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Abstract: Back Bay contains two distinct populations of zooplankton. One is a micro-zooplankton component composed primarily of ciliated protozoans, the other is a macrozooplankton group dominated by calanoid copepods, crustacean larvae, rotifers and polychaete larvae. Seasonal periods of abundance for these zooplankters are identified and discussed.

Introduction

The purpose of this study is to determine the seasonal composition and abundance of zooplankton in Back Bay over a one year period. Emphasis is directed to both the microzooplankton (<150 µm) and the larger zooplankton (>150 µm) populations.

Methods

Zooplankton samples were taken twice a month from April 1987 through October 1987, once monthly from November through February 1988, and twice in March 1988, at four stations in Back Bay. These stations were the same used for phytoplankton collections (No's. 3, 9, 20, 22). Refer to Figure 1 in Marshall (1991) of this proceedings for their location. For zooplankton >150 µm a Clarke-Bumpus plankter sampler, with a #10 filter cup and net, was towed at the surface (<1m) for one minute, with the sample preserved immediately in buffered formalin. Each sample concentrate was brought to a known volume by adding distilled water. After mixing, a 1 ml subsample was taken and placed in a Sedgewick-Rafter cell for microscopic examination and counting. A total of three 1 ml replicates from each sample was counted and averaged. For the micro-zooplankton (<150 µm), a surface (< 1m) water sample of one liter was taken at each station. This was preserved in Lugols solution and allowed to settle for five days. This was followed by three siphoning and settling periods where the original volume was reduced to 20 ml. The final concentrate was placed in a settling chamber of an inverted Zeiss plankton microscope and subsequently analyzed using a random field minimum count basis. Initially, three different preservatives were evaluated for use with the microzooplankton. These were buffered formalin, Bouins, and Lugols solution. A study over several collection periods indicated the Lugols gave a greater representation of animal forms and a more distinct presentation of their features. Lugols was then selected as the preservative to be used for this component during the study.

All counts were determined on a per unit volume (no./l) basis. The majority of the taxonomic forms were grouped into major categories during the monthly analyses. However, more specific identification of the major species, was conducted once for each season at two of the stations.

Results

The monthly temperature, salinity, and secchi readings for this period are given in Marshall *et al.* (1988). The seasonal temperature pattern is typical for temperate waters. A temperature rise during spring continued to a summer high of 30.5°C in July 1987 and a low of 0.5°C in January 1988. In January there were periods when a thin layer of ice formed over the Bay, but this was a rare event that would last for only brief periods. Similar temperature ranges and seasonal patterns were found at each station. Lowest salinities occurred during late winter and early spring when they were associated with spring rains and enhanced drainage into Back Bay. Highest salinities were in late summer and fall, before declining into winter. Station differences were common. The less saline waters were generally found at Station 9. This site was farthest from the southeast region of the Bay that connects with Currituck Sound. Similar seasonal patterns were at each station, but the degree of differences between stations varied throughout the year. The salinity range for this year of study was from 1.1 o/oo (January 1988) to 3.2 o/oo (August 1987). Both of these extremes were noted at Station 9.

The secchi disc readings followed similar patterns at the four stations. Highest readings (greatest transparency) were in summer, declining into fall to winter lows, before rising in spring. Light entry was consistently deepest at Station 22 and least at Station 9. A major influence on the secchi readings was the changing seasonal patterns of wind direction and the intensity of prevailing winds. Whenever wind speed was excessive (>10 knots) there was upwelling action, increased turbidity, and often added salt water to the water column. Increased saline water entry was most common when there were strong winds of long duration from the south or southeast. Secchi readings ranged from 7.6 cm in January 1988 to 40.6 cm in June 1987.

A list of the zooplankton categories with their mean sample concentrations for the year and the percentage of this total to the whole collection are given in Table 1. This table lists both the macrozooplankton and microzooplankton components. The macrozooplankton consisted of mainly copepods, cladocerans, rotifers, and a miscellaneous zooplankton category. This last grouping included polychaete larvae, insect larvae, harpacticord copepods, crab zoea and a variety of other crustacean larval forms. Within the microzooplankton, the major components were tintinnids and other protozoan microzooplankton.

