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THE DISTRIBUTION OF PHYTOPLANKTON ALONG A 140 MILE TRANSECT IN THE CHESAPEAKE BAY

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The waters of the Chesapeake Bay are described by Pritchard (1952) as being composed of two horizontally moving layers. The upper layer flows toward the mouth of the Bay, while the lower layer moves up the Bay. The influence these changing waters have on the composition and distribution of the phytoplankton is profound. Early references to these variations in the distribution of phytoplankton in the Chesapeake Bay were noted by Wolfe *et al.* (1926) and Cowles (1930). The effect of these estuarine conditions on the vertical distribution of phytoplankton has been discussed by Patten (1963) in the York River and Marshall (1966) for a diurnal study in the James River. Investigations on the seasonality of phytoplankton species in the lower bay region have been made by Mulford (1962, 1963) and Patten *et al.* (1963).

In the lower Bay region, Patten *et al.* (1963) report *Skeletonema costatum* as the dominant diatom species between December and February 1960, with *Nitzschia pungens* var. *atlantica* and *Cerataulina bergonii* more prominent in their March collections. They indicate the spring phytoplankton is primarily composed of the flagellate forms with population centers in the rivers and upper Bay region. A similar sequence in diatom succession was found by Morse (1947) in the Patuxent River where *Nitzschia seriata* and *Cerataulina bergonii* followed the winter dominant *Skeletonema costatum*. Mulford (1962, 1963) lists the most numerous diatoms for March in the lower Bay region as *Nitzschia pungens* var. *atlantica, Skeletonema costatum,* and *Rhizosolenia setigera.* Cowles (1930) reported the phytoplankton reached a spring maximum in March. He noted the highest diatom counts were at the mouths of rivers and the major species were *Skeletonema costatum, Cerataulina bergonii, Chaetoceros* spp., and *Rhizosolenia* spp. Morse (1947) also discusses the zooplankton population and indicates low numbers present during the spring with copepods and tintinids abundant in summer.

In these above studies, it should be noted that a variety of collection methods were employed. Due to this unconformity in sampling procedures, certain difficulties may arise in making valid comparisons concerning the concentration and composition of the nannoplankton. Mulford (1962, 1963) obtained samples by towing a net 15 minutes and by a pump that strained the water through a No. 20 net. Patten *et al.*

(1963) used a No. 20 net attached to a Clarke-Bumpus sampler with tows of 90 seconds, while Morse (1947) made hawls towing a No. 20 plankton net. These nets have apertures with an average dimension of 69.5 microns and will not retain large numbers of nannoplankters which have sizes smaller than these openings. Wolfe *et al.* (1926) and Cowles (1930) reported on centrifuged 250 ml samples originally obtained from water bottles and were prepared in Fleming's fluid and in later collections formalin. The delicate cell membrane of many of the motile nannoplankters is known to be destroyed by centrifuging techniques and formalin preservation (Steeman Nielsen, 1960, Utermöhl, 1958).

METHODS

Surface water samples were taken at 16 stations along a 140 mile transect in the Chesapeake Bay 10-11 March 1964 (Fig. 1). Two 24-hour stations were also established (Nos. 101, 102) where water samples were taken at three hour intervals. The depths sampled at Station 101 were at the surface and five meters. At Station 102 water samples were taken at the surface, 8, 17, 25, and 32 meters. The collection techniques and preservative employed in this study were different from those used by the investigators mentioned above. All water samples were obtained with a Van Dorn two-liter water sampler. Glass bottles were used to store 500 ml of each sample which was preserved immediately with Lugol-Rodhe solution (Rodhe *et al.* 1958). A settling and siphoning method was followed until a 10 ml concentrate was left. Aliquots of this concentrate were then examined on a microslide and phytoplankton recorded by species in numbers of cells per liter. The entire concentrate was examined for zooplankton, and these were recorded by species as to the number of individuals per liter. During each sampling, temperatures were taken with a Negretti-Zamba reversing thermometer and salinity determinations made by specific gravity procedures. Current velocities were noted at the diurnal stations with a Price current meter and oxygen content determined by the Winkler method.

