Virginia Journal of Science
Volume 44, Number 4
Winter 1993

Microzooplankton in the Lower Chesapeake Bay, and the Tidal Elizabeth, James, and York Rivers

Gyung-Soo Park and **Harold G. Marshall**,
Department of Biological Sciences, Old Dominion University,
Norfolk, Virginia 23529-0266

ABSTRACT

Results of a one year study in the lower Chesapeake Bay and three tidal rivers indicate an abundant microzooplankton population, with a mean concentration of 4,231.1/Liter. The most abundant components are the non-loricate ciliates (2,518.2/L, 59.5% of the annual total) and tintinnids (1,400.1/L, 33.1%). In lesser abundance were the rotifers (191.4/L) and nauplii larvae (121.7/L). Seasonal abundance maxima were highest in summer, followed by fall, spring and winter.

INTRODUCTION

Microzooplankton includes those planktonic animals from 20 to 200 μm in size (Sieburth et al., 1978). The microzooplankton represent an essential link in specific food webs and energy transfer steps between the basic trophic levels within estuarine and other aquatic ecosystems (Laval-Peuto et al., 1986). They are considered consumers of picoplankton and nanoplankton in various aquatic habitats and are themselves a common food source for larval fish and other zooplankters (Rassoulzadegan and Sheldon, 1986; Dolan, 1991). Because the microzooplankton possess this strategic position within the trophic structure of estuaries, it is important to know more about this community and specifically its seasonal patterns of abundance in the lower Chesapeake Bay.

The first microzooplankton observations in the Chesapeake Bay were from whole water samples studied by Wolfe et al. (1926), with this same material discussed further by Cowles (1930). Their results included the listing of several protozoa in a mixed category that also contained dinoflagellates. Other early plankton studies in the Bay region by Morse (1947) and Whaley and Taylor (1968), used net collections that contained several groups of microzooplankton (e.g. tintinnids, rotifers, copepod larvae). More recently, Brownlee and Jacobs (1987) discussed both mesozooplankton ($>200\ \mu$m) and microzooplankton ($<200\ \mu$m) composition, abundance and biomass in the upper Chesapeake Bay.

Dolan and Coats (1991) studied the vertical distribution of microzooplankton in the upper Chesapeake Bay and noted the ciliate component was dominated by oligotrichs and tintinnids. Dolan (1991), using whole water samples, discussed the ciliate populations in the Chesapeake Bay in relation to their role as consumers. In Back Bay, Virginia, Marshall et al. (1988) conducted a year study of macrozooplankton and microzooplankton ($<150\ \mu$m). Using whole water samples, they found peak abundance occurred in late spring, with the samples dominated by tintinnids and non-loricate ciliates.

To obtain a more accurate estimate of the composition and abundance of the microzooplankton, several investigators have emphasized the importance of using whole water samples for analysis over net tow samples. For instance, Beers and Stewart (1964) noted a loss of 88% of the total microzooplankton when using a 35 μm mesh net. Those forms likely to be lost are the ciliated protozoans, which have been reported as accounting for >95% of the microzooplankton assemblages (Chang, 1990). In a comparison study on methodology, Brownlee and Jacobs (1987) used a combination of net sizes (44 μm & 20 μm) and whole water samples. Based on the numbers of organisms present in the samples, the two net samples greatly underestimated the total microzooplankton. The percentage retained of the total microzooplankton concentrations in the 44 μm and 20 μm nets were 5% and 26% respectively for a Choptank River sample and only 2% and 4% respectively for a Chester River sample. In regard to biomass, the percent loss was 49% and 44% retained by the 44 μm mesh net for the Choptank and Chester Rivers respectively. In their monthly sampling, they based their analysis on collections from a 44 μm mesh net, resulting in counts of "only the larger microzooplankton", with a significant amount of microzooplankton lost through their nets.

The results from earlier cruises that sampled microzooplankton composition in the lower Bay (Wolfe, et al., 1926, Whaley & Taylor, 1968), were incomplete in their coverage of the non-loricate ciliates. This is in contrast to the upper Bay, where these ciliates have been investigated by Brownlee and Jacobs (1987), Dolan and Coats (1991), and Dolan (1991). The present study was undertaken to provide general information on the abundance of microzooplankton in the lower Chesapeake Bay (Marshall, 1993). The specific objective of this report is to present the seasonal abundance patterns of the four major microzooplankton categories at stations in the lower Chesapeake Bay and the tidal James, York and Elizabeth Rivers. The four microzooplankton groups are: tintinnids, non-loricate ciliates, rotifers, and nauplii larvae.