Microzooplankton

Seasonal fluctuations were common for the microzooplankton, with the different stations having generally similar patterns (Fig. 1). However, higher concentrations were common at the more southern stations (Stations 20 and 22). Peak concentrations were in late spring 1987, then decreased into summer and fall, with lowest numbers in mid-winter. A sharp increase in abundance occurred in late winter and continued into spring 1988. There were also seasonal differences in abundance within this group. The tintinnids had their highest concentrations in spring, decreasing during summer and fall, with lowest numbers in winter (Fig. 2). A comparison of the seasonal concentrations for the tintinnids averaged 256 cells/l during winter, compared to the spring when their mean count was 36,825 cells/l. The other protozoan ciliates had peak concentrations in late winter and early spring, decreasing in late spring during the tintinnid pulse of growth, with fluctuating maxima during summer and fall (Fig. 3). There appeared to be a slight pattern of inverse abundance relationships between the tintinnids and the other ciliates. However, the other ciliates (non-tintinnids) maintained high, but fluctuating concentrations throughout the sampling period.

The individual tintinnids possessed distinct seasonal patterns of abundance. These were typically a spring high, that decreased into summer and fall, with a low during winter. In contrast, there were generally overlapping patterns among the other ciliates. However, these other protozoans were most abundant in summer, with several having a second peak in late fall to early winter.

Macrozooplankton

The general trend of macrozooplankton abundance in Back Bay indicated highest concentrations from late winter through spring, decreasing into summer, rising again in fall, to decrease into winter (Fig. 4). This general pattern was found at each station, with Station 9 having the highest concentrations. The rotifers were most abundant during spring with lowest numbers during summer and fall (Fig. 5). The polychaete larvae were most common in fall and winter in contrast to spring-summer lows. The copepods had more of a spring-fall bimodal pattern of greatest abundance, with lower concentrations for summer-winter (Fig. 6). Mean seasonal concentrations of the miscellaneous zooplankton category indicated a winter abundance low, but varied, having higher concentrations during other seasons, with a general high during summer. Many constituents in this category were crustacean larvae, that preceded the adult concentrations noted for copepods in the fall. The seasonal concentrations for the different zooplankton categories are given in Table 2. In Table 3 a more detailed identification of the macrozooplankton is given seasonally at Station 9 and 22. Among the copepods, *Acartia tonsa* was most common, with highest numbers during spring. *Acartia clausi* was also noted in spring, but not at other times. *Eurytemora affinis*, *Cyclops vernalis* and *Cyclops varicans rubellus* were found during several seasons, but were most common in winter, or spring. The nauplii and copepodites were most abundant in late winter and spring.

There were distinct seasonal patterns among the different rotifers. For instance, spring development was noted for *Brachionus angularis*, *Filinia* sp. and *Keratella quadrata*. *Brachionus calyciflorus* peaked in late winter-early spring, but was also common in low concentrations other times of the year. In contrast, *Keratella cochlearis* had major development in late winter and through spring, before declined into summer. Among other groups, the nauplii were common year-round, but had their highest concentrations in spring at

Station 9, with numbers decreasing southward to Station 22. The crab zoea were noted only in summer and early fall, with several insect larvae present in late spring and summer. The cladocerans (e.g. *Bosmina coregoni, B. longirostris*) did not represent a major community in Back Bay, and occurred only sporadically in low numbers.

Conclusions

Zooplankton populations in Back Bay may be divided into two distinct groups. One is a microzooplankton component that is dominated by a variety of ciliated protozoans, and characterized by an abundant tintinnid component. The other group is represented by a macrozooplankton assemblage, characterized by copepods, rotifers and a miscellaneous group of zooplankters.

Seasonal patterns of abundance were identified for various zooplankton components. Spring assemblages were characterized by calanoid copepods, rotifers, tintinnids, and other protozoan ciliates. Concentrations generally decreased with the increased temperatures and salinities of summer, with the protozoan ciliates and various copepod larval stages becoming more abundant. In fall, salinity values and temperatures decreased with the calanoid copepods added to the summer assemblages. Populations decreased to a winter low, but calanoid copepods were again increasing in abundance and the polychaete larvae reached a seasonal peak. At this time, there also occurred the lowest temperature, salinity and secchi disc readings for the year.

