aquatic Coleoptera were present in vegetation samples only occasionally, and in very low numbers. Six genera, representing four families, were collected, with four of these genera only found at the 1989 site; two of these four, Dubiraphia and Phloeonomus, were collected only once (Table 4). Adult Gyrinidae eluded capture even by the dip net, although they were often observed in small groups in the marsh. Two Gyrinus larvae were captured in Gerking-Mittelbach samples in 1989 (Table 4).

Five of the nine Hemiptera species found were collected only from the 1990 site (Table 4). Four of these species, including the only Notonectidae and Veliidae found, were only collected in dip net samples (Table 4). Trichocorixa naias Kirkaldy was the most abundant hemipteran in the vegetation community (Table 4). T. naias was present from mid-July through September of both years, reaching a mean abundance of 640 adults and larvae$\cdot m^{-2}$ on August 10, 1990

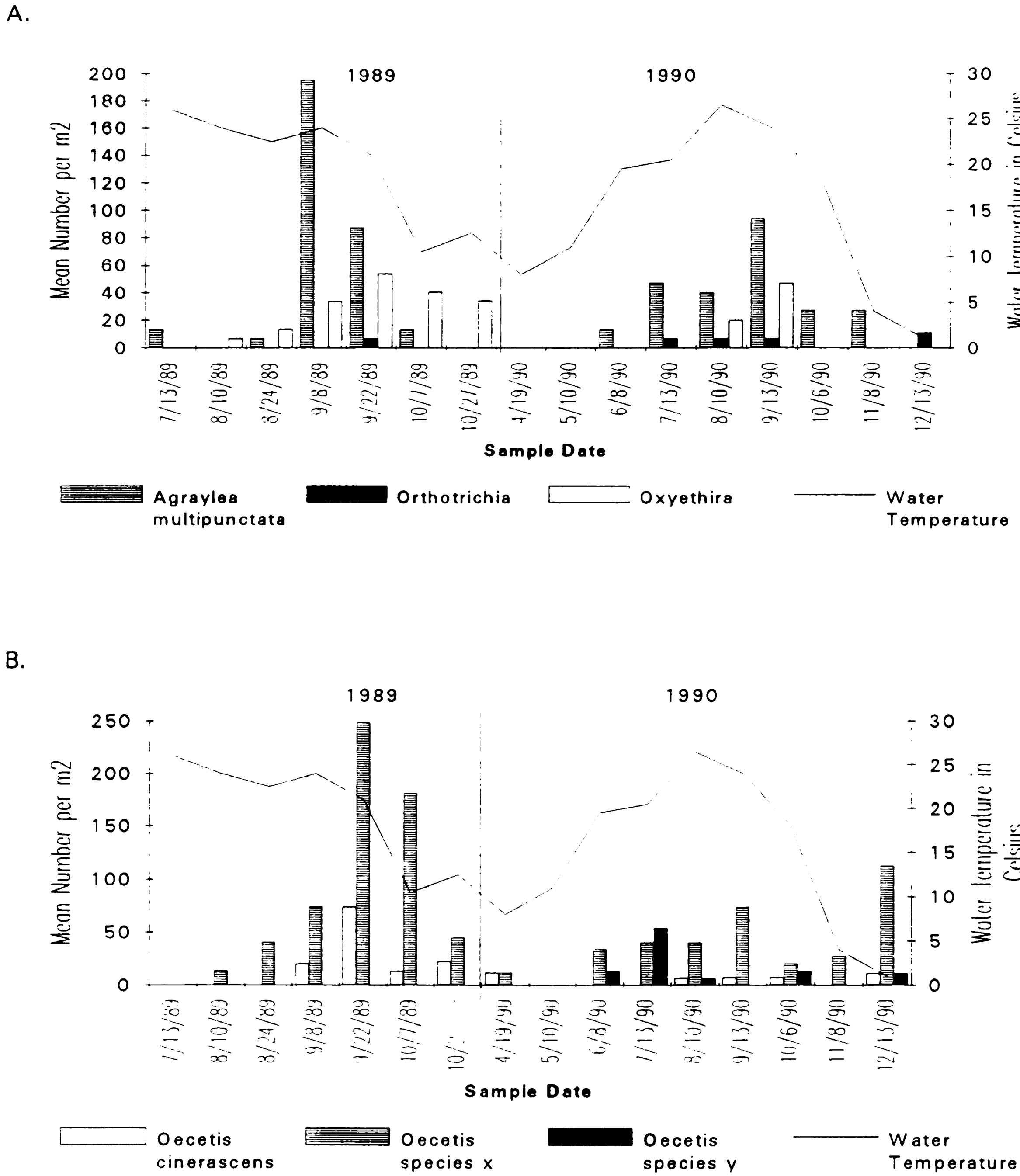


Figure 16. Abundance trends of selected Trichoptera species in the vegetation community of a Saginaw Bay coastal marsh. A. Selected Hydroptilidae. B. Selected Leptoceridae.

(Table 4). Adult T. naias and Mesovelia mulsanti White were not collected until at least August (1990 site) or early September (1989 site).

3. Crustacean Zooplankton

Crustacean zooplankton community abundance in the vegetation was low in July and August of 1989 (Figure 17). The biomass peak for 1989, however, occurred on July 13, the first date sampled, with 9,300 $mg \cdot m^{-3}$ (Figure 18). While zooplankton biomass generally declined after July 13 (Figure 18), abundance did not peak until October 27, 1989, with 243,600 $zooplanktors \cdot m^{-3}$ (Figure 17). Numbers and biomass were low for the vegetation zooplankton community during April of 1990 (Figure 17 and 18), with only $4{,}600 \cdot m^{-3}$ and 86 $mg \cdot m^{-3}$, respectively. Zooplankton abundance and biomass increased to a small June peak, and then rose to a larger peak on August 10, 1990, with $220{,}000 \cdot m^{-3}$ and 15,100 $mg \cdot m^{-3}$ (Figures 17 and 18). From this peak, density and biomass declined through the rest of 1990.

The Cladocera were generally the most abundant zooplankton in the vegetation samples. Twenty-nine cladoceran species from five families were collected, with the family Chydoridae being the best represented (Table 5). The Chydoridae dominated the zooplankton community abundance during September and October of 1989, with 66% of the total mean abundance (Figure 17). They also made up about half of the zooplankton community biomass from September 22 through the end of the 1989 sampling on October 27 (Figure 18).

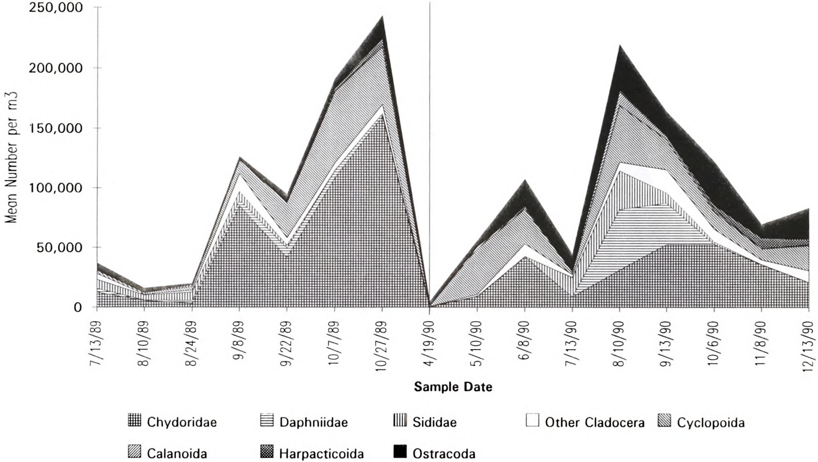


Figure 17. Abundance trends of crustacean zooplankton associated with the vegetation of a Saginaw Bay coastal marsh.

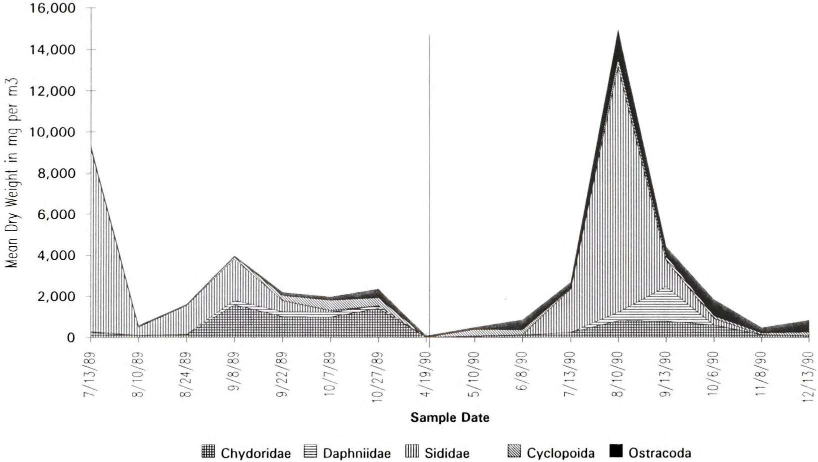


Figure 18. Mean dry weight of crustacean zooplankton associated with the vegetation of a Saginaw Bay coastal marsh.

However, during July and August of both years, the two large Sididae species, Sida crystallina (O.F. Muller) and Latona setifera (O.F. Muller), dominated the biomass of the crustacean zooplankton community (Figure 18), despite never representing more than 37% of the zooplankton numbers (Figure 17). This was especially apparent on August 10, 1990: Sididae mean biomass reached 12,000 mg·m^{-3} (Table 5), representing 79% of the zooplankton community biomass (Figure 18).

Cyclopoida was the most abundant copepod family in the vegetation community. Two species, tentatively identified as Acanthocyclops vernalis Fischer and Eucyclops agilis Koch, were collected in the marsh (Table 5). Cyclopoida were abundant during September and October of 1989, and May, June, and August of 1990 (Figure 17). The Cyclopoida reached their greatest abundance of 60,100 copepods·m^{-3} on October 7, 1989 (Figure 17), with a biomass of 500 mg·m^{-3} (Figure 18). The Cyclopoida made up 69% of the zooplankton community abundance (Figure 17) and 64% of the zooplankton biomass on May 10, 1990 (Figure 18). The cyclopoid population declined through July, 1990, then rose to its 1990 maximum of 48,000 copepods·m^{-3}, 400 mg·m^{-3}, in August (Figures 17 and 18). The Cyclopoida declined through the fall of 1990, but exhibited a small peak in December (Figures 17 and 18).

Only one species of calanoid copepod, tentatively identified as Eurytemora affinis Poppe, was a common part of

Table 5. Crustacean zooplankton of the vegetation community of a Saginaw Bay, Lake Huron, coastal marsh: Percent occurrence, maximum mean number per m3, and maximum mean dry weight (mg/m3) for selected taxa.

FAMILY	OPERATIONAL TAXONOMIC UNIT		% OCCUR	MAX MEAN NUM/M3 ±SE	MAX MEAN WT ± SE (mg/m3)
CLADOCERA					
Bosminidae	Bosmina longirostris (O.F. Muller)*		S	10,000 ± 3,000	18
	Eubosmina coregoni Baird	b	S	2,200 ± 540	
Chydoridae	Acroperus harpae Baird *		C	59,200 ± 43,600	355
	Alona quadrangularis (O.F. Muller)*		VC	17,900 ± 8,500	730
	Alona rectangula Sars	a	U	600 ± 520	
	Camptocercus rectirostris Schodler*		C	25,900 ± 25,700	130
	Chydorus gibbus Lilljeborg*	b	S	3,150 ± 1,900	
	Chydorus sphaericus (O.F. Muller)*		C	107,200 ± 68,800	210
	Disparalona acutirostris Birge	b,c	U	115 ± 115	
	Dunhevedia crassa King	a,c	U	60 ± 60	
	Eurycercus lamellatus (O.F. Muller)*		C	14,400 ± 8,700	1,150
	Leydigia acanthocercoides Fischer*		U	1,900 ± 1,600	10
	Leydigia quadrangularis		U	1,300 ± 580	8
	Monospilus dispar Sars*	b	S	8,000 ± 5,900	
	Pleuroxus denticulatus Birge*		C	2,500 ± 2,200	
	Pleuroxus procurvus Birge*		C	7,400 ± 1,600	30
Daphniidae	Ceriodaphnia megalops Sars*		S	13,400 ± 10,700	35
	Ceriodaphnia quadrangula (O.F. Muller)*		S	1,900 ± 700	8
	Diaphanosoma brachyurum Lieven*	b,c	U	4,200 ± 4,000	30
	Daphnia galeata Birge	b	U	370 ± 370	15
	Daphnia pulex Leydig	b,c	U	140 ± 85	
	Scapholeberis kingi Sars*		U	1,600 ± 780	30

Table 5 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT	% OCCUR	MAX MEAN NUM/M3 ±SE	MAX MEAN WT ± SE (mg/m3)
	Simocephalus serrulatus Koch*	S	19,400 ± 19,000	970
	Simocephalus vetulus Schodler*	S	14,400 ± 13,700	720
Macrothricidae	Ilyocryptus spinifer Herrick*	C	11,100 ± 5,000	120
	Macrothrix laticornis Jurine*	S	5,800 ± 5,800	12
	Macrothrix rosea Jurine	U	8,100 ± 7,700	15
Sididae	Latona setifera (O.F. Muller)*	S	1,700 ± 1,100	460
	Sida crystallina (O.F. Muller)*	C	30,700 ± 7,500	11,400
COPEPODA				
Calanoida	Eurytemora affinis Poppe	C	11,000 ± 4,800	65
	Skistodiaptomus oregonensis Lilljeborg a	U	450 ± 340	
Cyclopoida	Acanthocyclops vernalis Fischer	VC	32,600 ± 16,600	280
	Eucyclops agilis Koch	VC	24,100 ± 17,500	190
Harpactacoida*		C	8,800 ± 8,200	45
OSTRACODA*		VC	62,400 ± 10,800	1,374

Percent Occurrence:
VC = very common, present in 80% or more of vegetation samples.
C = Common, present in 50 - 79% of vegetation samples.
S = Scarce, present in 20 - 49% of vegetation samples.
U = Uncommon, present in less than 20% of vegetation samples.
a = Present in 1989 vegetation samples only.
b = Present in 1990 vegetation samples only.
c = Found in vegetation samples on only one date.
* = Made up at least 1% of vegetation zooplankton community on at least one date.

the vegetation zooplankton community (Table 5). E. affinis had abundance peaks at the end of August, and again in early October at the 1989 site, but was generally more abundant at the 1990 site. In 1990, E. affinis exhibited a small spring peak and then a much larger peak in August, with a mean abundance of 11,000$\cdot m^{-3}$ (65 $mg \cdot m^{-3}$).