METHODS

Monthly collections were made at 10 stations in the lower Chesapeake Bay and the James, York and Elizabeth Rivers from July 1992 through June 1993 (Figure 1). Whole water samples were taken in order to collect a more accurate representation of the microzooplankton (Brownlee and Jacobs, 1987; Beers and Stewart, 1964; and Chang, 1990). Two 15 liter carboys were filled on station, with composite water samples, taken from a vertical series of 5 depths above the pycnocline at 4 stations in the Chesapeake Bay (WE4.2, LE5.5, CB6.1, CB7.4), and two stations from the James River (TF5.5, RET5.2), the York River (TF4.2, RET4.3) and the Elizabeth River (ER2, ER5). The carboys were thoroughly mixed when filled, and a 1 liter sub-sample was taken from each and preserved with Lugol's solution (10 ml). Each sample was settled for 72 hours in the laboratory before a series of two siphoning and settling steps were taken to obtain a 100 ml concentrate. The analysis process consisted of analyzing three sub-sets from the 100 ml concentrate from each replicate sample. The analysis of three sub-groups is necessary to reduce the problem of silt covering specimens in the samples and to be able to separate the microzooplankters that vary greatly in size and weight. The first step involves removing detritus and larger zooplankton from the sample. This is accomplished

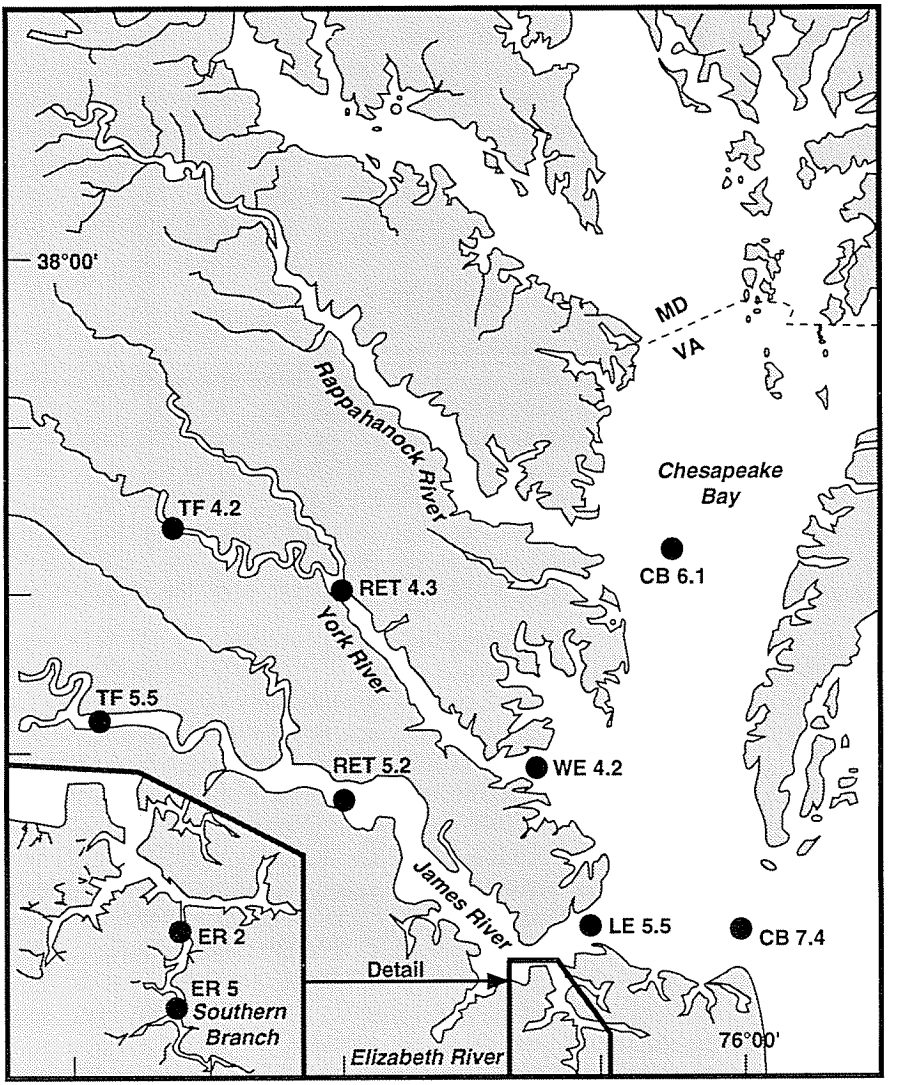

FIGURE 1. Station locations in the Chesapeake Bay, and the Elizabeth, James and York Rivers.

by passing the 100 ml concentrate through an 80 μm mesh screen. In order to count trapped microzooplankton larger than 80 μm, the material on the screen is washed into a container, transferred to a settling chamber to settle for 24 hours and is then examined with an inverted plankton microscope for counting the microzooplankton. This represented the first sub-set counted.