In general, the macrozooplankton had their lowest total concentrations at Station 22, with abundance and temporal patterns for this group similar at the four Bay stations. The microzooplankton had greater station differences, but similar temporal patterns of abundance. Highest concentrations of microzooplankton were associated with Station 9. Only a few zooplankters seasonally dominated these samples which were characterized by low species diversity. This may be a product of the oligohaline nature of the habitat that is seasonally variable and appears to favor only a limited number of dominant species throughout the year. There is also little opportunity for an exchange pattern to be developed through the Back Bay - Currituck Sound connection. This reduces any flushing action and the entry of additional species into Back Bay from nearby estuaries. Freshwater species entering from canals, ditches or creeks into Back Bay apparently have a low survival rate for their appearance in the oligohaline waters are rare.

However, the zooplankton of Back Bay are not unique and these species are found in other regional estuarine habitats (Birdsong *et al.*, 1988) and there appears to be a lower species diversity in comparison to these other locations. The microzooplankton were abundant throughout the year. However, more detailed study of the microzooplankton is needed in relation to their identity and seasonal contribution to the trophic status of Back Bay. Additional investigations of predator-prey relationships throughout the trophic steps within Back Bay and over a multi-year period are also considered essential for a clearer understanding of this Bay ecosystem. In relation to recent plankton studies in Back Bay, Marshall (1988, 1991) conducted a two year investigation (1986-87) of the phytoplankton, with the second year overlapping this zooplankton study. In general, there were highest phytoplankton concentrations during summer, with these cells composed mainly of cyano-bacteria less than 5μm in size. This season was the period of decreasing populations for many of the macrozooplankton (e.g. rotifers, copepods), with the tintinnids also in decline, but other ciliates were increasing in number. The larger phytoplankters had limited periods of high abundance with major development during spring for the diatoms and chlorophyceans, in spring and fall for cryptomonads, and in summer for dinoflagellates. The growth pulses for many of the larger phytoplankters and zooplankters were similar. The smaller pico-nanoplankton ($<5\ \mu$m) cyanobacteria were common year-round, and their major pulses coincided with the high abundance of the non-tintinnid ciliates. However, these relationships cannot adequately be interpreted without more annual data and the inclusion of other predators in the analysis, such as the various life stages of the local fish populations.

Acknowledgement

Appreciation is given to David Bird for providing taxonomic and general information on the macrozooplankton observed in this study. Special thanks are also extended to Mitchell Norman from the Virginia Department of Game and Inland Fisheries who assisted during sample collections and provided data on salinity, temperature and secchi readings during this study. This study was funded by the Virginia Department of Game and Inland Fisheries.

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Table 1. Mean sample concentrations and percent of total composition for zooplankton at Back Bay stations from April 1987 to March 1988 in numbers per liter and percent of the annual total concentration.

	Concentration	%
CILIATA		
Ciliate #1	7738.515	10.48
Ciliate #2	9185.065	12.44
Ciliate #3	211.780	0.29
Ciliate #4	171.872	0.23
Ciliate #5	17846.126	24.18
Ciliate #6	12000.427	16.26
Tintinnid #1	15059.037	20.40
Tintinnid #2	657.115	0.89
Tintinnid #3	9650.667	13.07
CRUSTACEA: CLADOCERA		
Bosmina coregoni	0.033	0.00
Bosmina longirostris	0.001	0.00
Bosmina sp.	0.001	0.00
Ceriodaphnia sp.	0.001	0.00
Cladoceran (unident.)	0.001	0.00
Eurycerus sp.	0.001	0.00
Latonopsis occidentalis	0.001	0.00
CRUSTACEA: COPEPODA		
Copepod #1	1.297	0.00
Copepod #2	0.069	0.00
Copepod #3	0.001	0.00
Harpacticoid copepods	0.001	0.00
CRUSTACEA: OTHERS		
Nauplii (unident.)	0.094	0.00
Ostracod (unident.)	<0.001	0.00
ROTIFERRA		
Ascomorpha sp.	0.001	0.00
Asplanchna sp.	<0.001	0.00
Brachionus angularis	0.001	0.00
Brachionus calyciflorus	0.735	0.00
Brachionus sp.	<0.001	0.00
Filinia sp.	0.027	0.00
Keratella cochlearis	0.259	0.00
Keratella quadrata	0.129	0.00
Pleurotrocha sp.	<0.001	0.00
Rotifer (unident.)	<0.001	0.00
ZOOPLANKTON: MISC		
Brachyuran larvae	<0.001	0.00
Crab zoea	0.001	0.00
Insect larvae	<0.001	0.00
Magalopa	<0.001	0.00
Polychaete larvea	0.426	0.00
Zooplanter #1	498.502	0.68
Zooplanter #2	45.760	0.06
Zooplanter #3	7.200	0.01
Zooplanter #4	20.640	0.03
Zooplanter #5	711.198	0.96
Zooplanter #6	7.680	0.01