Harpactacoida density in the vegetation community was very low until October of 1989 (Figure 17); on October 27, harpactacoid copepods reached a mean abundance of 6,200$\cdot m^{-3}$, with a mean dry weight of 30 $mg \cdot m^{-3}$. Like the other copepod groups, the Harpactacoida exhibited spring, summer, and fall peaks at the 1990 site (Figure 17). The harpactacoid copepods reached their greatest abundance on November 8, 1990, with a mean density of 8,800$\cdot m^{-3}$ (45 $mg \cdot m^{-3}$). They were nearly equal to the cyclopoid copepods in abundance on this date (Figure 17).

Ostracoda abundance and biomass in the vegetation were low until October 27, 1989, when there were 19,200 ostracods$\cdot m^{-3}$, with a mean biomass of 422 $mg \cdot m^{-3}$ (Figures 17 and 18). The Ostracoda were more abundant, and made up a larger percentage of the zooplankton community, at the 1990 site, however (Figures 17 and 18). Ostracoda made up 77% of the zooplankton abundance (Figure 17), and 91% of the biomass (Figure 18), in the April 19, 1990, Gerking-Mittelbach sample due to the very low numbers of Cladocera and Copepoda. The Ostracoda were also at their lowest density for 1990. Ostracoda increased to a June peak, and then reached even greater abundances on August 10 and October 6, 1990, with 37,100$\cdot$m^{-3} and 36,800$\cdot$m^{-3}, respectively (Figure 17). Greatest biomass for the Ostracoda in the vegetation community was on August 10, 1990, with 1,370 mg$\cdot$m^{-3} (Table 5).

The Cladocera collected in the vegetation community represented two species of Bosminidae, fourteen species of Chydoridae, eight species of Daphniidae, three species of Macrothricidae, and two species of Sididae (Table 5). Of these, seven Chydoridae, one Macrothricidae, and one Sididae species were present in 50% or more of the Gerking-Mittelbach samples (Table 5).

Overall, most of these 29 species of Cladocera were uncommon, with only a few species dominating cladoceran abundance and biomass. Chydorus sphaericus (O.F. Muller) reached the greatest densities of any cladoceran in the vegetation community, and dominated Cladocera abundance on October 27, 1989, and June 8, November 8, and December 13 of 1990 (Figure 19). Acroperus harpae Baird made up most of the rest of the October 27, 1989, abundance peak (Figure 19). Sida crystallina (O.F. Muller) dominated Cladocera biomass on several dates when it was abundant: July 13, August 10, and August 24 of 1989, and July 13 and August 10 of 1990 (Figure 20). Either Eurycercus lamellatus (O.F. Muller) or Alona quadrangularis Sars dominated the cladoceran biomass during October of 1989, while

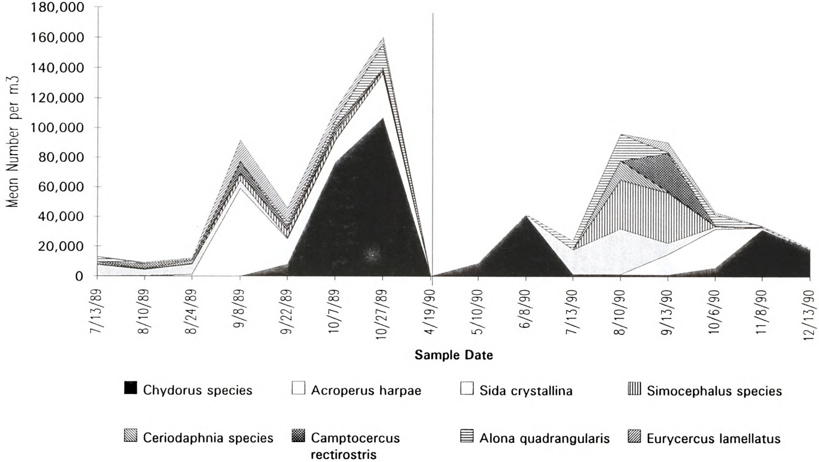


Figure 19. Abundance trends of selected Cladocera in the vegetation community of a Saginaw Bay coastal marsh.

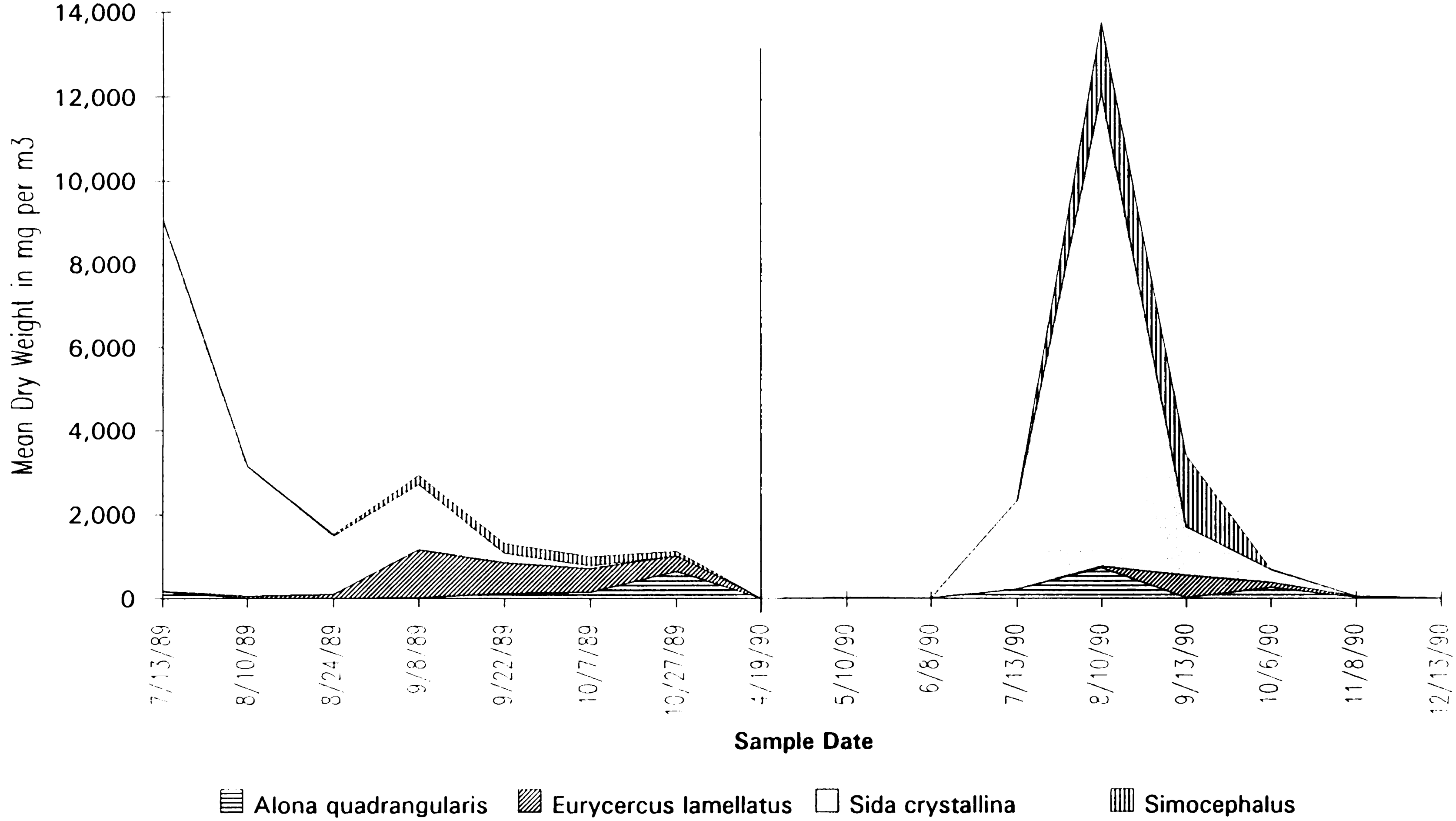


Figure 20. Mean dry weight of selected Cladocera in the vegetation community of a Saginaw Bay coastal marsh.

Simocephalus had the greatest biomass on September 13, 1990 (Figure 20).

Two species of Chydoridae, Alona rectangula Sars and Dunhevedia crassa King, were present only at the 1989 site. Three other Chydoridae, Chydorus gibbus Lilljeborg, Disparalona acutirostris Birge, and Monospilus dispar Sars, were present only at the 1990 site (Table 5). However, C. sphaericus was commonly collected, and reached the highest densities of any of the Cladocera. C. sphaericus reached a mean abundance of $107{,}200 \cdot m^{-3}$ on October 27, 1989 (Figure 19), but had a mean dry weight of only 210 $mg \cdot m^{-3}$ due to its small size. Another chydorid, A. harpae, was the most abundant cladoceran on September 8, 1989, with a mean density of 59,200 $individuals \cdot m^{-3}$ (Figure 19). This species also had a small mean biomass of only 355 $mg \cdot m^{-3}$ (Table 5). A. harpae was only abundant in samples during September and October of each year (Figure 19).

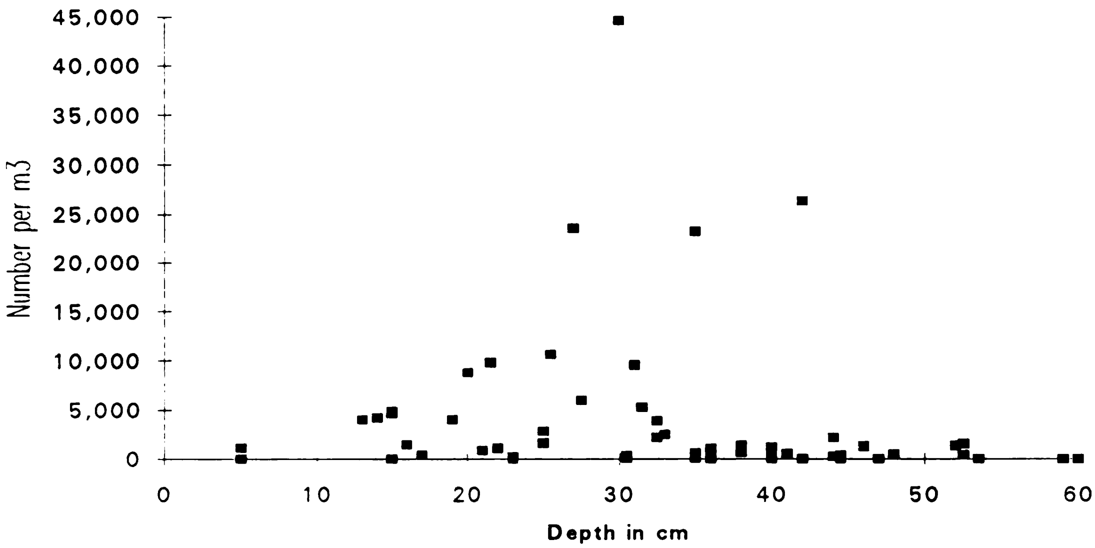
The Chydoridae Camptocercus rectirostris Schodler was collected on all 1989 sampling dates, and reached its peak abundance on September 8 with a mean density of $7{,}800 \cdot m^{-3}$ (Figure 19). C. rectirostris was only collected from September through November of 1990. This species had a mean abundance of $25{,}900 \cdot m^{-3}$ on September 13, 1990, but had declined to $370 \cdot m^{-3}$ by October 6 (Figure 19). A. quadrangularis was collected in Gerking-Mittelbach samples on every date except August 10, 1989. The greatest abundances for this species were on October 27, 1989, with

16,100·m^{-3}, and on August 10, 1990, with 17,900·m^{-3} (Figure 19). A. quadrangularis had calculated mean dry weights of 640 mg·m^{-3} and 730 mg·m^{-3}, respectively, on these dates (Figure 20).

E. lamellatus, one of the largest Chydoridae, was collected in all 1989 vegetation samples. This species had its greatest abundance on September 8, 1989, with a mean of 14,400 individuals·m^{-3} (Figure 19), and a mean dry weight of 1,150 mg·m^{-3} (30% of the cladoceran biomass, Figure 20). Larger individuals of E. lamellatus were sometimes found in dip net samples (mesh size was 1 mm). E. lamellatus reached its greatest abundances in water depths of 25 to 45 cm (Figure 21A). The abundance of E. lamellatus increased with increasing distance from shore to about 300 to 400 m, and then declined (Figure 21B). E. lamellatus was also more abundant at the 1989 site than at the 1990 site (Figure 21B).

S. crystallina dominated the cladoceran biomass, however, on the dates on which it was abundant (Figure 20). This Sididae was only present through early October each year, and was not found in 1990 Gerking-Mittelbach samples until June (Figure 19). S. crystallina was usually the largest zooplanktor in the vegetation community, and was often collected with the dip net. S. crystallina reached abundances of 7,600·m^{-3} in June, 1989, and 30,700·m^{-3} on August 10, 1990 (Figure 19). S. crystallina had a mean biomass of 8,850 mg·m^{-3} and 11,400 mg·m^{-3} on these two

A.



B.

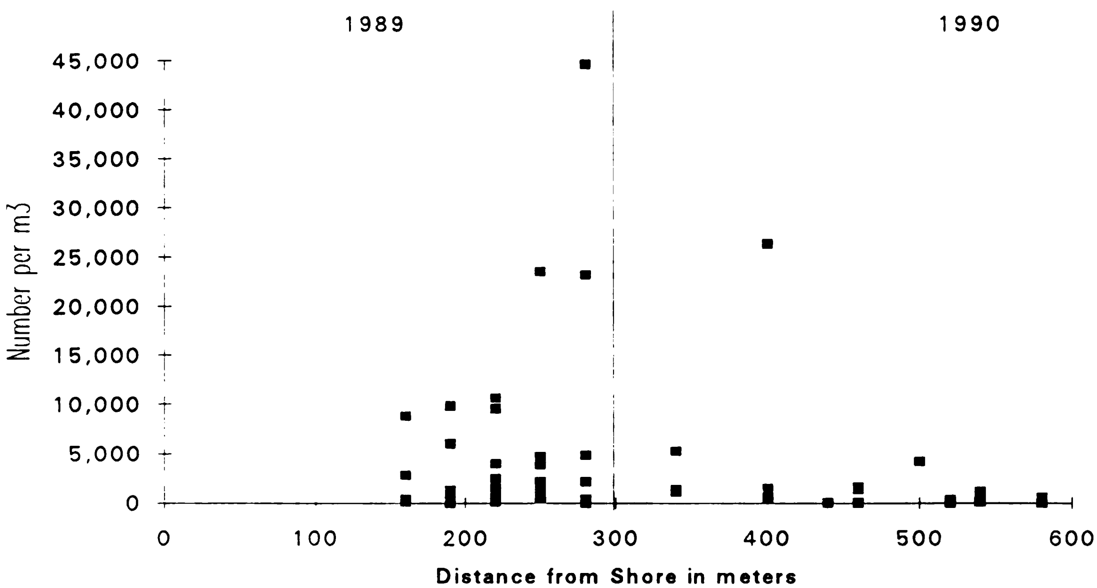


Figure 21. Relationship between abundance and A. water depth, or B. distance from shore for Eurycercus lamellatus (Cladocera: Chydoridae) in the vegetation community of a Saginaw Bay coastal marsh.

dates, respectively, dominating the entire vegetation zooplankton community biomass (Figures 17 and 19).