To obtain the other two sub-sets, the 100 ml concentrate is gently swirled and mixed. Based on the amount of detritus and plankters, a 5 or 10 ml aliquot is taken

and placed in a second settling chamber, with enough buffered formalin solution added to the chamber to bring to a 25 ml volume. After 10 minutes, 10 ml is removed and placed in a third settling chamber. Both of these chambers (representing the 2nd and 3rd sub-sets) are allowed to settle for 24 hours before examination with the inverted plankton microscope. Counts from the third chamber represent mainly the smaller, and lighter non-loricate ciliates and other protozoa that are often covered with silt if not separated in this fashion. Mid-sized microzooplankters are common in the second chamber. Multiplication constants for count determinations are made, with replicate counts averaged on samples coming from the two carboys at each station.

RESULTS

Station Locations

Mean salinities were determined using monthly salinity measurements taken at each of these stations over a 5 year period (Marshall, 1992). The tidal fresh stations were TF5.5 and TF4.2, in the James and York Rivers respectively. The James River station RET5.2 (1.9‰) is oligohaline, with the York River station RET4.3 (9.6‰) mesohaline. The Elizabeth River stations (ER2, ER5) are within meso-polyhaline ranges. All the Chesapeake Bay stations are polyhaline, with mean salinity values for the stations as follows: WE4.2 at the mouth of the York (21.2‰), LE5.5 at the mouth of the James (23.3‰), CB6.1 (19.7 ‰), and CB7.4 (28.3‰).

Seasonal Microzooplankton Abundance

A. Non-loricate ciliates.

This group represents one of the most abundant components of the microzooplankton throughout the year at river and Bay stations. Common genera within this group were *Strombidium* and *Strobilidium* (Oligotricha) and *Didinium* (Holotricha). Found in every sample throughout the year, the greatest abundance of ciliates was from mid-summer (July) to early fall (Figure 2). These concentrations decreased into winter and gradually increased in spring, with high concentrations associated with waters across a broad salinity gradient. Concentrations ranged from a low of 20/L in December at TF4.2 to a high of 19,500/L in June at ER5. The annual monthly mean was 2,518.2/L (Table 1) across all stations, with a December mean low of 272/L and a July high of 7,199/L. In general, lowest mean monthly concentrations occurred at TF4.2 (830/L), but at the other tidal fresh station (TF5.5), the abundance was greater at 2,181/Liter (Figure 3). Highest mean station values were at ER5 and RET4.3 at 5,232 and 4,601/L respectively. Brownlee and Jacobs (1987) reported September counts of non-loricate ciliates for the Choptank and Chester Rivers as 5,600 and 10,000/L respectively, but did not report on this group from their Bay samples. Marshall et al. (1988) found high ciliate counts in Back Bay during winter and spring that ranged from 3-5 x 10^4/L.

B. Tintinnids (loricate ciliates).

The tintinnids had two seasonal periods of maximum growth (Figure 4). These included a spring peak and increased abundance from summer into early fall. Highest concentrations of 12,913 and 11,253/L were recorded for February at CB7.4 and April at WE4.2 respectively (Marshall, 1993). The annual monthly mean was 1,400.1/L (Table 1), ranging from a January low of 216/L to a high of 3,305/L

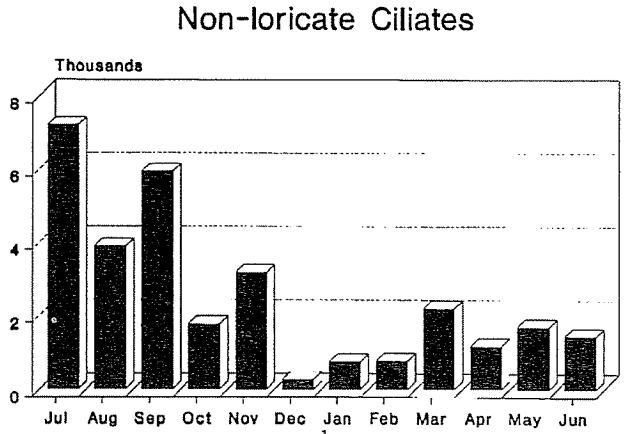

FIGURE 2. Monthly concentration means (No.L^{-1}) of non-loricate ciliates at all stations from July 1992 through 1993.