Table 2. Mean seasonal concentrations for zooplankton categories at the four Back Bay Stations between April 1987 and March 1988. Numbers are individuals per liter.

	Winter	Spring	Summer	Fall
		STATION 3		
I. **Macrozooplankton**				
Cladocerans	——	0.52	——	——
Copepods	0.66	1.78	0.73	1.99
Misc. Zooplankton	86.94	576.00	1,472.00	819.54
Rotifers	0.14	1.94	0.01	0.01
II. **Microzooplankton**				
Tintinnids	256.00	36,825.60	12,681.50	15,872.00
Other Ciliates	50,714.66	22,105.60	17,323.00	19,302.40
		STATION 9		
I. **Macrozooplankton**				
Cladocerans	0.01	0.01	0.01	——
Copepods	1.47	1.50	0.91	——
Misc. Zooplankton	43.92	4,288.01	2,363.67	1,254.87
Rotifers	0.22	2.23	0.01	0.01
II. **Microzooplankton**				
Tintinnids	554.66	10,352.00	24,957.83	19,251.20
Other Ciliates	30,848.00	36,835.60	45,511.33	21,708.80
		STATION 20		
I. **Macrozooplankton**				
Cladocerans	——	——	——	——
Copepods	0.44	1.25	1.01	1.16
Misc. Zooplankton	2.02	921.60	2,538.66	1,664.56
Rotifers	0.03	1.57	0.01	0.01
II. **Microzooplankton**				
Tintinnids	768.00	77,081.60	17,418.66	21,273.60
Other Ciliates	32,768.08	32,780.80	27,472.16	26,624.01
		STATION 22		
I. **Macrozooplankton**				
Cladocerans	0.01	0.01	——	0.01
Copepods	1.51	1.15	0.77	0.40
Misc. Zooplankton	87.34	409.61	1,350.33	
Rotifers	0.01	2.14	0.01	0.01
II. **Microzooplankton**				
Tintinnids	682.66	35,315.20	9,005.83	7,398.40
Other Ciliates	43,477.33	36,416.00	32,079,83	21,516.80

Table 3. Seasonal concentrations of macrozooplankton at Stations 9 and 22 between April 1987 and January 1988 in numbers of individuals per liter.

	Station 9				Station 22			
Date:	4/29	7/22	10/23	1/25	4/29	7/22	10/23	1/25
Acartia tonsa	0.37	0.19	0.02	0.02	0.09	0.05	——	0.24
Acartia clausi	0.12	——	——	——	——	——	——	——
Acartia copepodite	2.75	0.43	3.51	——	1.25	1.20	0.10	0.03
Eurytemora affinis	0.25	——	——	——	0.12	——	——	0.03
Cyclops vernalis	1.15	——	——	——	0.06	——		
Cyclops varicans rubellus	——	0.01	——	——	0.06	0.01	——	0.06
Orthocyclops modestus	——	——	——	——	——	0.01	——	——
Canthocamptus spp.	0.03	——	——	——	——	——	——	——
Unk. harpacticoida	——	0.01	——	——	——	——	——	——
Copepod nauplii	0.25	0.01	0.18	——	——	0.01	0.01	——
Rithropanopeus harrisi zoea	——	0.01	——	——	——	——	——	——
Palaeomonetes zoea	——	0.01	——	——	——	——	——	——
Podon polyphemoides	——	——	——	——	——	——	0.01	——
Barnacle nauplii	0.12	0.01	——	——	16	——	——	——
Spionidae nectochaete	——	——	0.37	——	——	0.01	2.81	——