S. crystallina, like E. lamellatus, showed evidence of a relationship between abundance and water depth/distance from shore (Figure 22). S. crystallina was more abundant at depths greater than 30 cm (Figure 22A). This species was most abundant in the samples taken farthest from the shore at the 1989 site, but no such relationship was evident at the 1990 site (Figure 22B).

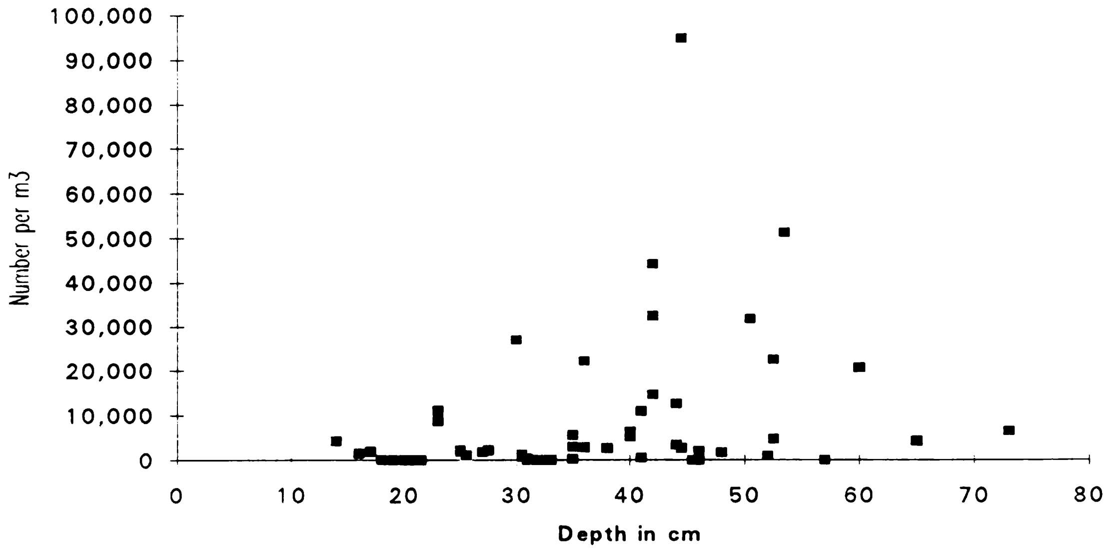
Sediment Invertebrate Community Composition

1. Macroinvertebrates

Nine orders of non-insectan macroinvertebrates were present in the sediment of the Quanicassee marsh (Table 6). Three of these, Oligochaeta, aquatic mites, and Nematoda, were present in 50% or more of the sediment core samples (Table 6). The sediment macroinvertebrate community was dominated by aquatic insects, oligochaetes, and nematodes (Figure 23). Aquatic insects made up a large percentage of the abundance and biomass at the 1989 site, while nematodes were a large percentage of the sediment macroinvertebrate community abundance at the 1990 site (Figure 23). It was the Oligochaeta, however, which most often dominated the biomass of the sediment macroinvertebrate community (Figure 23).

Although the macroinvertebrate community in the sediments did not reach its 1989 maximum abundance until

A.



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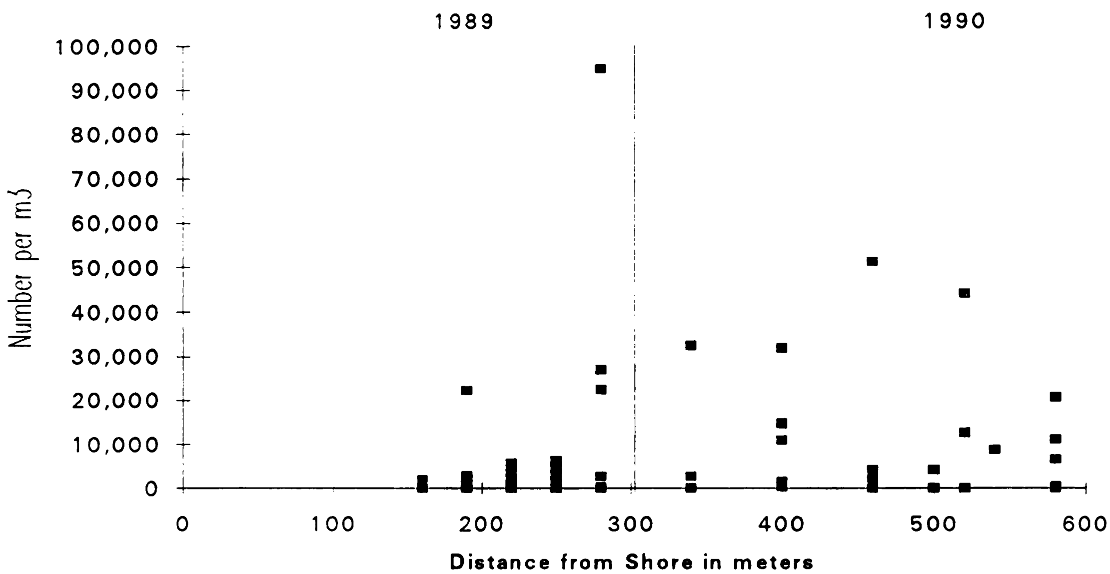


Figure 22. Relationship between abundance and A. water depth, or B. distance from shore for Sida crystallina (Cladocera: Sididae) in the vegetation community of a Saginaw Bay coastal marsh.

Table 6. The macroinvertebrate taxa (excluding insects) in the sediment of a Saginaw Bay, Lake Huron, coastal marsh: Percent occurrence, maximum mean number per m2, and maximum mean dry weight (mg/m2) for selected taxa

FAMILY	OPERATIONAL TAXONOMIC UNIT	% OCCUR	MAX MEAN NUM/M2 ± SE	MAX MEAN WT ± SE (mg/m2)
OLIGOCHAETA*		VC	10,400 ± 6,300	
Naididae			550 ± 120	65 ± 20
Tubificidae	Branchiura		580 ± 260	840 ± 340
	Others		9,500 ± 2,900	1,100 ± 300
HIRUDINAE		U	770 ± 770	
AQUATIC MITES*		C	1,400 ± 660	50 ± 10
AMPHIPODA				
Gammaridae	Gammarus pseudolimmnaeus Bousfield	U	100 ± 100	
GASTROPODA				
Physidae	Physa heterostropha Say	U	200 ± 200	10 ± 5
Planorbidae	Gyraulus parvus Say*	S	480 ± 220	100 ± 25

Table 6 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT	% OCCUR	MAX MEAN NUM/M2 ± SE	MAX MEAN WT ± SE (mg/m2)
HYDROZOA				
Hydridae	Hydra	U	200 ± 200	
NEMATODA*		C	24,200 ± 8,300	15 ± 2
TARDIGRADA*		S	3,200 ± 1,000	10 ± 4
TURBELLARIA		U	100 ± 100	

Percent Occurrence:
VC = very common, present in 80% or more of sediment samples.
C = Common, present in 50 - 79% of sediment samples.
S = Scarce, present in 20 - 49% of sediment samples.
U = Uncommon, present in less than 20% of sediment samples.

* = Made up at least 1% of sediment macroinvertebrate community on at least one date.

October 27 (Figure 24A), the community's greatest biomass was on July 13, the first date samples were collected, with 2,300 $mg \cdot m^{-2}$ (Figure 24B). On this date, aquatic insects made up 87% of the macroinvertebrate biomass (Figure 23). Macroinvertebrate abundance was about $9{,}000 \cdot m^{-2}$ to $10{,}000 \cdot m^{-2}$ during July and August of 1989. The sediment macroinvertebrate community then increased to a peak abundance of $28{,}700 \cdot m^{-2}$ on October 27, 1989 (Figure 24A), 75% of which were insects (Figure 23). The biomass, however, had declined from its July 13 peak to 1,000 $mg \cdot m^{-2}$ by October 7 (Figure 24B).

The sediment macroinvertebrate community, unlike the macroinvertebrate community in the vegetation, was moderately abundant in the spring of 1990, with 6,000 $individuals \cdot m^{-2}$ on April 19 (Figure 24A). 16,000 $macroinvertebrates \cdot m^{-2}$ were present by May 10, and the macroinvertebrate community reached $48{,}900 \cdot m^{-2}$ on July 13, 1990, the last date sediment samples were processed (Figure 24A). Nematoda made up 50% of the macroinvertebrate abundance on July 13, 1990 (Figure 23). Aquatic insects made up a much smaller percentage of the sediment macroinvertebrate community in 1990 than they did in 1989 (Figure 23).

Oligochaeta was the main component of the sediment macroinvertebrate community biomass on four of the five dates for which biomass was calculated, even though they never made up more than 40% of the macroinvertebrate

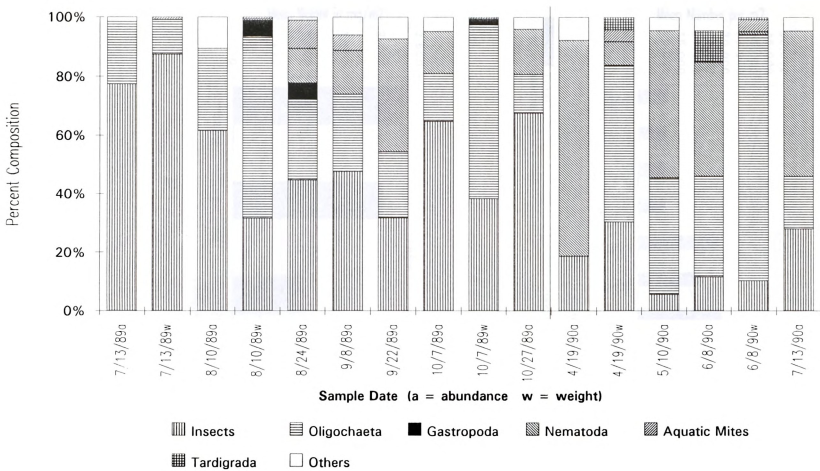


Figure 23. Composition of the sediment macroinvertebrate community of a Saginaw Bay coastal marsh, based on abundance and dry weight.

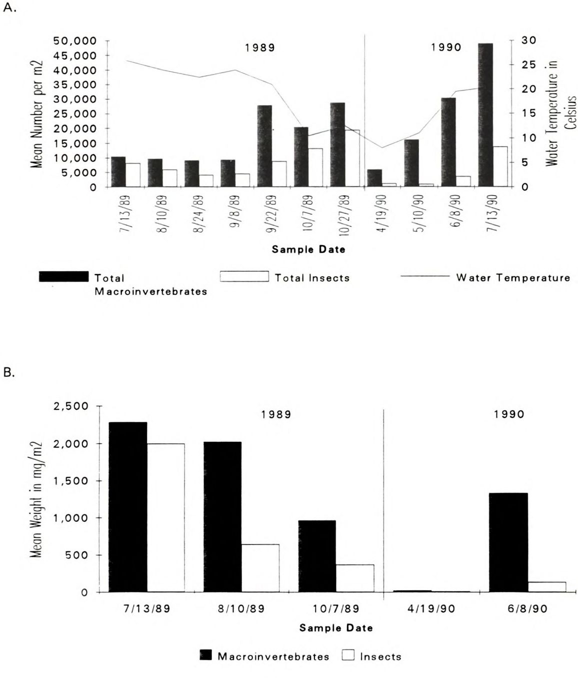


Figure 24. A. Abundance trends, and B. mean weight of macroinvertebrates and insects in the sediment community of a Saginaw Bay coastal marsh. In both graphs, the macroinvertebrate series includes the insects.

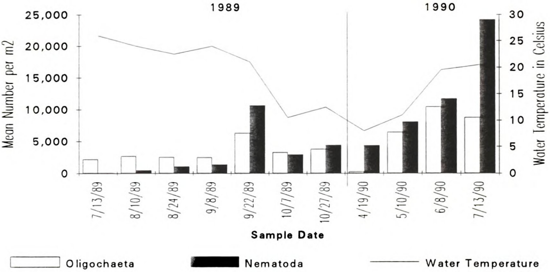
community's abundance (Figure 23). Oligochaete abundance in the sediment was between $2,000 \cdot m^{-2}$ and $4,000 \cdot m^{-2}$ on most dates in 1989 (Figure 25A). Oligochaeta densities were between $5,000 \cdot m^{-2}$ and $10,000 \cdot m^{-2}$ during 1990. Their greatest mean abundance and biomass in the sediments was on June 8, 1990, when there were $10,400 \cdot m^{-2}$, with a mean dry weight of $1,120\ mg \cdot m^{-2}$ (Table 6, Figure 25A).

Most of the oligochaetes in the sediments were Tubificidae. The genus Branchiura made up a large percentage of the oligochaete biomass on August 10 ($840\ mg \cdot m^{-2}$) and October 7 ($505\ mg \cdot m^{-2}$) at the 1989 site (Figure 26). Branchiura reached a peak mean density of $580 \cdot m^{-2}$ on October 7, 1989. The other Tubificidae reached mean abundances of $9,500 \cdot m^{-2}$ on June 8, 1990, with a calculated mean dry weight of $1,100\ mg \cdot m^{-2}$ (Table 4).

Nematoda were much more abundant in the sediment during 1990 than in 1989 (Figure 25A). They made up nearly 75% of the macroinvertebrates collected on April 19, 1990 (Figure 23), and reached a maximum mean abundance of $24,200 \cdot m^{-2}$ on July 13, 1990, (Figure 25A), with a mean biomass of $15\ mg \cdot m^{-2}$ (Table 6). At the 1989 site, Nematoda densities were low until September 22, and did not get as high as during 1990 (Figure 25A).

Aquatic mites were commonly collected in the marsh sediment, although they did not make up a major percentage of the macroinvertebrate community abundance or biomass (Table 6). Aquatic mite numbers were low in July and early

A.



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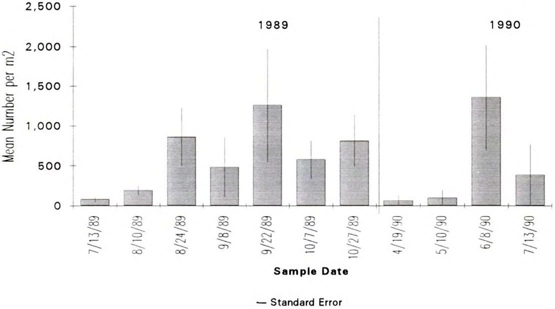


Figure 25. Abundance trends of A. Oligochaeta (Annelida) and Nematoda, and B. aquatic mites in the sediment community of a Saginaw Bay coastal marsh.