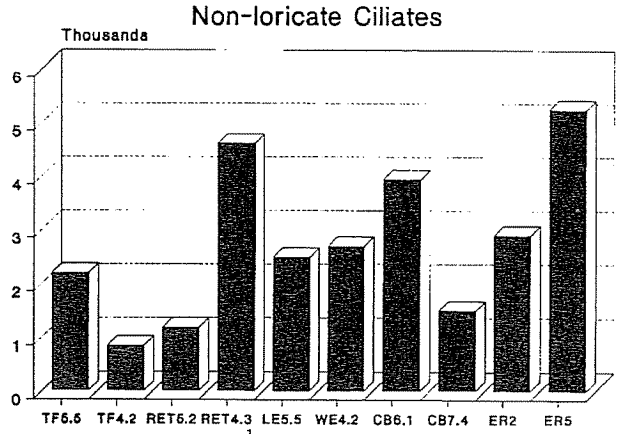

FIGURE 3. Mean concentrations (No.L^{-1}) of non-loricate ciliates for all stations from July 1992 through June 1993.

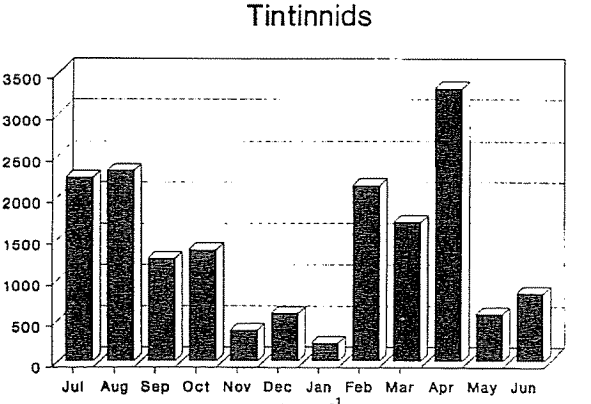

FIGURE 4. Monthly concentrations means (No.L^{-1}) of tintinnids for all stations from July 1992 through June 1992.

in April. The annual station means for tintinnids ranged from 515/L per month at TF4.2 to 2,522/L at CB7.4 (Figure 5). This group was a common constituent in all samples and across a broad salinity gradient throughout the year. The common genera were *Tintinnopsis*, *Tintinnidium*, and *Eutintinnus*. Brownlee and Jacobs (1987) reported the mean concentrations of tintinnids for all stations and dates in the Chesapeake Bay as 160/L, with September counts in the Choptank and Chester Rivers of 17,600 and 4,600/L. They found the tintinnids common year round in the Bay, with peak growth in spring, summer and fall. Marshall et al. (1988) noted tintinnid abundance in Back Bay ranged from 256/L in winter to a high of 36,825/L in spring.

Dolan and Coats (1991) determined the concentrations of ciliates at stations in the upper Chesapeake Bay between the months of April and September. They noted surface abundance ranged from 1,000 to 90,000/L, with maximum numbers occurring in late spring to early summer. Dolan (1991), commented further on these populations, stating the macrophagous microzooplankters (mostly tintinnids and large oligotrichs) ranged between 1-20 x 10^3 organisms/L, with the microphagous components (large scuticociliates and small oligotrichs) between 1-22 x 10^3 organisms/L. The smaller ciliates increased in abundance from April through July, with the tintinnids and larger oligotrichs reaching an earlier peak in June.

C. Nauplii larvae.

A variety of nauplii (mostly copepod larvae) representing different species and stages-in-development were present in the samples. All of these forms were counted within this category. Across all stations, there was a single major development that extended from summer through mid-fall (Figure 6). At the Chesapeake Bay stations there was another pulse that began in February, reached its peak in April, then declined. This development, however, may represent a pattern of an extended spring-fall period of development. Only once during the sampling (December at ER5) were no nauplii found in the samples. The highest counts occurred in September at RET4.3 with 1,418/L (Marshall, 1993). The mean monthly count was 121.7/L (Table 1), with January and September having the lowest and highest values respectively at 17 and 375/L (Figure 6). In general, the tidal fresh stations (TF5.5, TF4.2) had the lowest mean concentrations (47 and 22/L), in contrast to RET4.3 (199/L) and the two stations at the river mouths, LE5.5 and WE4.2 (176 and 173/L), which had the highest abundance (Figure 7). Brownlee and Jacobs (1987) reported a concentration mean of copepod nauplii at 39.2/L for the Chesapeake Bay, with spring and early fall peaks. They also reported nauplii abundance in the Choptank and Chester Rivers for September at 200 and 100/L respectively.