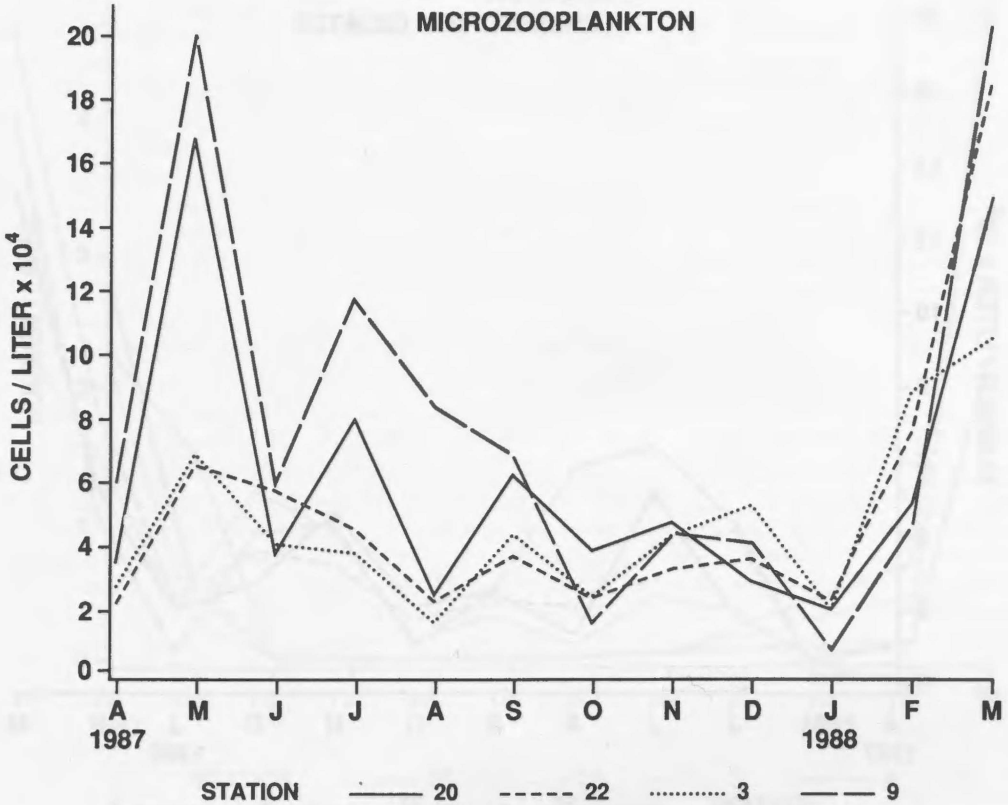

Figure 1. Concentrations of microzooplankton from April 1987 through March 1988 at stations in Back Bay.

