ZOOPLANKTON OF THE NEW YORK BIGHT: A COMPARISON OF THE YEARS 1975 AND 1976 DURING THE MONTHS OF MAY AND JUNE

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INTRODUCTION

The seasonal abundance and distribution of copepods and other zooplankton in the New York Bight has been described by Judkins, et al. (1980). Their analysis was based on 218 samples collected on 11 cruises over the period September 1974 through September 1975. We made similar collections with the same gear and at the same station locations during May and June of 1976. These last two cruises were made during a widespread bloom of the dinoflagellate *Ceratium tripos*, which may have contributed to an unprecedented anoxic condition off the New Jersey coast in July and August, 1976.

It was felt that an analysis of the May and June 1976 collections, and a comparison with the 1975 data might prove instructive in determining whether the apparently drastic differences in oceanic conditions and phytoplankton populations between the two (1974-75 and 1976) were accompanied by changes in zooplankton abundance and species composition. Coincidental (in time) changes in both trophic levels might be expected through three mechanisms, among others. These are: 1) similar physical forcing such as large scale advection of water masses containing distinct populations, 2) zooplanktonic population changes induced by the unsuitability of *C. tripos* as food, or 3) phytoplankton composition changes brought about by selective grazing pressure by anomalous zooplankton populations. Since only pre-anoxic conditions could be addressed, effects of the anoxia itself, and changes immediately preceding the onset of anoxia are outside the scope of this report.

METHODS

The samples discussed here were obtained on cruises 75-5 (May 6-12, 1975), 75-6 (June 2-9, 1975), 76-7 (May 17-24, 1976), and 76-10 (June 9-13) of the R/V DELAWARE II. The positions of the 19 stations occupied in both years are indicated in Fig. 1. Station G-6 was not occupied in 1975; stations A-2, B-3, C-2, and D-1 were occupied twice in 1976. Data from G-6 and the repeat sampling from the above stations were analyzed, but excluded from the yearly comparisons to prevent biasing toward the shallower depths.

The station protocol is described in Judkins et. al. (1980). An oblique tow was made from the surface to near bottom or to a depth of 200 meters and back to the surface using 20 cm diameter paired bongo nets with 223 micrometer mesh netting. A flow meter was mounted in the mouth of one net, and a bathykymograph was attached to the main net frame. The two samples were combined prior to preservation with 10% buffered formalin.

The preserved samples were subsampled with a piston pipette to yield a fraction (0.005 - 0.04 of the total volume) containing at least 500 copepods, and all zooplankton in the fraction were identified to species level where possible, and tallied. The counts were converted to density (numbers per cubic meter) based on the volume of water sampled by the net and the fraction counted, and then converted to biomass (numbers per square meter) by multiplying the density by the sampling depth. This was done to avoid biasing of data due