D. Rotifers.

A variety of rotifers were in the samples, including representatives from the genera *Synchaeta, Filinia, Brachionus*, *Keratella*, and *Trichocerca.* Only on 11 occasions were rotifers absent in the samples; concentrations thus ranged from zero to a maximum of 1,915/L in August at TF5.5. The seasonal patterns indicated a spring maximum and a larger summer-fall peak (Figure 8) over a growth period that began in early spring and extended into early fall. Concentrations were greatest from mid-summer through early fall. The river stations indicated more of a

TABLE 1. Mean concentrations and composition percentages of the four microzooplankton components from all stations from July 1992 through June 1993. Composition ranges indicate monthly variations.

Microzooplankton	No./L	Mean %	%Ranges
Ciliates*	2,518.2	59.5	35.2 - 77.1
Tintinnids	1,400.1	33.1	19.6 - 60.5
Rotifers	191.4	4.5	1.3 - 11.4
Nauplii larvae	121.7	2.9	1.2 - 4.4
Total	4,231.4		

*Non-loricate ciliates

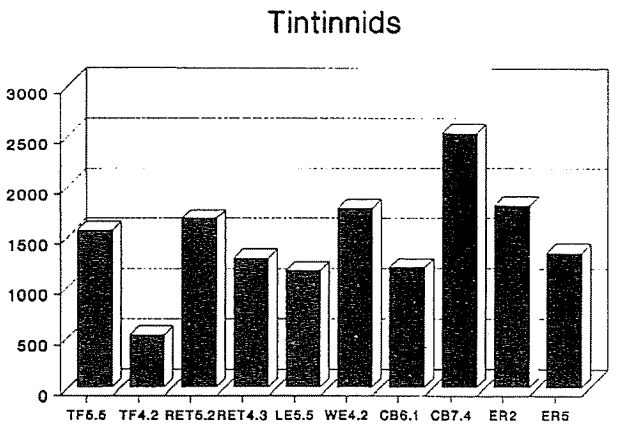

FIGURE 5. Mean concentrations (No.L^{-1}) of tintinnids for all stations from July 1992 through June 1993.

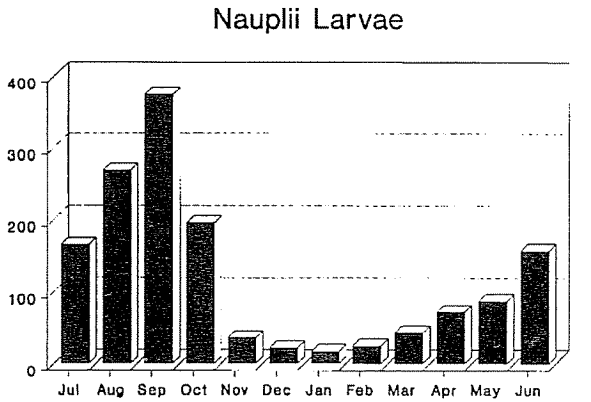

FIGURE 6. Monthly concentration means (No.L^{-1}) of nauplii larvae at all stations from July 1992 through 1993.

bi-modal growth pattern compared to a rather sporadic appearance in the Chesapeake Bay, where growth was more consistent during fall and early winter (Marshall, 1993). The monthly mean was 191.4/L (Table 1), with the lowest (40/L) concentrations in December and the highest (446/L) in August. Highest mean concentrations (420 and 470/L) were associated with two stations, both in the James River (TF5.5, RET5.2), with the lowest concentrations (44/L) at the most saline site, CB7.4 (Figure 9). Brownlee and Jacobs (1987) reported a mean value of 476/L for rotifers in the Chesapeake Bay, with September concentrations of 100 and 500/L for the Choptank and Chester Rivers, and found rotifers more common in the Bay during the colder months. At Back Bay, concentrations were highest in spring at 21/L, but low during other seasons (Marshall et al., 1988).

E. Total Microzooplankton

Seasonal microzooplankton concentrations were greatest in summer followed by fall, spring and winter months (Figure 10). There was a mid-summer maximum that occurred in July (10.0×10^3/L), with high concentrations maintained in August (6.9×10^3/L) and early fall (7.9×10^3/L). The overall monthly concentration mean for the microzooplankton in this study was 4,231.4/L (Table 1). For the Choptank and Chester Rivers in September, Brownlee and Jacobs (1987) reported total concentrations of 24.3 and 15.2×10^3/L respectively. The major component in their samples were tintinnids. A spring pulse of less magnitude, with microzooplankton concentrations lowest during December and January (910 and 1,058/L) was observed. They reported a similar pattern for the total microzooplankton in the Bay, with late summer and fall peaks, with some groups (e.g. tintinnids) having a spring peak at certain stations.