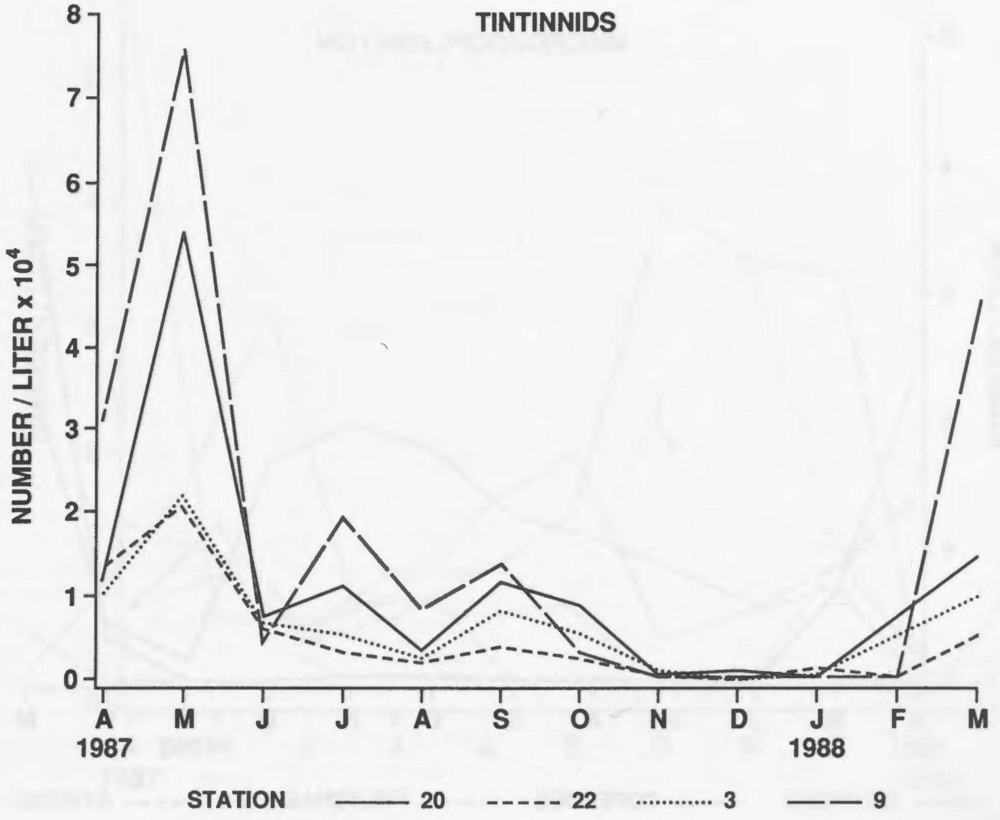

Figure 2. Concentrations of tintinnids from April 1987 through March 1988 at stations in Back Bay

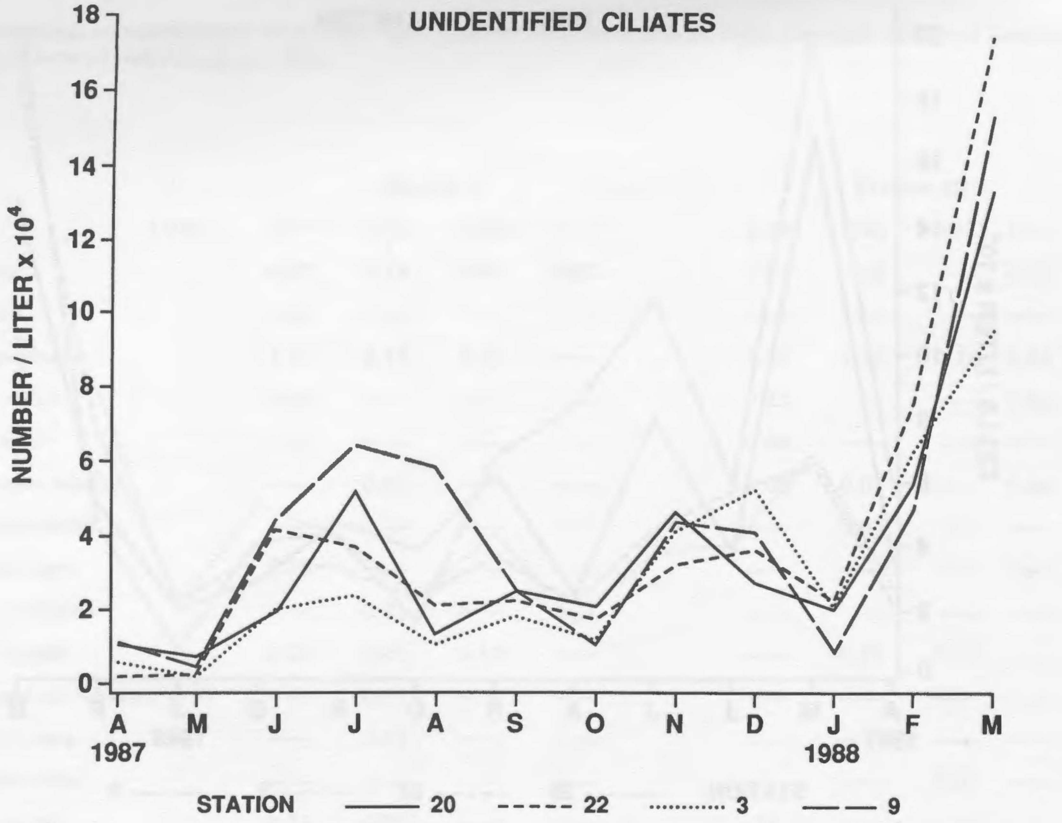

Figure 3. Concentrations of unidentified ciliates from April 1987 through March 1988 at stations in Back Bay