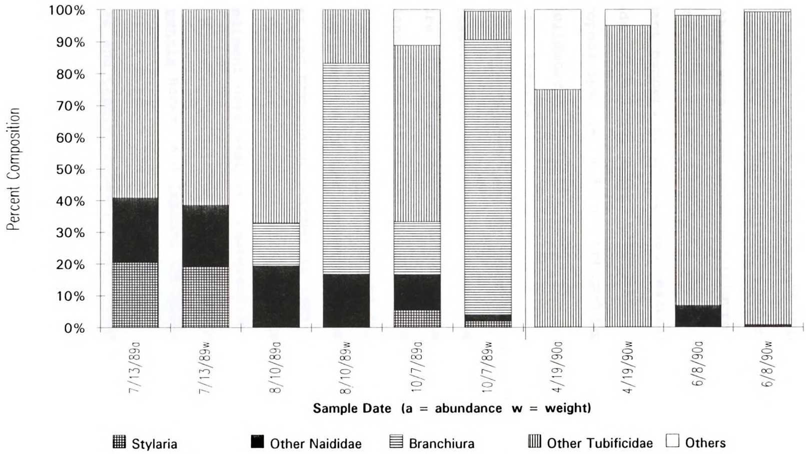


Figure 26. Composition of the Oligochaeta community in the sediment of a Saginaw Bay coastal marsh, based on abundance and dry weight.

August of 1989. After August 24 aquatic mite mean densities ranged between $500 \cdot m^{-2}$ and $1,500 \cdot m^{-2}$ (Figure 25B). Mite abundances were low during 1990, except on June 8. On this date there were $1,300$ mites$\cdot m^{-2}$ (Figure 25B), with a mean biomass of 50 $mg \cdot m^{-2}$ (Table 6). Other, less common and abundant members of the sediment macroinvertebrate community included Hirudinae, Hydra, Tardigrada, Turbellaria, two Gastropoda species, and the amphipod Gammarus pseudolimmnaeus Bousfield (Table 6).

2. Insects

Aquatic insects were an important part of the Quanicassee marsh sediment macroinvertebrate community (Figure 24). They made up 77% of the macroinvertebrate abundance, and 87% of the biomass on July 13, 1989, the first sampling date (Figures 23 and 24). Aquatic insects made up over 60% of the community numerically during early August and throughout October of 1989 (Figure 23).

More than 16 species of aquatic insects were collected in sediment core samples, representing 12 families (Table 7). However, only three taxa, Chironomidae, Caenis latipennis Banks, and Ishnura verticalis Say, were present in 50% or more of the samples (Table 7). Chironomidae larvae and Caenis (Ephemeroptera) nymphs dominated the sediment insect community abundance and biomass (Figure 27).

Aquatic insect numbers were low during the summer and early fall at the 1989 site (Figure 24A). They increased to their greatest abundance on October 27, 1989, with

Table 7. The insect taxa in the sediment of a Saginaw Bay, Lake Huron, coastal marsh: Percent occurrence, maximum mean number per m2, and maximum mean dry weight (mg/m2) for selected taxa.

FAMILY	OPERATIONAL TAXONOMIC UNIT		LIFE STAGE	% OCCUR	MAX MEAN NUM/M2 ±SE	MAX MEAN WT ± SE (mg/m2)
COLEOPTERA						
Elmidae	Stenelmis	a	A	U	100 ± 100	
Staphylinidae		a,b	A	U	100 ± 100	
COLLEMBOLA						
Isotomidae	Isotomurus tricolor Packard	a,b		U	55 ± 55	
DIPTERA						
Ceratopogonidae			L, P	S	590 ± 180	30 ± 15
Chironomidae*			L, P	VC	13,300 ± 4,500	
Chironominae	Chironomini		L		3,400 ± 850	770 ± 170
	Tanytarsini		L		4,200 ± 720	1,000 ± 200
Tanypodinae			L		1,000 ± 1,000	75 ± 20
EPHEMEROPTERA						
Baetidae	Baetis levitans McDunnough	a,b	L	U	30 ± 30	
Caenidae	Caenis amica Hagen*	a	L	U	4,600 ± 2,200	135 ± 40
	Caenis latipennis Banks*		L	C	9,700 ± 1,900	80 ± 30
HEMIPTERA						
Corixidae	Trichocorixa naias Kirkaldy	a,b	L,A	U	55 ± 55	

Table 7 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT		LIFE STAGE	% OCCUR	MAX MEAN NUM/M2 ± SE	MAX MEAN WT ± SE (mg/m2)
LEPIDOPTERA						
Pyralidae	Acentria niveus Olivier	a,b	L	U	30 ± 30	
ODONATA						
Coenagrionidae	Ishnura verticalis Say	a	L	C	390 ± 240	25 ± 6
TRICHOPTERA						
Hydroptilidae	Oxyethira	a,b	L	U	390 ± 240	
Leptoceridae	Oecetis cinerascens Hagen	a,b	L	U	200 ± 200	
	Oecetis species x	a	L	S	970 ± 530	25 ± 10

Percent Occurrence:
VC = very common, present in 80% or more of sediment samples.
C = Common, present in 50 - 79% of sediment samples.
S = Scarce, present in 20 - 49% of sediment samples.
U = Uncommon, present in less than 20% of sediment samples.

a = Present in 1989 sediment samples only.
b = Collected in sediment samples on one date only.

* = Made up at least 1% of sediment macroinvertebrate community on at least one date.

19,400 insects·m^{-2} (Figure 24A), most of which were Chironomidae and C. latipennis (Figure 27). Maximum mean insect biomass in the sediment community was on July 13, 1989, however, with 2,000 mg·m^{-2} (Figure 24B), comprised almost entirely of Chironomidae (Figure 27). Chironomidae made up 28% to 100% of the insects collected in the sediment on all dates (Figure 27). The Chironomidae reached their greatest densities in 1989 during July and at the end of October, with over 7,000 larvae·m^{-2} (Figure 28A). The Chironomidae made up most of the sediment macroinvertebrate community abundance and biomass during July (Figure 27).

Chironomidae larvae were the only insects found in the April 19, 1990, sediment samples (Figure 27). Their numbers and biomass were low this early in the year, only 1,100·m^{-2} and 7 mg·m^{-2}, respectively (Figure 28A). The density of Chironomidae in the sediments had greatly increased by July 13, 1990, with 13,300 larvae·m^{-2} (Figure 28A), when they again made up most of the sediment insect community (Figure 27).

Twelve Chironomini, five Tanytarsini, and three Tanypodinae taxa were identified from sediment samples on two dates (Table A-2). Orthocladiinae were not generally present in the sediment samples, with the possible exception of Cricotopus sylvestris gr. larvae (Table A-2). Larvae from the tribe Chironomini were the only Chironomidae found in the two samples from the 1990 site. Chironomini made up at least 20% of the Chironomidae collected from the

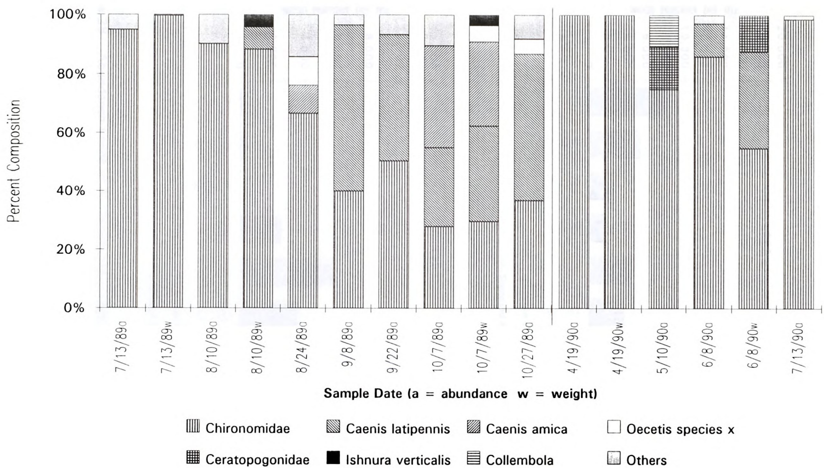
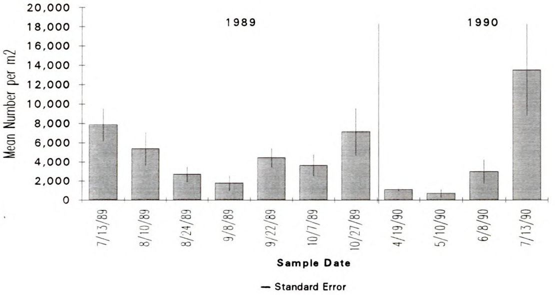


Figure 27. Composition of the sediment insect community of a Saginaw Bay coastal marsh, based on abundance and dry weight.

A.



B.

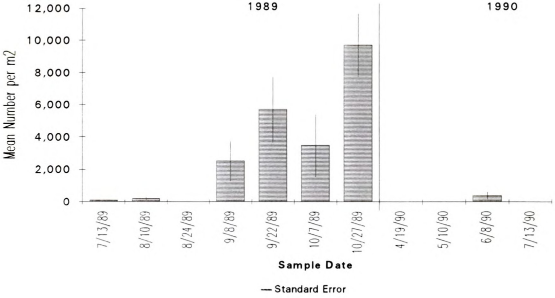


Figure 28. Abundance trends of A. Chironomidae (Diptera), and B. Caenis latipennis Banks (Ephemeroptera: Caenidae) in the sediment community of a Saginaw Bay coastal marsh.

sediments at the 1989 site (Figure 29). Chironomini larvae had their greatest abundance on July 13, 1989, with a mean of $3{,}400 \cdot m^{-2}$, and with a calculated mean dry weight of $770\ mg \cdot m^{-2}$ (Table 7).

Larvae of the tribe Tanytarsini made up the greatest percentage of the Chironomidae on July 13 and August 10, 1989 (Figure 29). However, Tanytarsini were not present in the other three sediment samples examined (Figure 29). The Tanytarsini also reached their peak mean densities in the sediment on July 13, 1989, with $4{,}200\ larvae \cdot m^{-2}$, and a mean biomass of $1{,}000\ mg \cdot m^{-2}$ (Table 7). Tanypodinae were the least abundant chironomid taxa in the sediment samples, but did comprise 50% of the chironomid biomass on October 7, 1989 (Figure 29). This was not their greatest biomass, however; on August 10, 1989, the Tanypodinae mean biomass reached $75\ mg \cdot m^{-2}$ (Table 7).

The only other dipteran family collected from the sediments of the Quanicassee marsh was the Ceratopogonidae (Table 7). This family made up less than 5% of the insect community abundance and biomass throughout 1989 (Figure 27). Ceratopogonidae numbers were very low in the sediment until September 22, after which they increased to their peak mean abundance of $600 \cdot m^{-2}$ on October 27, 1989 (Figure 30). Fourteen percent of the insects collected on May 10, 1990, were Ceratopogonidae larvae. Ceratopogonidae also comprised about 15% of the insect biomass on June 8, 1990 (Figure 27). May 10 and June 8 were the only two dates in 1990 when

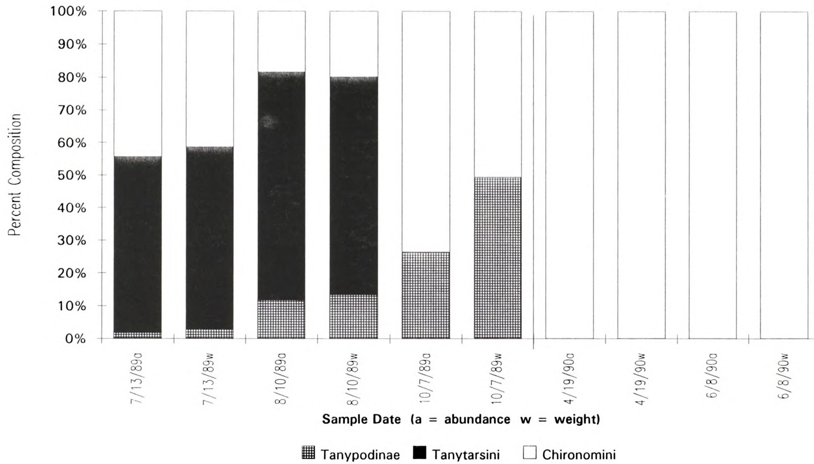


Figure 29. Composition of the Chironomidae community in the sediment of a Saginaw Bay coastal marsh, based on abundance and dry weight.

Ceratopogonidae were collected in the sediment (Figure 30).

Three species of Ephemeroptera, *Baetis levitans* McDunnough, *Caenis amica* Hagen, and *Caenis latipennis* Banks, were part of the insect community in the marsh sediment. The only species commonly collected was *C. latipennis* (Table 7). *C. latipennis* was only abundant in the sediment in the fall of 1989, but made up at least 50% of the insects collected during September and October (Figure 27). The two *Caenis* species together comprised 60% of the insect biomass on October 7, 1989 (Figure 27). By October 27, 1989, *C. latipennis* reached a mean abundance of 9,700 nymphs$\cdot m^{-2}$ (Table 7, Figure 28B).

The only Odonata collected in sediment core samples was the Coenagrionidae, *Ishnura verticalis* Say (Table 7). Nymphs of this damselfly species were often collected at the 1989 site, but were not found in the sediment core samples during 1990 (Table 7, Figure 30). *I. verticalis* reached its greatest mean abundance and biomass on September 22, 1989, with 400 nymphs$\cdot m^{-2}$ and 25 mg$\cdot m^{-2}$, respectively (Figure 30).

Only three species of Trichoptera were found in sediment samples, and two of them were only found once (Table 7). The third, an unidentified *Oecetis* species ("species x"), was fairly abundant on August 24 and October 27 of 1989, with nearly 1,000 larvae$\cdot m^{-2}$ (Figure 30). The other insects present in sediment samples were found on only one date, with the exception of *Stenelmis* (Elmidae), which was collected on two dates in 1989 (Table 7).