The distribution of these microzooplankton and their abundance at the Bay and river stations were not similar over the sampling area (Figs. 3,5,7,9,11). Highest mean station concentrations were associated with the Chesapeake Bay, RET4.3 in the York and the stations in the Elizabeth River. The highest numbers were at ER5, with mean monthly concentrations of 7,292/L. The lowest figures were at stations in the York tidal fresh waters (TF4.2) at 1,480/L, and the James River (TF5.5, RET5.2) and the Bay station at the mouth of the James (LE5.5). Station TF4.2 consistently had low concentrations of each microzooplankton category. The tintinnids had their lowest abundance in the James River, but were well represented at the other stations. In contrast, the rotifers were more abundant at the James River sites. The nauplii larvae consistently had high concentrations in the Bay.

The non-loricate ciliates composed 59.5% of the microzooplankton, ranging from 35.2% to 77.1% at the different stations (Table 1). The concentrations were below 50% at only two (RET5.2, CB7.4) of the ten stations, with the highest percentage (77.1%) at ER5 in the Elizabeth River. The tintinnids were the second most abundant group, with a range of 19.6% to 60.5% of the total microzooplankton, and a mean concentration of 33.1%. Their highest concentrations of 50.5% and 60.3% were at RET5.2 and CB7.4 respectively (Marshall, 1993), with their lowest values of 20.4%, 21.5%, and 19.6% at stations RET4.3, CB6.1 and ER5 respectively (Marshall, 1993). The nauplii larvae concentrations ranged from 1.2% to 4.4% of the total, with a mean of 2.9% (Table 1). These lowest and highest percentages were at stations TF5.5 and LE5.5 (Marshall, 1993). Concentrations of rotifers did not exceed 11.4%, with this value found at station RET5.2. Rotifers

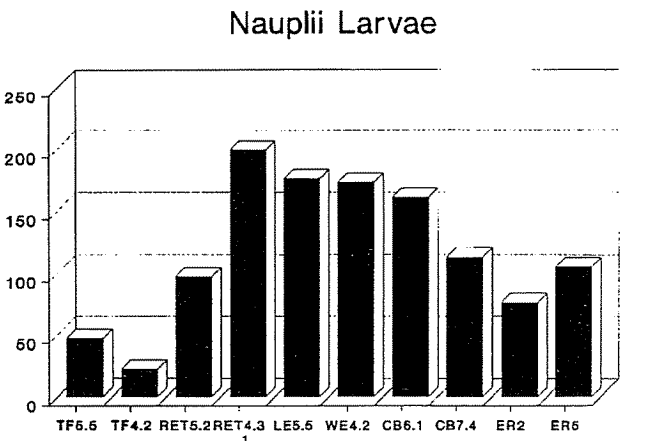

FIGURE 7. Mean concentrations (No.L^{-1}) of nauplii larvae for all stations from July 1992 through June 1993.

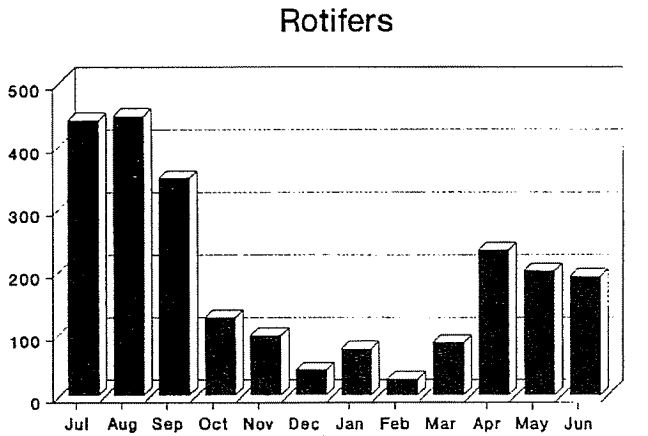

FIGURE 8. Monthly concentrations means (No.L^{-1}) of rotifers for all stations from July 1992 through June 1992.

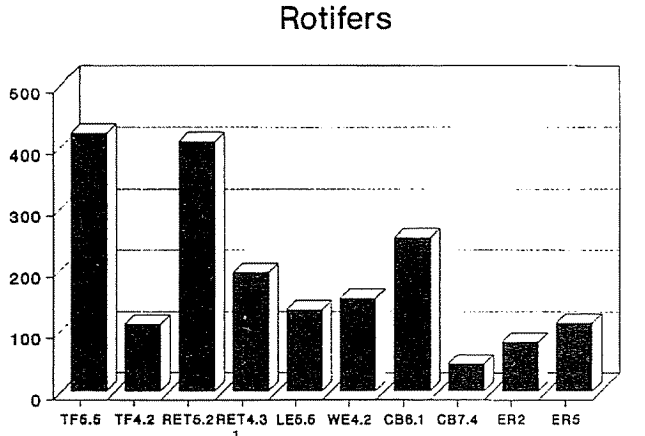

FIGURE 9. Mean concentrations (No.L^{-1}) of rotifers for all stations from July 1992 through June 1993.