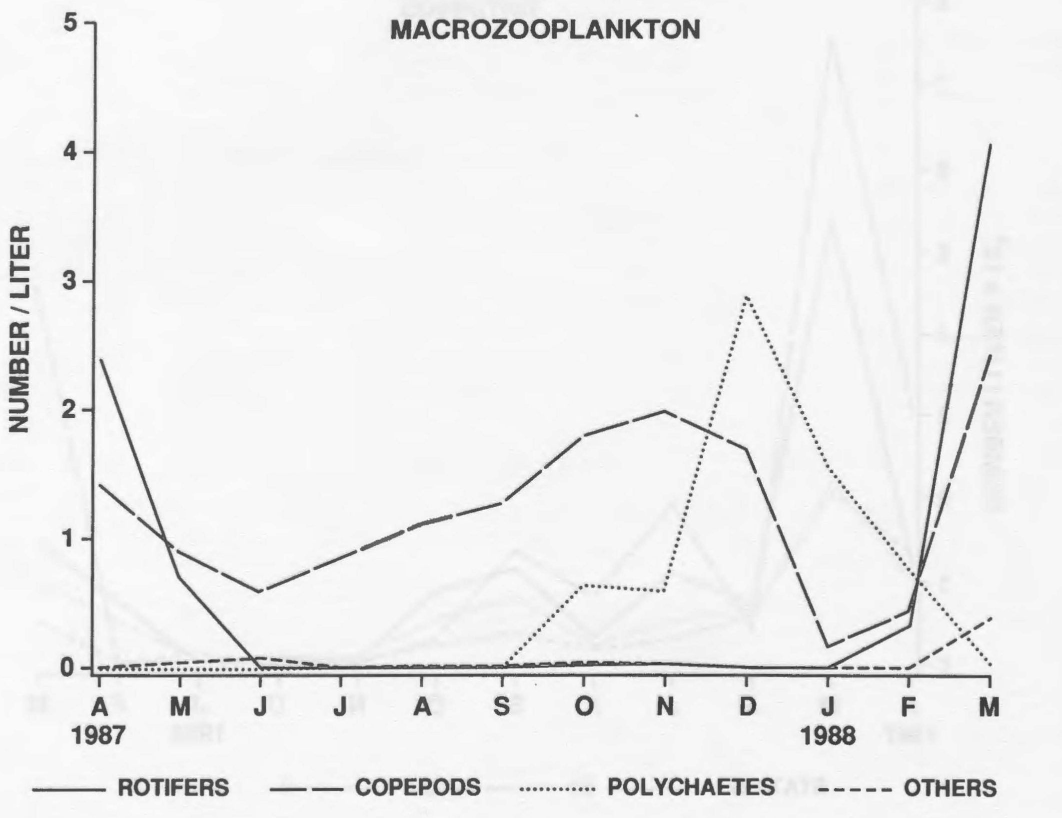

Figure 4. Mean concentrations of macrozooplankton components at stations in Back Bay from April 1987 through March 1988