RESULTS

A total of 67 phytoplankters were identified. There were distinct differences in the composition of the dominant phytoplankters along the Chesapeake Bay transect (Table 1). The typical neritic diatoms predominated in the higher saline waters of the lower Bay with the numbers of flagellates high and increasing toward the upper Bay region. The more numerous species in the lower Bay region were *Asterionella japonica* Cl., *Nitzschia pungens* var. *atlantic* Cl., *Skeletonema costatum* (Grev.) Cl., *Thalassiosira gravida* Cl., and *Chaetoceros decipiens* Cl. These were

found in abundance at Stations 201, 202, and 203. *Skeletonema costatum* (Grev.) Cl. composed the bulk of the phytoplankton concentrations at Stations 201 with counts of approximately 950,000 cells per liter. Six species were conspicuous in the samples taken from Station 201 through 213. These were *Cryptomonas* sp., *Nitzschia pungens* var. *atlantica* Cl., *Skeletonema costatum* (Grev.) Cl., *Rhizosolenia alata* Brightw., and *Rhizosolenia setigera* Brightw. *Cryptomomas* sp. was the most numerous nannoplankter in all the samples examined. It attained numbers of approximately 1,080,000; 1,500,000, and 1,350,000 cells per liter, respectively, for Stations 214, 215, and 216. In each of these stations, *Cryptomonas* represented at least 95% of the total phytoplankters found at the surface. A common dinoflagellate was *Gonyaulax spinifera* Clap. & Lach. at Stations 201 through 209.

There were 23 zooplankters identified at the 16 stations with the counts ranging from 52 to 2,660 per liter. Calanoid copepods, various nauplii larval stages, and an unidentified brachionid rotifer were the most numerous forms found the entire length of the transect. The tintinnids were found in low numbers except at Stations 215 and 216. Here they rose to 232 and 2,640 individuals per liter, respectively. The unidentified rotifer reached counts of 408, 266, and 344 per liter at Stations 205, 210, and 211.

The concentration of phytoplankton and zooplankton presents an inverse relationship in the surface samples (Fig. 2). Since the majority of zooplankters present were herbivores, e.g., copepods, advanced stages of nauplii larvae, a grazing effect may be the major factor for this pattern. To substantiate this viewpoint, visual observations revealed the digestive tracts of these copepods filled and numerous green fecal pellets were noted in direct relationship to the number of zooplankters. Although not conclusive, this supports a similar association of copepods grazing on phytoplankton examined by Gauld (1953).

Station 101. A diurnal study of the plankton was carried out at Station 101 which is located at the mouth of the Great Wicomico River in water seven meters deep. The temperature range was 6.2 to 9.0°C and the salinity 18.0 to 19.4 ppm. A definite cyclic fluctuation in the zooplankton occurred reaching maximum numbers after the high tidal period at 2200 on March 10, then decreasing with the ebb (Fig. 3). Daytime peaks, prior and after this night maximum, were greater at 5 meters than at the surface in the majority of samples. The vertical distributions for the copepods indicated greater numbers at the surface than at five meters from 2400 to 0600.

Extreme fluctuation in the surface phytoplankton took place during the sampling period (Fig. 4). The surface phytoplankton reached highest

numbers at 1200 March 10 when counts exceeded 1,400,000 cells per liter. These populations were composed mainly of *Rhizosolenia setigera* Brightw., *Nitzschia pungens* var. *atlantica* Cl. *Cryptomonas* sp., and *Gymnodinium* sp. These species were found in the same proportion during each peek, which coincided with low water and reduced concentrations of zooplankton. A similar composition was found at five meters where the diatoms predominated and the flagellate forms were present in low cotncentrations. There were several fluctuations in the total phytoplankton at this depth with an inverse relationship to the zooplankton concentrations.

Station 102. This station was located in the Patuxent River off Point Patience in water 33 meters deep. The study was made April 9, 1964. Maximum flood water occurred at 0019 with ebb slack at 1755 and 0619. The greatest temperature range was at 1530 at the surface and 32 meters at 8.3 and 9.0°C, respectively. The average temperature range during the other periods for these depths was .61°C. There were only minor fluctuations in the salinity during the study period with a mean of 13.01 ppm. The highest concentration of oxygen was found at all depths during the incoming tidal sequence. There were also two minima periods of oxygen content at ebb slack.