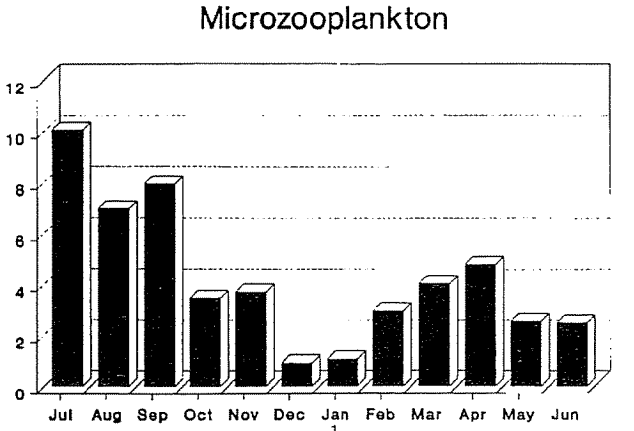

FIGURE 10. Monthly concentrations means (No.L^{-1}) of total microzooplankton for all stations from July 1992 through June 1992.

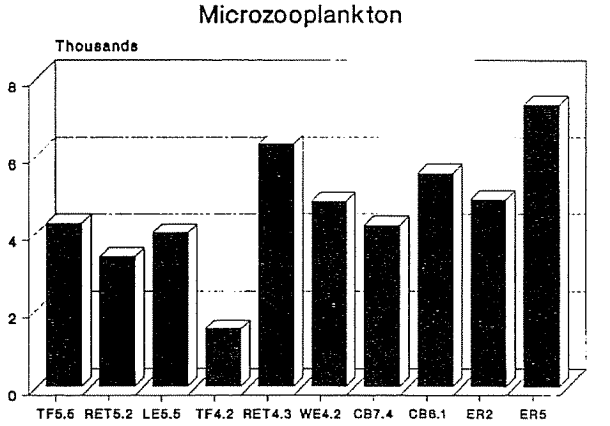

FIGURE 11. Mean concentrations (No.L^{-1}) of total microzooplankton for all stations from July 1992 through June 1993.

represented 4.5% of the total, with a range of 1.3% to 11.4%. The lowest percentages of rotifers were associated with the two Elizabeth River stations (1.8%) and the Bay entrance, at CB7.4 (1.3%).

SUMMARY

The most common and abundant microzooplankton throughout the study were the non-loricate ciliates and tintinnids. They had respectively monthly mean concentrations of 2,518.2 and 1,400.1/L. These two components had the greatest percentage of microzooplankters in the samples. The non-loricate ciliates represented 59.5% of the microzooplankton, with the tintinnids 33.1%. The nauplii larvae had mean monthly concentration of 121.7/L, with rotifers at 191.4/L. In reference to the total microzooplankton composition, the nauplii larvae and the rotifers represented 2.9% and 4.5% respectively of the total.

The seasonal abundance pattern for microzooplankton in the lower Chesapeake Bay indicated a spring and mid-summer to early fall maxima. This

expression is similar to previous findings in the Bay region (Brownlee and Jacobs, 1987; Dolan and Coats, 1991) and elsewhere (Smetacek, 1981; Hargraves, 1981, Capriulo and Carpenter, 1983; Marshall et al., 1988). Individual concentrations for the microzooplankton categories were also within those previously reported for the Bay (Brownlee and Jacobs, 1987; Dolan, 1991; Dolan and Coats, 1991).

The relationship of microzooplankton populations to host and prey associations has been studied in the Chesapeake Bay (Dolan, 1991), however the role microzooplankton play as a consumer and as prey for other organisms has not been clearly defined. The seasonal growth maxima of the microzooplankton components occur from early spring to late fall. These peaks coincide with the development of major phytoplankton pulses within the Bay system (Marshall, 1992). For instance, there are significant floral growth periods occurring during spring, summer and fall, and these include phytoplankters of nano and picoplankton sized cells that are available as food for the microzooplankters. The most dramatic growth of autotrophic picoplankton occurs in summer (June-August), when they increase from background concentrations of 10^6 to 10^9 cells/L. They reach their peak abundance in July, or early August, and consist of mostly cyanobacteria (Marshall, 1992). In addition to the year round presence of the picoplankton (autotrophic and heterotrophic), other smaller phytoplankton exist in abundance in spring (chlorophytes), summer (phytoflagellates, cyanobacteria), and fall (phytoflagellates). One would assume there is currently an adequate supply of phytoplankton year round as a food source for the smaller members within this group. This opinion is supported by Dolan and Coats (1991) who state the ciliate component is not linked to the standing phytoplankton crop, with the ciliates still representing the largest microzooplankton component in the lower Chesapeake Bay.