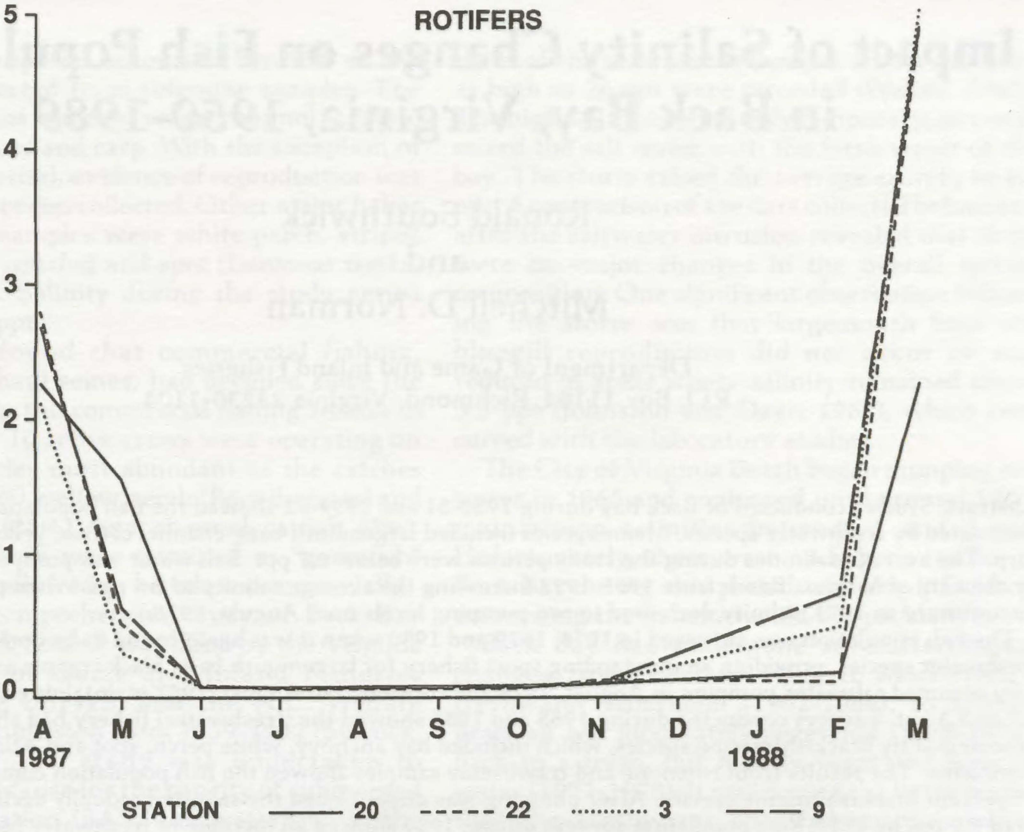

Figure 5. Concentrations of rotifers from April 1987 through March 1988 at stations in Back Bay

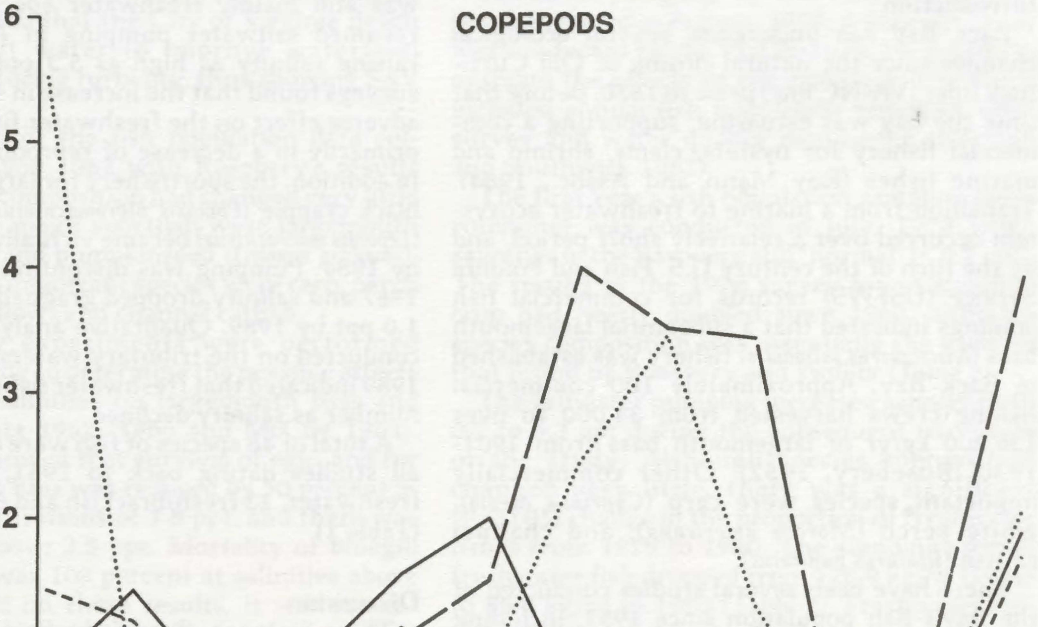

Figure 6. Concentrations of adult copepods from April 1987 through March 1988 at stations in Back Bay