The phytoplankton was primarily composed of flagellate forms with the diatoms of secondary importance. *Cryptomonas* sp. was numerically dominant with rather uniform vertical distribution over the 24 hour period. Only during slack water was there a tendency for greater numbers of this species near the surface. These periods occurred in late afternoon and the following morning. *Leptocylindrus danicus* was the major diatom in this diurnal series. The diatoms *Nitzschia pungens* var. *atlantica, Thalassiosira gravida, Synedra* sp., and *Cosinodiscus perforatus* Ehr. were also abundant.

The vertical distribution of the total phytoplankton population illustrates slight variation in density between the surface and 32 meters. (Fig. 5). There is a tendency for the phytoplankton to be inversely concentrated to the numbers of zooplankton (Fig. 6). These relationships are more apparent between 1830 and 0630. The vertical distribution of the zooplankton population center fluctuates during the 24 hour period, there being greater numbers in the shallower depths at night. The population center is concentrated in the upper water betwen 1830 and 1630.

The major zooplankton species were calanoid copepods, nauplii larval stages, and the same identified branchionid rotifer found in Bay samples. The tintinnids were found in low numbers.

DISCUSSION

Steeman Nielsen (1960) emphasizes the fallibility of net and filtration techniques in quantitative studies of phytoplankton. The use of sedimentation methods provides a more precise measurement of the nannoplankters in the water samples (Braarud, 1958; Willen, 1962). In order to reduce the destruction of naked flagellates, frequently associated with the use of formalin preservatives, a Lugol-Rodhe solution was added to each sample (Utermöhl, 1958; Rodhe et al., 1958). The results indicate a greater number of these smaller flagellates, for this time period and area, than reported previously in studies using different collection procedures (Wolfe *et al.*, 1926; Morse, 1947; Mulford, 1963; and Patten *et al.* 1963). *Cryptomonas* sp. was found as one of the most numerous organisms in the samples taken along the transect. It was found in greatest numbers at stations 214, 215, and 216.

In addition to the numerical dominance of *Cryptomonas* sp., large numbers of other nannoplankters were noted in the samples. *Prorocentrum micans, Prorocentrum* sp., *Exuviaella* sp., and an unidentified phytoflagellate (cell diameter 3-5 microns) were abundant in samples 206 through 212, and present in lesser concentrations at the other stations. The large numbers of nannoplankters, their rapid rate of cell division (Parke, 1949), and their presence as a potential food source for herbivores are salient features regarding their significance to the plankton community.

The phytoplankton and zooplankton concentrations in the surface samples present an inverse relationship with evidence indicating a grazing phenomenon. However, the presence of these organisms will be influenced by physical factors over which they have little control. The flow patterns in the Bay would be a major influence in the distribution and stratification of plankters in the Bay. Due to vigorous current action in these waters, entirely new populations of plankters may be constantly deployed throughout the water. The horizontal transport of the plankters would enhance their duration in the water and influence their relative abundance. This action contributes to a continual fluctuation of members in both groups of plankton which may produce fortuitous relationships.

A cyclic turbulence was indicated in the two 24-hour studies directly related to the tidal flow patterns. The tidal action and river flow will tend to counteract the settling action of many phytoplankters and impede the movements of the more feeble swimmers. The subsequent upwelling action will aid in the distribution of seston and the plankters that have settled. Few of the zooplankters and phytoplankters found in the samples are probably endemic to these stations. Each ebb and flood period

will introduce new populations from upstream and the Bay respectively. The entry, duration of stay, and concentration of the plankton population will be influenced by various periods of the tidal cycle and current flow.

SUMMARY

Surface water samples were taken at 16 stations along a 140 mile transect in the Chesapeake Bay. A series of samples were obtained at different depths over a 24-hour period at two stations located near the mouth of the Great Wicomico River and in the Patuxent River. The composition and distribution of the major phytoplankters along the transect is discussed and general relationships with the zooplankters noted. The composition and vertical stratification of the phytoplankton and zooplankton is given for the two 24-hour stations.