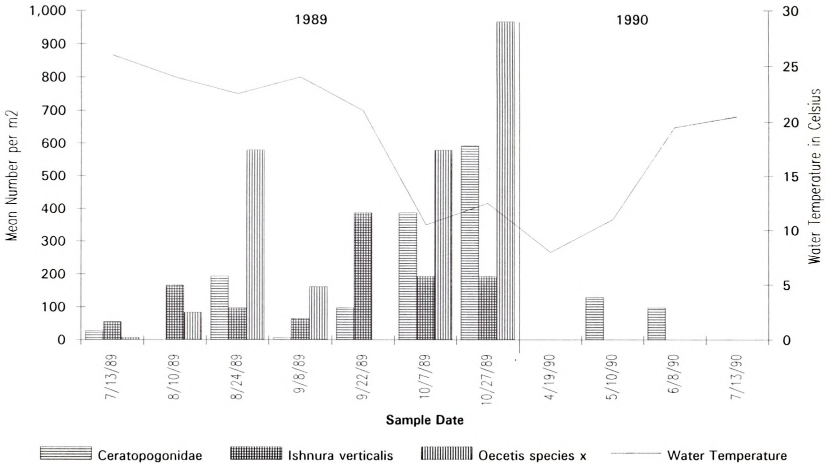


Figure 30. Abundance trends of selected insects in the sediment community of a Saginaw Bay coastal marsh.

3. Crustacean Zooplankton

The crustacean zooplankton community abundance and biomass peaks generally occurred on the same dates in the Quanicassee marsh sediment and the water column above it (Figures 31 and 32). The sediment zooplankton gradually rose to a peak abundance and biomass on October 27, 1989, with 356,700 zooplanktors$\cdot m^{-3}$ (Figure 31). The zooplankton had another peak of 239,400$\cdot m^{-3}$ on July 13, the last date the sediment was sampled (Figure 31). Total community biomass was also greatest on these two dates, with 5,300 $mg\cdot m^{-3}$ and 5,000 $mg\cdot m^{-3}$, respectively (Figure 32).

The sediment crustacean zooplankton community was dominated by chydorid Cladocera and Ostracoda, although harpactacoid and cyclopoid Copepoda were occasionally abundant (Figures 31 and 32). Twenty-two species of Cladocera, representing five families, were collected in sediment samples, but most of these were uncommon (Table 8). Only four species, Alona quadrangularis (O.F. Muller), Chydorus sphaericus (O.F. Muller), Eurycercus lamellatus (O.F. Muller), and Ilyocryptus spinifer Herrick, were present in more than 20% of the samples (Table 8). No calanoid copepods were collected, but two species of Cyclopoida were found. Harpactacoid copepods and ostracods were present in 80% or more of the sediment samples (Table 8).

Ten of the 22 species of Cladocera collected in sediment samples were present only in 1989, while six were

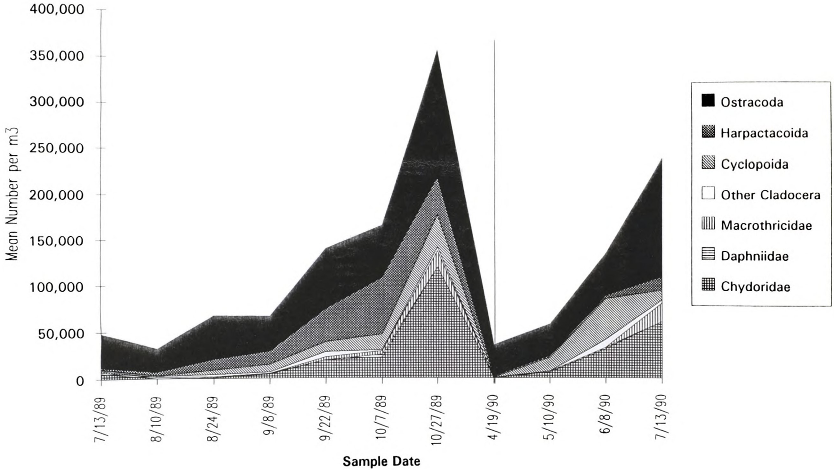


Figure 31. Abundance trends of crustacean zooplankton associated with the sediment of a Saginaw Bay coastal marsh.

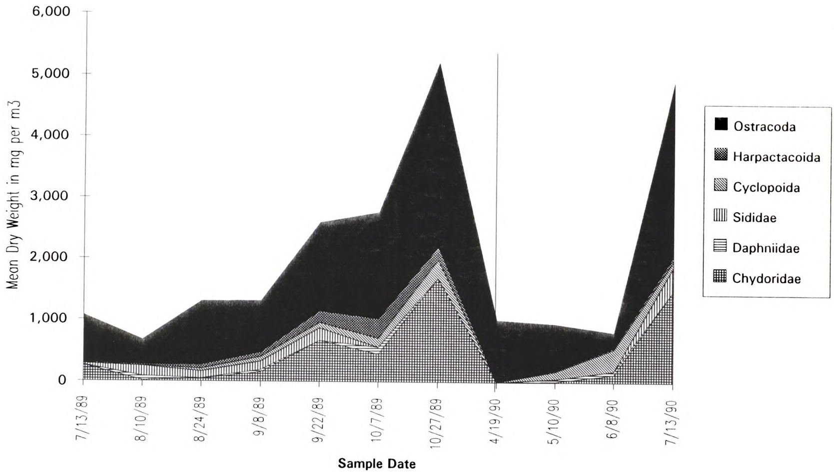


Figure 32. Mean dry weight of crustacean zooplankton associated with the sediment of a Saginaw Bay coastal marsh.

Table 8. The crustacean zooplankton in the sediment of a Saginaw Bay, Lake Huron, coastal marsh: Percent occurrence, maximum mean number per m3, and maximum mean dry weight (mg/m3) for selected taxa.

FAMILY	OPERATIONAL TAXONOMIC UNIT		% OCCUR	MAX MEAN NUM/M3 ± SE	MAX MEAN WT ± SE (mg/m3)
CLADOCERA					
Bosminidae	Bosmina longirostris (O.F. Muller)*	b,c	U	7,600 ± 2,100	14
	Eubosmina coregoni Baird	b,c	U	770 ± 770	
Chydoridae	Acroperus harpae Baird *	a	U	4,400 ± 3,000	25
	Alona quadrangularis (O.F. Muller)*		S	36,700 ± 9,900	1,400
	Camptocercus rectirostris Schodler*		U	2,200 ± 1,300	10
	Chydorus gibbus Lilljeborg*	b,c	U	1,500 ± 900	
	Chydorus sphaericus (O.F. Muller)*		S	83,600 ± 46,400	170
	Eurycercus lamellatus (O.F. Muller)*	a	S	4,900 ± 2,400	400
	Leydigia acanthocercoides Fischer*	b,c	U	21,700 ± 15,800	130
	Leydigia quadrangularis*	a	U	1,100 ± 900	7
	Monospilus dispar Sars*	b	U	1,700 ± 1,700	
	Pleuroxus procurvus Birge	a,c	U	110 ± 110	0
Daphniidae	Ceriodaphnia megalops Sars	a	U	1,100 ± 1,100	5
	Ceriodaphnia quadrangula (O.F. Muller)*	a,c	U	1,000 ± 750	5
	Daphnia galeata Birge	b,c	U	1,600 ± 1,100	55
	Scapholeberis kingi Sars	a,c	U	770 ± 770	2
	Simocephalus serrulatus Koch*	a	U	1,400 ± 1,400	70
	Simocephalus vetulus Schodler*	a	U	2,100 ± 2,100	110
Macrothricidae	Ilyocryptus spinifer Herrick*		S	20,100 ± 16,400	120
	Macrothrix laticornis Jurine*	a	U	14,600 ± 7,300	30
Sididae	Latona setifera (O.F. Muller)	a,c	U	3,100 ± 2,300	210
	Sida crystallina (O.F. Muller)*		U	3,100 ± 2,300	400

Table 8 (cont'd).

FAMILY	OPERATIONAL TAXONOMIC UNIT	% OCCUR	MAX MEAN NUM/M3 ± SE	MAX MEAN WT ± SE (mg/m3)
COPEPODA				
Cyclopoida	Acanthocyclops vernalis Fischer	C	28,300 ± 7,900	240
	Eucyclops agilis Koch	S	44,400 ± 17,800	360
Harpactacoida*		VC	61,900 ± 33,800	320
OSTRACODA*		VC	137,300 ± 31,100	3,000

Percent Occurrence:
VC = very common, present in 80% or more of sediment samples.
C = Common, present in 50 - 79% of sediment samples.
S = Scarce, present in 20 - 49% of sediment samples.
U = Uncommon, present in less than 20% of sediment samples.

a = Present only in 1989 sediment samples.
b = Present only in 1990 sediment samples.
c = Found in sediment samples on only one date.
* = Made up at least 1% of sediment zooplankton community on at least one date.

collected only in 1990 (Table 8). Five of the 10 species of Chydoridae were collected only in 1989, while three were part of the sediment community only in 1990 (Table 8). Cladocera abundance and biomass were fairly low until September 22, 1989 (Figure 33).

A. quadrangularis and C. sphaericus were abundant in the sediment by October of 1989 (Figure 33). Cladocera density and biomass in the sediment were often dominated by only one or two species (Figures 33 and 34). A. quadrangularis and C. sphaericus, together, comprised the October 27, 1989, abundance and biomass peak (Figures 33 and 34). C. sphaericus had a mean abundance of 83,600$\cdot m^{-3}$ on October 27 (Figure 33), but A. quadrangularis made up most of the cladoceran biomass with 1,200 mg$\cdot m^{-3}$ (Figure 34). A. quadrangularis was even more abundant (36,700$\cdot m^{-3}$) and had slightly greater biomass on July 13, 1990 (Figures 33 and 34). E. lamellatus, a Chydoridae, and Latona setifera (O.F. Muller), a Sididae, had abundance peaks on September 22, 1989, but were overwhelmed by the larger numbers of the other species (Figure 33). However, these two species made up over 50% of the cladoceran biomass on this date (Figure 34), due to their relatively large size (Table 2).

Very few Cladocera were present in sediment samples in the spring of 1990, but by July 13 there were 80,000 Cladocera$\cdot m^{-3}$ (Figure 33), with a mean biomass as great as that on October 27, 1989 (Figure 34). The most abundant species were A. quadrangularis, I. spinifer Herrick, and

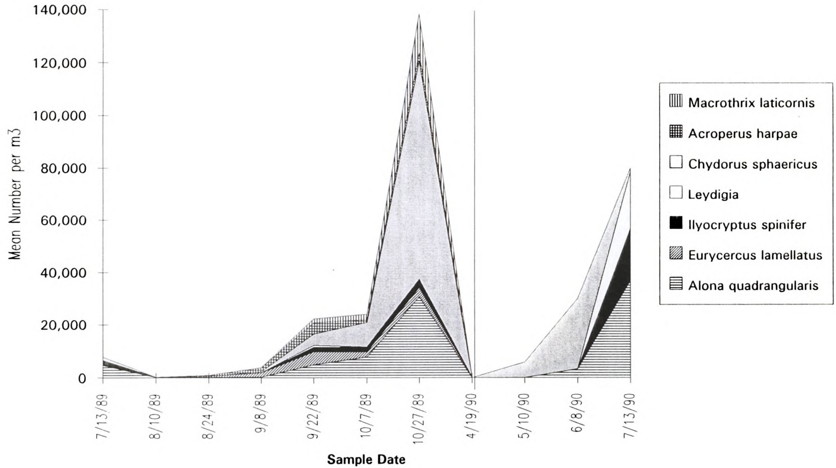


Figure 33. Abundance trends of selected Cladocera in the sediment of a Saginaw Bay coastal marsh.

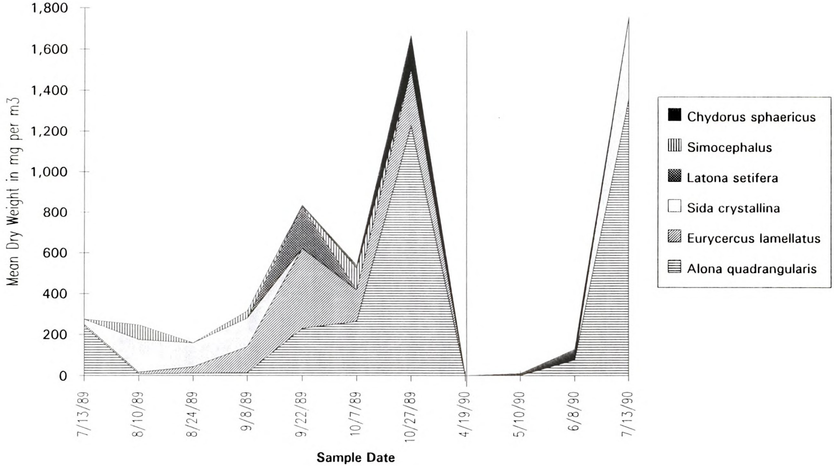


Figure 34. Mean dry weight of selected Cladocera in the sediment of a Saginaw Bay coastal marsh.

Leydigia (Figure 33), with most of the biomass consisting of A. quadrangularis (Figure 34).

Harpactacoid copepods were collected on all dates sediment core samples were taken (Table 8). They were abundant in sediment samples from August 24 through October 27, 1989, and on July 13, 1990 (Figure 31). Harpactacoida made up 37% of the zooplankton abundance on October 7, 1989 (Figure 31). However, they did not make up a large percentage of the zooplankton biomass on any date, due to their small size (Figure 32).

Cyclopoida were less abundant than the Harpactacoida in the fall of 1989, but were more abundant in the spring and summer of 1990 (Figure 31). Eucyclops agilis Koch made up 33% of the sediment zooplankton community abundance (with 44,400 individuals$\cdot m^{-3}$) and 43% by weight (360 $mg \cdot m^{-3}$) on June 8, 1990 (Figures 31 and 32). This species had its greatest density on June 8, and was the only cyclopoid copepod collected in the sediment. The only other Cyclopoida present in sediment samples was Acanthocyclops vernalis Fischer. A. vernalis reached its greatest abundance in the sediment community on October 27, 1989, with $28,300 \cdot m^{-3}$.

The Ostracoda most often dominated the sediment zooplankton community, however (Figures 31 and 32). They made up over 50% of the sediment zooplankton community abundance from July through September of 1989, and April, May, and July of 1990 (Figure 31). The Ostracoda also made

up over 50% of the zooplankton biomass on all dates except June 8, 1990 (Figure 31). The lowest ostracod density in the sediment during 1989 was 25,200$\cdot m^{-3}$ on August 10, 1989 (Figure 31). Ostracoda abundance generally remained between 40,000$\cdot m^{-3}$ to 50,000$\cdot m^{-3}$ until October 27, 1989. There were 137,300 ostracods$\cdot m^{-3}$ on October 27 (Figure 31), with a mean biomass of 3,000 mg$\cdot m^{-3}$ (Figure 32). Ostracod density was between 35,000$\cdot m^{-3}$ and 45,000$\cdot m^{-3}$ during April, May, and June of 1990 (Figure 32). There were 129,600 ostracods$\cdot m^{-3}$ on July 13, 1990 (Figure 32). Ostracod biomass was about 1,000 mg$\cdot m^{-3}$ on April 19, 1990, decreased to a low of 253 mg$\cdot m^{-3}$ on June 6, then quickly rose to 2,850 mg$\cdot m^{-3}$ during the peak abundance on July 13, 1990 (Figure 32). On October 27, 1989, and July 13, 1990, 57% of the sediment zooplankton community biomass was Ostracoda (Figure 32).