In conclusion, the lower Chesapeake Bay and the tidal regions of the three rivers in this study contain an abundant microzooplankton community that is dominated by the ciliate protozoa.

ACKNOWLEDGEMENTS

This study is a component of the Chesapeake Bay Monitoring Program that was funded by the Virginia Department of Environmental Quality. G.S. Park is a graduate student in the Department of Biological Sciences who collected and analyzed the samples. The study was conducted in the Old Dominion University Phytoplankton Laboratory under the supervision of H.G. Marshall, who prepared the manuscript and figures. Special thanks is given to Karen Soucek for data entry and to other members of the Old Dominion University Phytoplankton, and Zooplankton Laboratories who helped in collecting the samples.

LITERATURE CITED

Beers, J.R. and G.L. Stewart. 1967. Microzooplankton in the euphotic zone at five locations across the California Current. J. Fisheries Research Board of Canada, 24:2053-2068.

Brownlee, D.C. and F. Jacobs. 1987. Mesozooplankton and microzooplankton in the Chesapeake Bay. *In*: S. Majumdar, L. Hall, and H. Austin (eds.) Contaminant Problems and Management of Living Chesapeake Bay Resources, The Pennsylvania Academy of Science, Easton, Pa., pp.217-269.

Capriulo, G.M. and E.J. Carpenter. 1983. Abundance, species composition and feeding impact of tintinnid micro-zooplankton in central Long Island Sound. Marine Ecol. Prog. Ser. 10:277-288.

Chang, F.H. 1990. Quantitative distribution of microzooplankton off Westland, New Zealand. New Zealand Journal Marine and Freshwater Research, 24:187-195.

Cowles, R.P. 1930. A biological study of the offshore waters of Chesapeake Bay. Bull. Bureau Fisheries, 46:277-381.

Dolan, J.R. 1991. Guilds of ciliate microzooplankton in the Chesapeake Bay. Estuarine, Coastal and Shelf Science, 33:137-152.

Dolan, J.R. and D.W. Coats. 1991. Changes in fine-scale vertical distributions of ciliate microzooplankton related to anoxia in Chesapeake Bay waters. Marine Microbial Food Webs, 5:81-93.

Hargraves, P.E. 1981. Seasonal variations of tintinnids (Ciliophora:Oligotrichida) in Narragansett Bay, Rhode Island, U.S.A. J. Plankton Research, 3:81-91.

Laval-Peuto, M., H. Heinbokel, O. Anderson, F. Rassoulzadegan and B. Sherr. 1986. Role of micro-and nanozooplankton in marine food webs. Insect Science Applications, 3:387-395.

Marshall, H.G., R. Southwick and B. Wagoner. 1988. Seasonal zooplankton composition and abundance patterns in Back Bay, Virginia. Old Dominion University Research Foundation, Special Report for the Commonwealth of Virginia, Dept. of Game and Inland Fisheries, 37 pp.

Marshall, H.G. 1992. Phytoplankton Community. In:Lower Chesapeake Bay Monitoring Program Synthesis Report, 1985-1989. Vol.II. Old Dominion University Research Foundation, Tech. Rpt. Norfolk, Va., 162 pp.

Marshall, H.G. 1993. Microzooplankton in the lower Chesapeake Bay, and the tidal James, York, and Elizabeth Rivers: July 1992-June 1993. Special Report. Old Dominion University Research Foundation, Norfolk, Va., 62 pp.

Morse, D.C. 1947. Some observations on seasonal variation in plankton population, Patuxent River, Maryland, 1943-1945. Chesapeake Biology Laboratory, 65:1-31.

Rassoulzadegan, F. and R. Sheldon. 1986. Predator-prey interaction of nanozooplankton and bacteria in an oligotrophic marine environment. Limnology and Oceanography, 31:1010-1021.

Sieburth, J. McN., V. Smetacek and J. Lenz. 1978. Pelagic ecosystem structure:heterotrophic compartments of the plankton and their relationship to plankton size fractions. Limnology and Oceanography, 23:1256-1263.

Smetacek, V. 1981. The annual cycle of protozooplankton in the Kiel Bight. Marine Biology, 63:1-11.

Whaley, R. and W. Taylor. 1968. A plankton survey of the Chesapeake Bay using a continuous underway sampling system. Chesapeake Bay Institute, Tech. Report. No. 36, 89 pp.

Wolfe, J., B. Cunningham, N. Wilderson and J. Barnes. 1926. An investigation of the microplankton of Chesapeake Bay. Journal of the Elisha Mitchell Scientific Society, 42:25-54.