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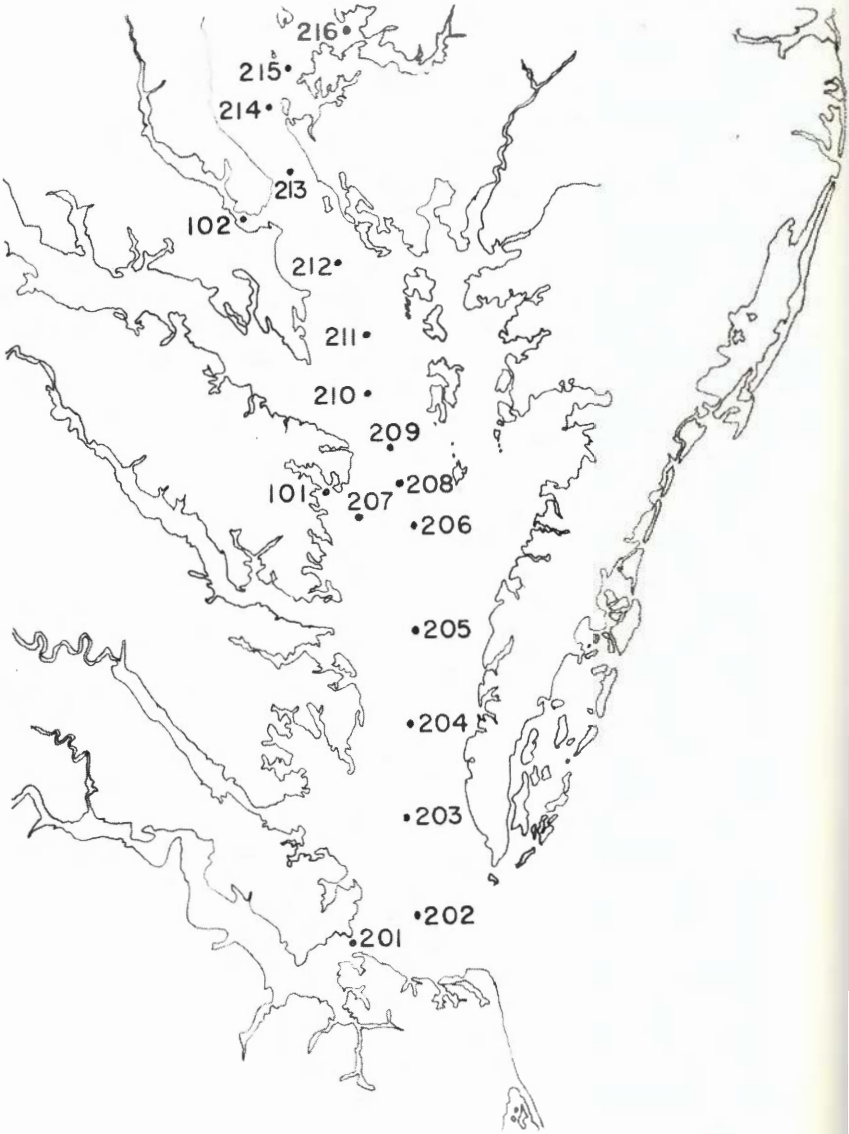

Figure 1. Location of sampling stations in the Chesapeake Bay along a 140 mile transect from Norfolk, Virginia, to Cambridge, Maryland.