DISCUSSION

Great Lakes Coastal Wetland Habitat

Duffy and Batterson (1987) described Great Lakes coastal wetland areas as being an alternately benign and harsh environment for macroinvertebrates. The water in the emergent marsh freezes down to or into the sediments during the winter (Duffy and Batterson 1987). Thus, invertebrate numbers are very low in the spring, as can be seen in the Quanicassee marsh during April of 1990 (e.g. Figure 5A). However, the water in the shallow wetlands heats up faster than deeper water areas, and gets warmer during the summer. The warmer water allows the eggs of many species to hatch earlier, and enables faster growth (Duffy and Batterson 1987). The water temperature in the Quanicassee marsh generally stayed within 5°C of the air temperature, reaching 26°C in July or August of 1989 and 1990 (Table A-3). Dissolved oxygen in the Quanicassee marsh was never below 77% saturation, even during the warm summer temperatures (Table A-3).

The abundant macrophyte growth in Great Lakes coastal wetlands benefits invertebrates in several ways. Kelley and fellow researchers (1985) found that nutrients are stored as emergent macrophyte biomass for only a short period of time before they are re-released into the marsh ecosystem. Decomposition of the macrophyte litter from the previous year is generally completed by early summer, providing a pulse of nutrients for the marsh community (Duffy and Batterson 1987). The macrophytes provide a substrate for abundant periphyton growth during the summer, greatly increasing the surface area available for colonization. Scirpus americanus Pers. shoots in the Quanicassee wetland provided up to twice as much surface area for periphyton growth as did the sediments on which the bulrushes grew (McNabb et al. pers. comm.). In addition, macrophyte vegetation may provide macroinvertebrates with protection from fish predation (Hershey 1985).

The emergent vegetation also dampens wave action in the marsh, providing further physical protection to invertebrates. McNabb and fellow researchers (pers. comm.) found that wave height in the Quanicassee marsh was approximately 30 cm at 500 m from shore, the outer edge of the emergent marsh. Wave height had decreased to only 5 cm when it was measured 100 m closer to the shore, due to the damping effect of the S. americanus (McNabb et al. pers. comm.). The S. americanus growth, and concomitant decrease in wave action, helped to stabilize the sandy substrate of the emergent marsh.

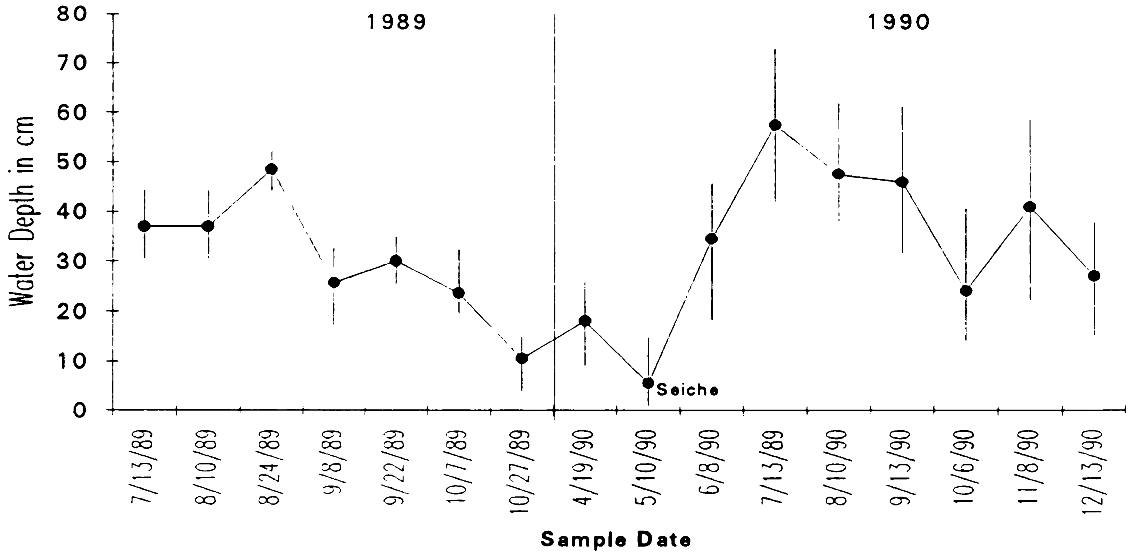
The coastal marsh can be a harsh environment even in the spring and summer, however. McNabb and fellow researchers (pers. comm.) measured a water level increase of

50 cm in the Quanicassee wetland in just three hours during a summer storm over Saginaw Bay. The water level decreased just as rapidly after the storm (McNabb et al. pers. comm.). Mean depth during my study in the Quanicassee marsh rarely exceeded 50 cm (Figure 35A). While collecting samples during a seiche associated with a spring storm on May 10, 1990, I measured water levels which averaged 15 cm lower than those on April 19, and 30 cm lower than water levels on June 8 (Figure 35A). This seiche left much of the marsh with only 3 to 5 cm of water covering the sediments (Figure 35A). Large areas of the stems of emergent macrophytes are exposed to the air when seiches such as this occur during the growing season, a potentially lethal situation for all aquatic life which cannot migrate quickly. In fact, the periphyton community on S. americanus was well-developed only on the basal portion of the stems, below the low water line (Batterson et al. 1991). This decreased the periphyton distribution to only 46% of the potentially colonizable area of the stems below the median water level (Batterson et al. 1991).

Macroinvertebrate Community

The macroinvertebrate community in the Quanicassee emergent marsh vegetation consisted mostly of Chironomidae, Caenis latipennis Banks and Caenis amica Hagen, Ishnura verticalis Say, Stylaria and other Naididae, Gyraulus parvus Say, Physa heterostropha Say, and Nematoda (Tables 3 and 4).

A.



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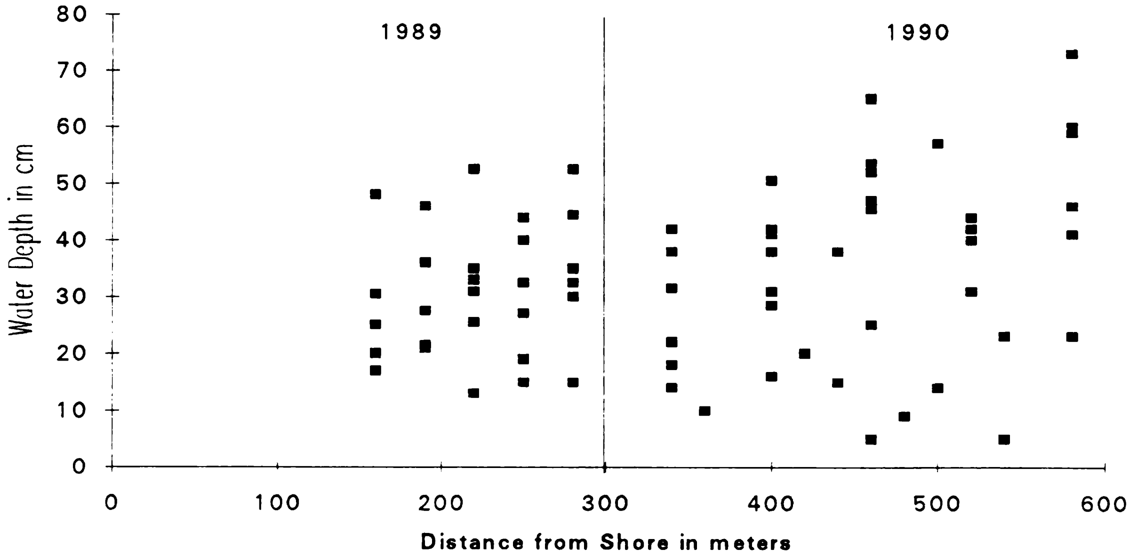

Figure 35. A. Average water depths, including highs and lows. B. Relationship between water depth and distance from shore for samples taken at both sites in the Quanicassee coastal marsh.

Certain Chironomidae, both Caenis species, and the Nematoda were also a large part of the sediment macroinvertebrate community (Figures 23 and 27). The only other numerous group in the sediment community was the oligochaete family Tubificidae (Figure 26).

The vegetation macroinvertebrate community was much more diverse than was the macroinvertebrate community in the sediment. This was especially true for the aquatic insects, where greater taxonomic resolution was possible (Table 4 versus Table 7). At least 54 species of aquatic insects were present in the vegetation community (Table 4), while only 16 were collected for the sediment community (Table 7). Nearly four times the number of insect species were present in the vegetation than were collected from the sediment, even when only 1989 samples are compared (Tables 4 and 7). The substrate of the S. americanus marsh was predominantly unstable sand, likely limiting the macroinvertebrate species able to reside there. Therefore, the sampling scheme for macroinvertebrates in such an emergent marsh should include sampling the vegetation in some manner. This habitat would be especially important during the late summer and fall, when most of the macroinvertebrates are associated with the senescent vegetation and detritus.

Sweep samples taken with an aquatic dip net did not prove adequate for sampling the vegetation macroinvertebrate community in the Quanicassee marsh. The data in Tables 3 and 4 give the impression that the dip net sampling provided a fair indication of the vegetation macroinvertebrate taxa and their relative abundance. However, sweep net sampling with the dip net consistently underrepresented the abundance of most taxa, and completely missed 21 species of aquatic insects (Table 4), plus 4 other macroinvertebrate species (Table 3). Many of the taxa that were missed were taxa that are generally considered macroinvertebrates. On the other hand, the dip net did capture seven insect species that did not show up in the more quantitative Gerking-Mittelbach samples (Table 4).

The sediment invertebrate community should not be neglected, either. Each sediment-core sample covered only about half the area of each vegetation sample, perhaps accounting for part of the difference in the number of taxa between the two sample types. Macroinvertebrate peak biomass, however, was greater in the Quanicassee marsh sediment than in the vegetation (Figures 5B and 24B). For example, macroinvertebrate biomass in the vegetation community reached a maximum of 1,500 $mg \cdot m^{-2}$ (Figure 5B), while in the sediment, biomass reached 2,300 $mg \cdot m^{-2}$ (Figure 24B). The greatest abundance of macroinvertebrates in the sediment was also as large as the highest density in the vegetation, around $50{,}000 \cdot m^{-2}$ (Figures 5A and 24A).

One of the most abundant macroinvertebrate groups in both the vegetation and the sediment was the Oligochaeta. The difference in the abundance of macroinvertebrates in the vegetation between 1989 and 1990 (Figure 5A) was largely due to the greater number of oligochaetes present in 1990 (Figure 6A). The Oligochaeta in the vegetation community were often dominated by the Naididae (Figure 7). The Naididae genus Stylaria, found only in the vegetation, was easily identified at 10x by its distinctive appearance: a short worm with a pointed "snout" on its anterior end and large clear "slots" perpendicular to its length on each segment. Stylaria fossularis was the only oligochaete Duffy and Batterson (1987) found in the wetlands along the St. Mary's River.

Kairesalo and Koskimies (1987) suggested that Stylaria lacustris L. migrated between the sediments and the vegetation, overwintering in the sediments and returning to the vegetation in early June. The data from the Quanicassee marsh partially support their suggestion. Stylaria were abundant in the vegetation on July 13, August 10, and October 7 of 1989, and August 10, 1990 (Figure 7). They were present in low densities on June 8 and October 6, 1990, but were not found in the April and December, 1990, vegetation samples. This provides evidence that Stylaria migrate onto the macrophytes early in the summer. However, Stylaria were not collected from the marsh sediment. If Stylaria overwinter there, they must move deeper than 15 cm into the sediment, or sampling was inadequate to detect them.

Oligochaetes and chironomid larvae in the Quanicassee marsh vegetation community were often found associated with

S. americanus. Early in the growing season these groups were on the macrophyte stems, associated with the periphyton. Krecker and Lancaster (1933) reported finding over 15,000 invertebrates$\cdot m^{-2}$ of substratum covered by Scirpus, with most of the invertebrates being chironomid larvae found on the plants. Smock and Stoneburner (1980) documented a correlation between greater density of chironomids and oligochaetes on wetland macrophytes and increasing decomposition of the vegetation. This correlation was probably related to either increased diatom density (Fairchild 1981) or increased microbial growth (Beckett et al. 1992). The number of Chironomidae and Oligochaeta found inside the cells of S. americanus in the Quanicassee marsh also increased with increasing macrophyte decomposition. These taxa were very rarely found inside green, growing vegetation, but as the vegetation began to yellow, greater numbers were found inside plant cells; the highest numbers were found in the most decomposed vegetation (personal observation).

Oligochaetes in the Quanicassee marsh vegetation reached a maximum mean density of 15,400$\cdot m^{-2}$ on July 13, 1990 (Figure 5A). This density is within the maximum abundance of 13,000 to 21,000 oligochaetes$\cdot m^{-2}$ reported by Kairesalo and Koskimies (1987), but the peak in that study occurred in early June, rather than in mid-July.

The high density of Chironomidae larvae on July 13, 1990, Quanicassee marsh vegetation community (12,000$\cdot m^{-2}$,

Figure 11A) was due to the presence of large numbers of very tiny larvae in Gerking-Mittelbach samples. Chironomidae abundance on this date was probably underestimated, since a mesh size of 250 μm was used. The tiny larvae would have been lost if they had not been entangled in mats of algae. Duffy and Batterson (1987) found that up to 16% of chironomid abundance could be lost using 250 μm mesh.

The large numbers of tiny Chironomidae larvae on July 13, 1990, indicate recruitment of another generation into the population. Thus, emergence for one or several of the more abundant species of chironomids in the Quanicassee marsh had taken place in the months before this, when the density of chironomid larvae was low (Figure 11A). There may also have been emergence and recruitment of young into the population in the late summer and/or fall (Figure 11A). Judd (1953) reported that the emergence of various chironomid species occurred throughout the spring, summer, and fall in the Dundas Marsh, Lake Ontario. Many species exhibited maximum emergence periods in May and/or August (Judd 1953).

Judd (1953) collected quite a few more species of Diptera emerging from the Dundas marsh, including species in the families Tipulidae and Culicidae. While very few Diptera other than Chironomidae and Ceratopogonidae were collected in the Quanicassee marsh (Table 4), there may have been other species in the dense beds of cattail, Typha latifolia L. No samples were taken in these cattail beds due to the density of the vegetative growth.