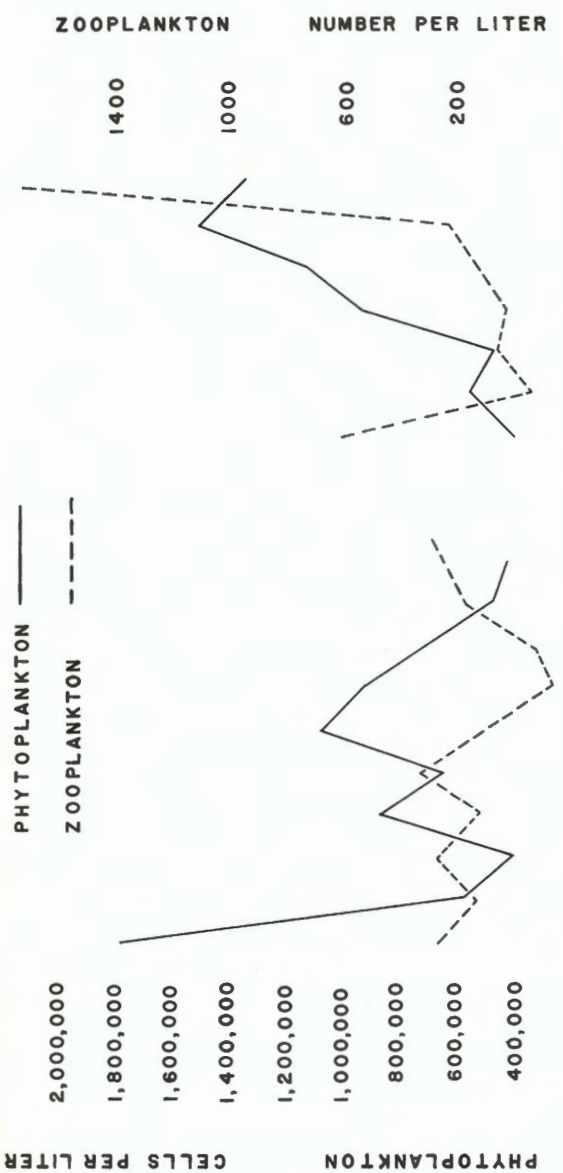

Figure 2. Concentration of phytoplankton and zooplankton taken at stations along the 140 mile transect in the Chesapeake Bay.

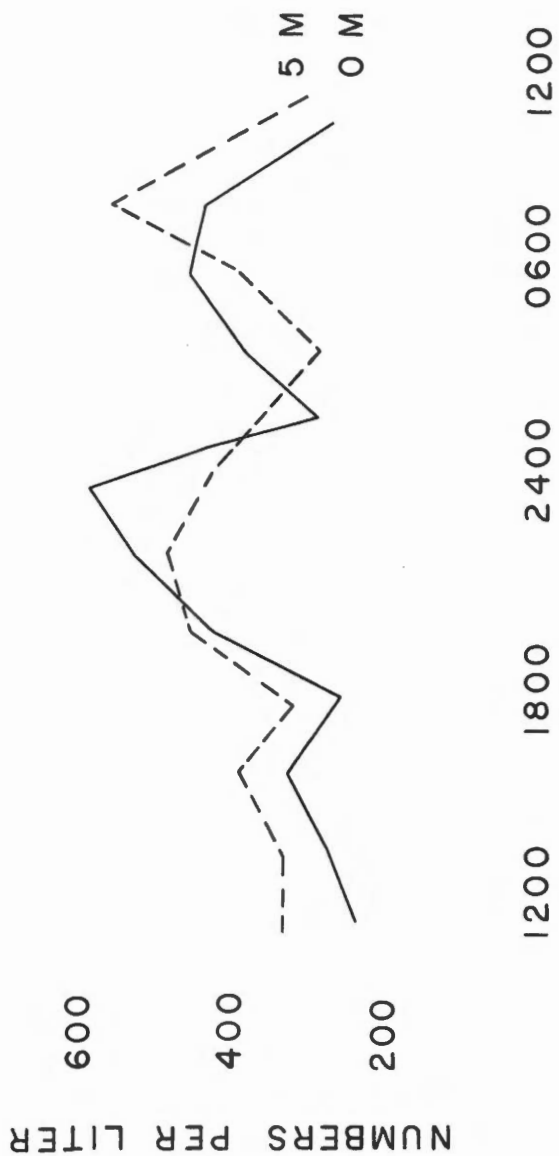

Figure 3. Concentration of zooplankton at the surface and five meters for 24 hours at Station 101 in the Great Wicomico River.

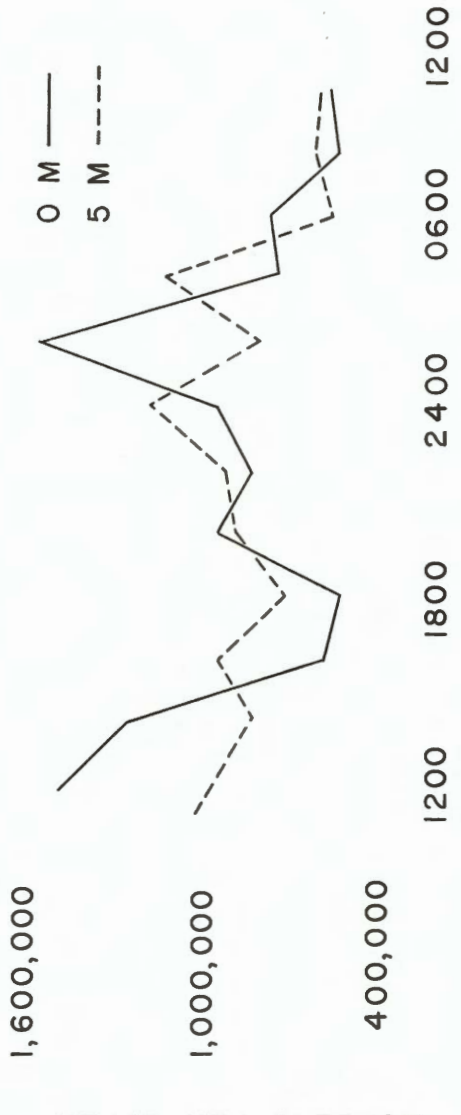

Figure 4. Concentration of phytoplankton at the surface and five meters for 24 hours at Station 101 in the Great Wicomico River.

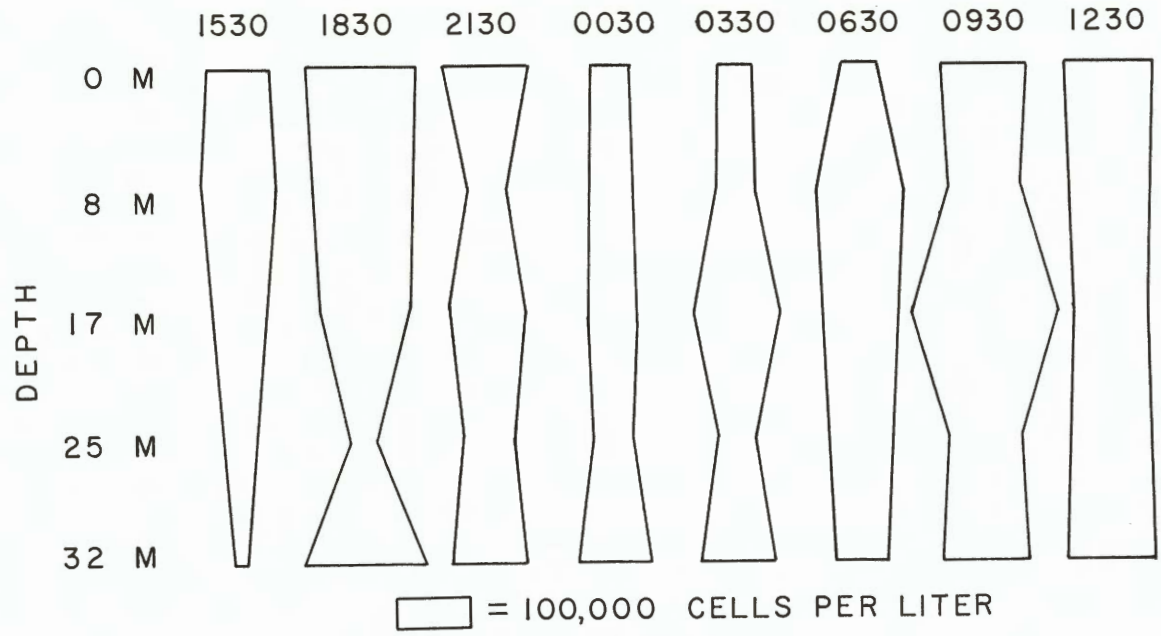

Figure 5. Vertical distribution of phytoplankton at Station 102 for 24 hours in the Patuxent River.