Oligochaetes in the marsh vegetation samples were often in much better condition than those in sediment samples. Oligochaetes in the sediment samples were more likely to be Tubificidae (Figure 26). The Tubificidae were more fragile than the Naididae that often dominated the vegetation samples, and were more likely to be fragmented. Therefore, Oligochaeta and Tubificidae densities in the sediment were likely overestimated, especially the large Branchiura. The biomass estimates, which were based on mean fragment size, should be more accurate. Oligochaete biomass in the sediments was greatest on June 8, 1990, with 1,100 $mg \cdot m^{-2}$ (Table 6). Nalepa and Quigley (1983) reported 1,005 $mg \cdot m^{-2}$ of oligochaete biomass in the 10 to 15 m depth of Lake Michigan in 1977, but they found twice this biomass in the same area in 1976.

Nematoda were much more abundant in the Quanicassee marsh sediment than in the vegetation (Figures 5A and 25A). They reached a mean density of $24,200 \cdot m^{-2}$ (Figure 25A), with a mean biomass of 14 $mg \cdot m^{-2}$ on July 13, 1990 (Table 6). Nalepa and Quigley (1983) reported Nematoda densities ten times greater than this from the 11 m depth of Lake Michigan, where Nematoda dominated the abundance and biomass of the meiobenthos. Nematoda reached mean densities of $200,000 \cdot m^{-2}$ (1976) to $300,000 \cdot m^{-2}$ (1977), with a biomass of

150 $mg \cdot m^{-2}$(1977) to 215 $mg \cdot m^{-2}$ (1976) (Nalepa and Quigley 1983).

The greatest density of Tardigrada in the Quanicassee marsh sediment, $3{,}200 \cdot m^{-2}$ (Table 6), was similar to the lower numbers reported from Lake Michigan sediments. Tardigrada were collected from the sediments of Lake Michigan at densities of $1{,}000 \cdot m^{-2}$ to $4{,}300 \cdot m^{-2}$ (Nalepa and Quigley 1983). Up to 320,000 tardigrades$\cdot m^{-2}$ were present during one year, however (Nalepa and Quigley 1983). At the Quanicassee marsh, the peak density of 26,800 tardigrades$\cdot m^{-2}$ occurred in the vegetation community on December 13, 1990 (Table 3, Figure 3).

Nalepa and Quigley (1983) observed that the Tardigrada were more abundant in the deeper areas they sampled, and speculated that the tardigrades preferred the colder temperatures. The presence of Tardigrada in samples from the Quanicassee marsh also appeared to be inversely related to water temperature: Tardigrada were present in 1990 samples from April through June and October through December. Many Tardigrada in the December samples were observed to be carrying egg sacs.

Caenis latipennis and C. amica were the two most abundant species of Ephemeroptera in the emergent wetlands near Quanicassee. These species were common and abundant in both the vegetation and sediment communities (Figures 15A and 28B). The Caenis are listed as sprawlers on the sediment, and are classified as collector-gatherers and/or scrapers in Merritt and Cummins (1984). These nymphs are fair swimmers, and were likely exploiting the abundant periphyton growth on the macrophytes, which would account for their presence in both communities. These *Caenis* species overwinter as nymphs in association with aquatic detritus. The nymphs are apparently able to withstand freezing temperatures, since most areas of the Quanicassee marsh probably freeze down to the sediment. Middle instar *C. latipennis* nymphs were collected on April 19, 1990, indicating their ability to overwinter (Figure 15A). The *Caenis* probably had emerged from the Quanicassee marsh by August, judging from nymphal size and the presence of exuvia in certain samples. The fall (September/October) caenid abundance peak (Figures 15A and 28B) was composed of many small, and therefore early instar, nymphs. Judd (1953) reported that the species of *Caenis* present in the Dundas Marsh emerged from June through early September, with the peak emergence in mid-July.

No other Ephemeroptera were abundant, and only two other genera were collected. Judd (1953) also found that the Ephemeroptera in the Dundas Marsh were mainly *Caenis*. The gill covers of the *Caenis* nymphs may have been one factor which allowed them to survive in the Quanicassee marsh. Siltation and sediment resuspension were high in parts of this marsh at all times during the year. Turbidity was high throughout the entire marsh during the spring, however, due to sediment resuspension from wave action and the spawning of carp (C. carpio; V. Brady pers. observ.). The emergent vegetation (Scirpus and Typha) reduced wave action to such an extent during the summer that the marsh was effectively divided into nearshore and offshore zones. McNabb and coworkers (pers. comm.) discovered that the nearshore zone in the Quanicassee marsh had high water clarity (turbidity <1 NTU), while the offshore zone had low clarity (turbidity ≈ 50 NTU). The transition between the two water types occurred quite sharply between 300 and 400 m from shore (McNabb et al. pers. comm.). The gill covers possessed by the Caenis species would have prevented silt from clogging their gills, while also offering physical protection against abrasion.

The Caenis species appeared less abundant at greater water depths (Figure 15B). However, the few dates on which depth exceeded 50 cm occurred during July (Figure 35A), when very few Caenidae were collected at any depth (Figure 15A). No relationship emerged when Caenis abundance was graphed against distance from shore. This indicates that turbidity due to sediment resuspension was not a problem for the Caenis, since samples in 1990 were taken out to nearly 600 m from shore. At least three of the five vegetation and sediment samples collected on each date were taken within the highly turbid offshore zone during 1990.

However, for Ishnura verticalis Say (Odonata: Coenagrionidae) there apparently was a relationship between abundance and distance from shore (Figure 14B). I.

verticalis was abundant at all sampling locations at the 1989 site, which was within the nearshore, clear water, zone (Figure 14B). The offshore zone began approximately 400 m from shore at the 1990 site, just offshore of a very dense T. latifolia bed. I. verticalis was much less abundant beyond 400 m from shore (Figure 14B). Since two-thirds of the samples in 1990 were collected from 400 m and beyond, this may account for the difference in abundance of I. verticalis between the two years.

I. verticalis may not have been sensitive to the increased turbidity, per se. I. verticalis is dependent on dense stands of macrophytes (Duffy and Batterson 1987), and macrophyte density, especially submergents, decreased beyond 400 m from shore in the Quanicassee marsh (Batterson et al. 1991). Decreased macrophyte density allowed greater wave action in the marsh, the cause of the high turbidity. The water movement itself may have been affecting the nymphs, or they may have been subject to increased fish predation in areas of lower density vegetation. The factor(s) influencing the distribution of I. verticalis need further investigation.

I. verticalis represented the Odonata almost exclusively in the Quanicassee marsh (Table 4). Judd (1953) found more Anisoptera and Enallagma species, especially Enallagma ebrium, emerging from the Dundas marsh on Lake Ontario. I. verticalis was present in the Dundas marsh, but only in very low numbers (Judd 1953). Adult dragonflies were often seen flying about the Quanicassee marsh, but only three nymphs were collected during the two year study. The Anisoptera nymphs may have been living in the stands of T. latifolia present at both sites. These cattail beds were very dense, and were not sampled.

The isopod Asellus forbesi Williams was present only in the samples taken nearest the shore at the 1990 site (Table 3). This nearshore area was protected from wave action by a large bed of T. latifolia, allowing detritus particles and organic muck to accumulate. Detritus did not build up anywhere else samples were taken in the marsh, due to the constant wave action.

Aquatic mites were often more abundant in the sediment than the vegetation community (Figures 5B and 25B). Some mites hunt by standing on the sediment with forelegs raised, waiting for prey to swim past (Smith 1991). Other mites are fast swimmers, pursuing their zooplankton prey, while still others eat Chironomidae larvae (Smith and Cook 1991). Immature mites also undergo metamorphosis in the sediments (Smith and Cook 1991). The mites in the Quanicassee marsh were probably also hunting or waiting for hosts while clinging to the vegetation, thus accounting for their presence in the vegetation community. Krecker and Lancaster (1933) found aquatic mites associated with Potamogeton and Cladophora, but not Scirpus; Potamogeton was present in protected locations at both sites.

The macroinvertebrate community in the Quanicassee marsh was both numerically abundant and had high biomass on occasion (Figures 5 and 24). Schneider, Hooper, and Beeton (1969) estimated the macrobenthic standing crop in the offshore areas of Saginaw Bay to be 3-4 $g \cdot m^{-2}$. The large mayfly, Hexagenia, disappeared from Saginaw Bay since that 1956 study, but probably would not have inhabited the shifting sands of the emergent marsh. However, the macroinvertebrate biomass in the vegetation and sediment of the Quanicassee marsh during the summer and fall was close to the 3-4 $g \cdot m^{-2}$ reported by Schneider et al. (1969) for deeper areas of the Bay in 1956 (Figures 5B and 24B). This high macroinvertebrate biomass would make these marshes particularly valuable as sources of food for higher trophic levels.

There were 49,700 macroinvertebrates$\cdot m^{-2}$ associated with the Quanicassee marsh vegetation on December 13, 1990 (Figure 5A), with a calculated mean weight of 1,500 $mg \cdot m^{-2}$ (Figure 5B). These numbers provide a better sense of the macroinvertebrate abundance the marsh supported when they are converted to larger areas of the emergent marsh. Based on these estimates, every 0.5 km^2 of emergent marsh vegetation along the southeastern shore of Saginaw Bay supported an average of 12.4 billion macroinvertebrates, and a macroinvertebrate biomass of 375 kg, on December 13, 1990. There were 7.6 billion macroinvertebrates$\cdot$0.5 km^{-2} on July 13, 1990, while in early October of 1989, the macroinvertebrate biomass in the vegetation community was around 180 kg·0.5 km^{-2}.

The Quanicassee marsh sediment community supported an even greater macroinvertebrate abundance and biomass during the summer. There were an estimated 12.2 billion macroinvertebrates·0.5 km^{-2} in the sediment on July 13, 1990, while on July 13, 1989, macroinvertebrate biomass was about 575 kg·0.5 km^{-2}. These numbers suggest that the wetland areas of Saginaw Bay may provide fish with an important source of food, since yellow perch (Perca flavescens Mitchill), as well as many other fish species, feed on wetland macroinvertebrates (e.g. Clady 1973).

Crustacean Zooplankton

The crustacean zooplankton community in the Quanicassee marsh vegetation reached its maximum abundance, approaching 250,000·m^{-3}, on October 27, 1989 (Figure 17). Watson and Carpenter (1974) reported a maximum of 324,000 zooplankton·m^{-3} in Saginaw Bay during August and September. Watson and Carpenter (1974) found that Cladocera were more abundant than Copepoda or Ostracoda in plankton tows in Saginaw Bay, as was the case for the Quanicassee vegetation-associated zooplankton community (Figure 17). The Saginaw Bay biomass peak was estimated as only 800 mg·m^{-3} AFDW (Watson and Carpenter 1974), while the marsh zooplankton community reached a peak of 15,000 mg·m^{-3} due to the larger size of the zooplankton in the marsh vegetation (Figure 18).

Clearly, the marsh supports a much higher standing crop of zooplankton than does the open bay.

The zooplankton community in the emergent wetlands associated with the St. Mary's River was also dominated by Cladocera (Duffy and Batterson 1987). Many of the same species present in that wetland were present in the vegetation community of the Quanicassee marsh, but were generally an order of magnitude more abundant in the St. Mary's wetland (Table 9). The dominant Cladocera species in the emergent wetlands of the St. Mary's river mouth delta were A. harpae, C. sphaericus (the most abundant), E. lamellatus, and S. serrulatus (Duffy and Batterson 1987). These species were also very abundant in the Quanicassee marsh vegetation community, along with A. quadrangularis, C. rectirostris, C. megalops, S. crystallina, and S. vetulus (Table 5, Figure 19).

C. sphaericus reached the greatest abundance of any Cladocera in the Quanicassee and St. Mary's River marshes (Duffy and Batterson 1987). C. sphaericus may have been significantly underrepresented in samples from the Quanicassee marsh. This species is very small, and a 250 μm sieve was used with all vegetation and sediment samples. C. sphaericus, while associated with the littoral zone, is a water column resident (Fairchild 1981). This explains its abundance in both Gerking-Mittelbach and sediment core samples (Table 9), since both types included the water column in samples.

Table 9. Comparison of the abundance of selected zooplankton collected in this study, with their abundance in other wetlands, as reported in the literature. Includes notes on species' status in Lake Huron, if known.

SPECIES	THIS STUDY MEAN NUMBER PER M3		LITERATURE	STATUS
	Vegetation	Sediment	MEAN NUMBER PER M3	in LAKE HURON + +
CLADOCERA				
Acroperus harpae	59,200	4,400	365,000	Not reported
Alona quadrangularis	17,900	36,700	29,000	Not reported
Bosmina longirostris	10,000	7,600	13,000	2,120*-142,000
Camptocercus rectirostris	25,900	2,200	64,000	1,700
Ceriodaphnia megalops	13,400	1,100	<1000	
Chydorus sphaericus	107,200	83,600	1,042,000	8,000-15,000
Eurycercus lamellatus	14,400	4,900	106,000	Low numbers
Ilyocryptus spinifer	11,100	20,100	<1000	
Pleuroxus denticulatus	2,500	0	32,000	Not reported
Pleuroxus procurvus	7,400	110	38,000	Not reported
Sida crystallina	30,700	3,100	44,000	5,000
Simocephalus serrulatus	19,400	1,400	222,000	Not reported
COPEPODA				
Acanthocyclops vernalis	32,600	28,700	67,000	Uncommon*
Eucyclops agilis	24,100	44,400	Rare	
Eurytemora affinis	11,000	0	2,600	Invader

Cladocera - Abundance in the St. Mary's River wetlands, Lake Superior; Duffy and Batterson 1987.
Copepoda - Abundance in the Old Woman Creek estuary, Lake Erie; Krieger and Klarer 1991.
+ + = As reported in Balcer et al. 1984, unless marked with *; abundances in #/m3.
* = Data from Watson and Carpenter 1974.

A. quadrangularis is a littoral zone resident which, as of 1984, had not been reported from Lake Huron (Table 9, Balcer et al. 1984). It reached a mean abundance of nearly 37,000$\cdot m^{-3}$ in the Quanicassee marsh sediment community, however (Table 9), and made up approximately 25% of the sediment zooplankton community biomass on two dates (Figure 34). This species is associated with littoral zone sediments and may even burrow (Dodson and Frey 1991), making it unlikely to be captured in plankton tows.

E. lamellatus is another littoral zone resident, one which climbs on macrophytes (Dodson and Frey 1991). Samples from the Quanicassee marsh vegetation provide evidence of depth/distance from shore correlations with the abundance of this species (Figure 21). The highest abundances of E. lamellatus occurred in the midrange of water depths sampled (Figure 21A), and near the middle distances from shore (Figure 21B). E. lamellatus grazes on periphyton (Fairchild 1981), but the periphyton community was not well-developed on S. americanus stems in the nearshore areas due to the frequent seiches (Batterson et al. 1991). Thus, E. lamellatus would not be expected to be as abundant in the shallower areas closer to shore. Possible explanations for the decreasing abundance of E. lamellatus with increasing water depth and distance from shore include 1) that this species, like I. verticalis, was associated with dense stands of macrophytes. Macrophytes were generally sparser beyond 400 m in the Quanicassee marsh. Or 2) E. lamellatus abundances were inversely correlated with turbidity or wave action, which were much higher in the offshore portion of the marsh (McNabb et al. pers. comm.).