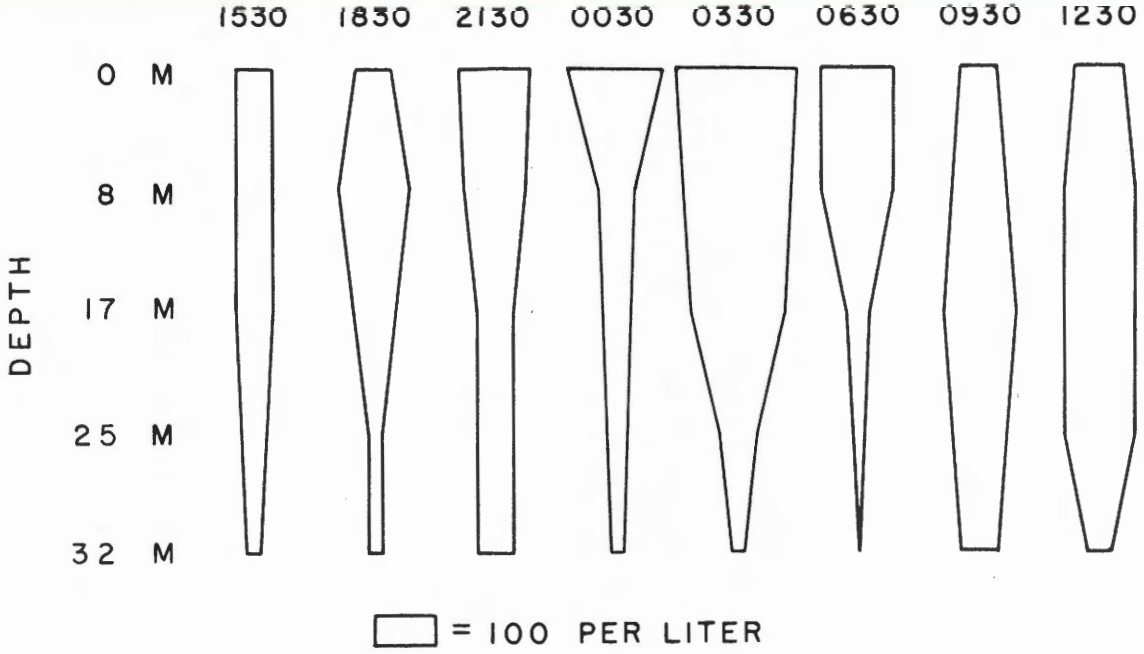

Figure 6. Vertical distribution of zooplankton at Station 102 for 24 hours in the Patuxent River.

Table 1. Distribution of the major phytoplankters at stations along a transect in the Chesapeake Bay. The most abundant species at each station and those of diminishing numbers are indicated respectively A, B, and C. X indicates presence of the organism.

	STATIONS							
	201	202	203	204	205	206	207	208
Asterionella japonica	C	X	X					
Chaetoceros decipiens	C	X	X					
Cryptomonas sp.	X	C	X	X	C	B	A	A
Exuviaella sp.					X		X	
Gonyaulax spinifera	X	X	X		X		X	X
Gymnodinium sp.	X		X	X	X		X	X
Leptocylindrus danicus								
Nitzschia pungens–atlantica	B	A	A	B	A	A	X	B
Peridinium triquetrum	X	X	X			X		
Prorocentrum micans	X	X	X		X			
Prorocentrum sp.	X	X		X				
Rhizosolenia alata	X	C	X	X		X	C	
Rhizosolenia setigera	C	B	B	A	B	B	B	B
Skeletonema costatum	A	X	X	X	C	C		
Thalassiosira nitzschioides	C	X	C	C				

	STATIONS							
	209	210	211	212	213	214	215	216
Cryptomonas sp.	B	C	A	C	A	A	A	A
Exuviaella sp.		X	X	X				
Gonyaulax spinifera	X							
Gymnodinium sp.	X							
Leptocylindrus danicus	X	X	X	X				X
Nitzschia pungens–atlantica	C	B	B	A	C	B	X	
Peridinium triquetrum	X		X	X				
Prorocentrum micans	X	X	X	X	X			
Prorocentrum sp.	X	X	X	X	X			
Rhizosolenia alata	X				X			
Rhizosolenia setigera	A	A	C	B	B	B	B	
Skeletonema costatum	X	X			X			
Thalassiosira nitzschioides	X	X		X				