Highest abundances for S. crystallina, on the other hand, appeared to be shifted toward deeper water and greater distances from shore in the Quanicassee marsh (Figure 22). S. crystallina is largely confined to the littoral zone, where it attaches to macrophytes using a cervical gland (Fairchild 1981). From this fixed position, S. crystallina filter-feeds on phytoplankton, rather than grazing periphyton like most other littoral Chydoridae (Fairchild 1981). S. crystallina had low abundances in water depths less than about 22 cm, but was abundant in water depths greater than 35 cm (Figure 22A). S. crystallina abundance was also correlated with distance from shore at the 1989 site (Figure 22B). This was not true at the 1990 site (Figure 22B), where the mean depth was generally greater (Figure 35B). S. crystallina may be limited to depths greater than the water level change of ±20 cm of the commonly occurring seiches (Batterson et al. 1991), or to depths at which it can migrate out with the outgoing water during larger seiches.

Ostracoda generally dominated the abundance and biomass of the Quanicassee marsh sediment zooplankton community (Figures 31 and 32). Ostracoda reached densities around $130{,}000 \cdot m^{-3}$ in the sediment at both the 1989 and 1990 sites (Figure 31), much higher than their numbers in the vegetation community (Figure 17). Duffy and Batterson (1987) found even greater numbers in the St. Mary's River marsh, with 201,000 ostracods$\cdot m^{-3}$ (Table 9). As with many of the smaller Cladocera and Copepoda, ostracod densities in the Quanicassee marsh may have been underrepresented due to the use of 250 μm mesh. Ostracoda were commonly collected in Gerking-Mittelbach samples, although they were not as abundant in the vegetation community (Table 5). Mbahinzineki et al. (1991) found that at least some littoral ostracods climb on macrophyte vegetation to graze the periphyton community, retreating to the sediments as a refuge from fish predation.

The mean filtering rates of several Cladocera species were obtained or calculated from the literature to provide a rough estimate of the filtering capacity of the most abundant Cladocera present in the Quanicassee marsh. The Cladocera were most abundant in the Quanicassee marsh vegetation community on October 27, 1989, and August 10, 1990. C. sphaericus was the principal filtering Cladocera present on October 27, 1989 (Figure 19). (A. quadrangularis and A. harpae were also abundant, but are periphyton grazers (Fairchild 1981)). Lair (1989) calculated a mean individual filtering rate of 403 $\mu l\cdot hr^{-1}$ for C. sphaericus. There were 107,200 C. sphaericus$\cdot m^{-3}$ on October 27 (Table 5), yielding a filtration rate of approximately 1,040 $l\cdot day^{-1}$. That is, on this date C. sphaericus was capable of filtering all the water in the marsh in one day.

S. crystallina, Simocephalus, and C. megalops were the most abundant filtering Cladocera present on August 10, 1990 (Figure 19). The average individual filtration rate for C. megalops was about 408 $\mu l \cdot hr^{-1}$ (Lair 1989). With 13,400 C. megalops$\cdot m^{-3}$ present on August 10 (Table 5), the calculated filtration rate was 130 $l \cdot day^{-1}$. The individual filtration rates for S. crystallina and Simocephalus were calculated from the general formula for Cladocera derived by Knoechel and Holtby (1986):

$$F=11.695L^{2.48}$$

F = filtering rate in $ml \cdot ind^{-1} \cdot day^{-1}$
L = Average length of Cladocera in mm

S. crystallina had a mean length of 1.038 mm on August 10, giving a individual filtering rate of 12.8 $ml \cdot day^{-1}$. There were 30,700 S. crystallina$\cdot m^{-3}$ present on August 10 (Table 5), which yields an approximate filtering rate of 394 $l \cdot day^{-1}$. Simocephalus, with an estimated average length of 0.9 mm, had a calculated individual filtering rate of 9 $ml \cdot day^{-1}$. With 32,800 Simocephalus$\cdot m^{-3}$ present on August 10, their filtration rate was calculated to be 295 $l \cdot day^{-1}$. Thus, a rough estimate of the filtration capacity of these Cladocera on August 10, 1990, was 820 $l \cdot day^{-1}$, or three-fourths of the water in the marsh per day on this date.

SUMMARY AND CONCLUSIONS

The invertebrate community of a coastal marsh on Saginaw Bay, Lake Huron, near Quanicassee, Michigan, was sampled from July through October of 1989, and April through December of 1990. Vegetation-water column, sediment core-water column and aquatic dip net samples were taken between 150 and 600 m from the shore in water depths averaging 30 to 60 cm. The emergent marsh was characterized by the emergent bulrush, Scirpus americanus Pers., growing on a substrate predominately composed of shifting sand, rather than the organic muck typical of many emergent marshes.

The macroinvertebrate community in the vegetation was represented by 54 species of insects and 11 other orders of macroinvertebrates. Macroinvertebrates in the marsh vegetation reached their greatest abundance and biomass on December 13, 1990, with 50,000 individuals$\cdot m^{-2}$ and 1.5 $g\cdot m^{-2}$ of biomass.

This community was dominated by Chironomidae, Oligochaeta, and the Ephemeroptera genus Caenis. Chironomid larvae were the most abundant insects, making up 80% of all insects collected on several dates. They reached mean densities of 12,000$\cdot m^{-2}$ on July 13, 1990, in the vegetation community. Chironomid larvae, along with oligochaetes and nematodes, were quite numerous in the cells of senescent S. americanus vegetation.

In addition to the Chironomidae, the Ephemeroptera, Caenis latipennis Banks and Caenis amica Hagen, were among the more common and abundant insects present in the marsh. However, taxa that were more unique to this community included the Coleoptera, Hemiptera, Lepidoptera, and the Odonata, Ishnura verticalis Say, which are all associated with aquatic macrophytes. I. verticalis was less abundant in the marsh beyond 400 m from shore. This area of the marsh was in the highly-turbid offshore zone, with lower macrophyte density and increased wave action. The correlation between I. verticalis abundance and distance from shore needs further investigation.

The oligochaetes in the vegetation community were represented mainly by Naididae, with the genus Stylaria present only in the vegetation. Oligochaeta reached mean densities of $15{,}500 \cdot m^{-2}$ in the vegetation community on July 13, 1990.

The macroinvertebrate community in the marsh sediment was less diverse, probably because of the instability of the marsh sediment. Sixteen species of insects and 9 other orders of macroinvertebrates were represented in the marsh sediment. The sediment community had its highest density and biomass during July, with 48,900 macroinvertebrates$\cdot m^{-2}$ on July 13, 1990, and a biomass of 2.3 $g \cdot m^{-2}$ on July 13, 1989. The sediment macroinvertebrate community consisted mostly of Chironomidae, Oligochaeta, and Nematoda, with the chironomids and oligochaetes making up most of the community's biomass. Oligochaetes in the sediments reached a maximum mean biomass of 1,100 $mg \cdot m^{-2}$, and a density of $10{,}000 \cdot m^{-2}$, on June 8, 1990, with most of these being Tubificidae. The sediment macroinvertebrate community reached a mean weight 1.5 times greater than the maximum mean weight of the macroinvertebrates in the vegetation community.

The Quanicassee marsh supported 7.6 billion macroinvertebrates in every 0.5 km^2 area of emergent vegetation, and every 0.5 km^2 area of sediment supported 12.2 billion macroinvertebrates on July 13, 1990. The macroinvertebrate biomass in every half square kilometer of marsh sediment averaged 575 kg on July 13, 1989.

The most abundant crustacean zooplankton in the Quanicassee marsh were Acroperus harpae Baird, Alona quadrangularis (O.F. Muller), Camptocercus rectirostris Schodler, Ceriodaphnia, Chydorus sphaericus (O.F. Muller), Eurycercus lamellatus (O.F. Muller), Sida crystallina (O.F. Muller), Simocephalus, Acanthocyclops vernalis Fischer, Eucyclops agilis Koch, Harpactacoida, and Ostracoda. Cladocera dominated the abundance and biomass of the vegetation zooplankton community, but the sediment zooplankton community was dominated by the Ostracoda.

C. sphaericus reached the highest abundances of any zooplanktor in either the vegetation or sediment communities. *S. crystallina* dominated the vegetation community biomass, while Ostracoda dominated the sediment zooplankton biomass. *S. crystallina* abundance was positively correlated with water depths greater than 35 cm. *E. lamellatus* abundance, on the other hand, seemed to be related more to distance from shore than water depth, and was greatest between 250 and 400 m from shore. The abundance correlations of both of these Cladocera need further investigation.

The zooplankton in the Quanicassee marsh sediment reached a mean abundance of 356,700$\cdot m^{-3}$ on October 27, 1989, with a biomass of 5 $g \cdot m^{-3}$. Zooplankton community abundance in the vegetation on this date was nearly 250,000 zooplankton$\cdot m^{-3}$. Zooplankton biomass in the vegetation was greatest on August 10, 1990, with 15.1 $g \cdot m^{-3}$. The macroinvertebrate and zooplankton communities in the vegetation and sediment of the Quanicassee marsh probably serve as an important food resource for fish inhabiting Saginaw Bay.

APPENDIX

Table A-1. Operational taxonomic unit and identification references for invertebrates collected from a Saginaw Bay coastal marsh near Quanicassee, Michigan.

INVERTEBRATE	OPERATIONAL TAXONOMIC UNIT	REFERENCES
INSECTA		
Coleoptera	Genus	White 1984; Moore 1974
Collembola	Species	Christiansen 1984; Waltz 1979
Diptera	Family	Merritt and Schlinger 1984; Teskey 1984
Chironomidae	Tribe (but see Table A-2)	
Ephemeroptera	Species	Edmunds 1984; Provonsha 1990; Bergman and Hilsenhoff 1978
Hemiptera	Genus/species	Pohlhemus 1984; Hilsenhoff 1970, 1986
Lepidoptera	Genus	Lange 1984; McCafferty and Minno 1979
Odonata	Genus/species	Westfall 1984; Walker 1953
Trichoptera	Genus/species	Wiggins 1977, 1984; Morse 1984; Nielsen 1948;
ANNELIDA		
Hirudinae	Class	Pennak 1978
Oligochaeta	Family/Genus	Pennak 1978

Table A-1 (cont'd).

INVERTEBRATE	OPERATIONAL TAXONOMIC UNIT	REFERENCES
AQUATIC MITES	---	---
CRUSTACEA		
Amphipoda	Species	Pennak 1978; Holsinger 1972.
Cladocera	Species	Brooks 1959; Balcer 1984; Dodson and Frey 1991
Copepoda		
Calanoida/Cyclopoida	Species	Balcer 1984
Harpactacoida	Order	
Gastropoda	Species	Pennak 1978; Brown 1991; Harman and Berg 1971
Isopoda	Species	Pennak 1978
Ostracoda	Class	Pennak 1978
HYDRIDAE	Class	Pennak 1978
NEMATODA	Phylum	Pennak 1978
TARDIGRADA	Phylum	---
TURBELLARIA	Phylum	Pennak 1978

Table A-2. Chironomidae present in vegetation and sediment samples on June 30 (preliminary sampling) and July 13, 1989, in a Saginaw Bay, Lake Huron, coastal marsh.

CHIRONOMIDAE*	VEGETATION MEAN NUMBER PER M^2	SEDIMENT MEAN NUMBER PER M^2
Chironominae		
Chironomus	13	2306
Cladopelma laccophila group	0	28
Cladotanytarsus mancus group	14	2417
Cladotanytarsus vanderwulpi gr.	0	28
Cryptotendipes	0	48
Dicrotendipes	14	214
Einfeldia species group A	27	83
Einfeldia species group B	0	110
Einfeldia species group C	0	359
Endochironomus	62	207
Glyptotendipes species group A	7	0
Glyptotendipes species group B	7	0
Glyptotendipes species group C	64	48
Microchironomus	0	55
Parachironomus arcuatus group	7	0
Paracladopelma	0	483
Paratanytarsus species	71	407
Polypedilum	17	28
Tanytarsus	98	1340
Virgatanytarsus	0	28
Orthocladiinae		
Corynoneura	174	0
Cricotopus bincinctus group	7	0
Cricotopus sylvestris group	1564	249
Cricotopus species	17	0
Orthocladius	13	0
Orthocladius s. str.	34	0
Thienemanniella	20	0
Tanypodinae		
Ablabesmyia	7	55
Procladius (Holotanypus)	7	55
Tanypus	34	83

* Identification references: Simpson and Bode 1980, and Wiederholm 1983.

Table A-3. Water quality of a Saginaw Bay, Lake Huron, coastal marsh near Quanicassee, Michigan.

Date	Air Temp (° C)	Water Temp (° C)	pH	Dissolved Oxygen ($mg \cdot l^{-1}$)	Percent Saturation (%)	Chloride ($\mu g \cdot l^{-1}$)	Total Alkalinity ($mg \cdot l^{-1}$)
1989							
7/13	27.0	26.0	7.7	--	--	--	--
8/10	22.0	24.0	7.4	7.8	95	76.5	190
8/24	20.5	22.5	7.7	7.8	94	41.2	113
9/8	28.5	24.0	7.5	7.2	87	59.2	156
9/22	20.0	21.0	7.8	7.7	89	49.4	148
10/7	10.0	10.5	7.8	10.0	93	62.5	158
10/27	18.5	12.5	7.6	9.3	90	53.5	159
Mean	--	--	7.6	8.3	91.2	57.05	154
± S.E.			±0.07	±0.46	±1.19	±4.95	±10.1
1990							
4/19	11.0	8.0	8.1	11.8	103	62.8	178
5/10	9.0	11.0	8.0	9.0	84	49.6	163
6/8	17.5	19.5	7.7	6.9	77	31.3	117
7/13	19.5	20.5	8.0	8.0	91	24.4	108
8/10	21.0	26.5	7.8	8.1	102	29.4	125
9/13	31.0	24.0	9.8	8.1	98	33.2	113
10/6	21.5	18.0	7.7	10.1	110	37.0	128
11/8	3.5	4.0	7.8	12.4	98	40.1	155
12/13	1.0	1.0	8.1	14.5	105	30.7	128
Mean	--	--	8.10	10.26	98.9	39.31	138.5
± S.E.			±0.13	±0.75	±3.84	±3.93	±8.08
Overall Mean	--	--	7.93	9.52	96.0	45.96	144.31
± S.E.			±0.13	±0.54	±2.58	±3.71	±6.40

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