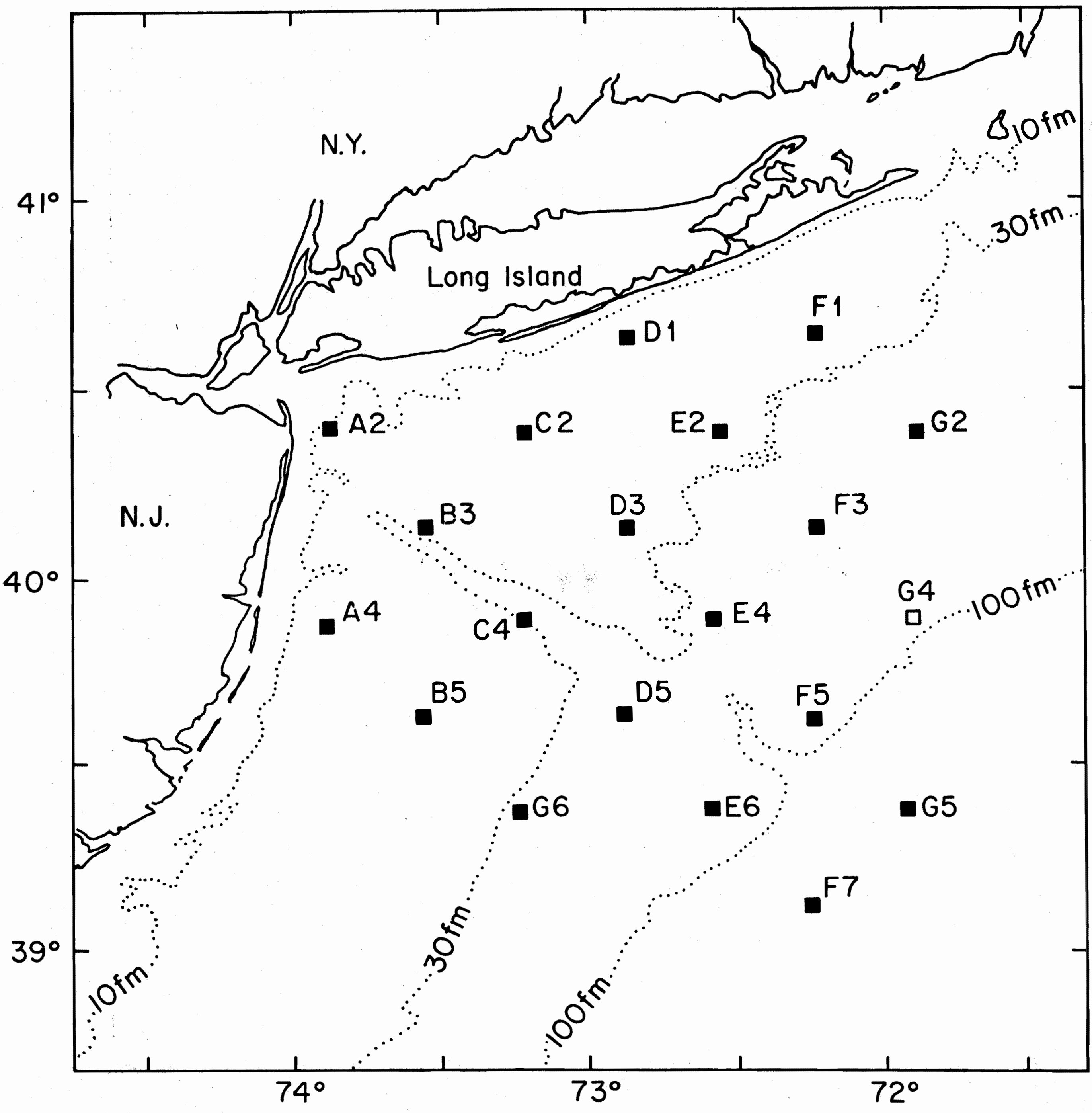

Fig. 1. Station locations for zooplankton sampling.

to vertical migration, or sampling of layers of high density, and is appropriate for a system whose principal energy input is a function of surface irradiance.

Hydrographic data were obtained from a Niskin bottle cast at each station (salinity, nutrients, chlorophyll a, and pheophytin), XBT, fluorescence profiles and underway maps, and phytoplankton species composition (BNL Data Report in preparation; Malone et al., 1979).

RESULTS

The reader is referred to Judkins et al., (1980) for a complete description of the 1975 analyses; only selected data are included here for comparison.

Analysis of the 1976 collections revealed the occurrence of 40 taxonomic groups. These are listed in Table I, along with the frequency of occurrence in individual samples, and in the depth zones of occurrence [less than 50 meters (Zone 1); greater than 50 meters (Zone 2); in depths of from <50 meters to >50 meters (Zone 3)]. Species encountered were very similar to those found in 1974-75, with the exception of the absence of the copepod *Clausocalanus pergens* in 1976. Although it is possible that this species was overlooked in 1976, this is unlikely. Its apparent absence probably represents a level of abundance below the limits for detection (about 20 individuals per square meter). See tables 2 - 4 of Judkins et al., (1980).

TABLE I

Listing of Organisms Encountered in 1976

By Depth Zones and Frequency of Occurrence

	May Zones*	Frequency of Occurrence (%)	June Zones*	Frequency of Occurrence (%)	Average Frequency of Occurrence (%)
Copepods (alphabetical)	3	100	3	100	100
Acartia longiremus	1	65	3	46	55
A. tonsa	3	5	3	17	12
Calanus finmarchicus	3	80	3	75	77
Candacia armata	2	10	0	0	5
Centropages hamatus	3	25	1	4	14
C. typicus	3	95	3	96	96
Mecynocera clausi	2	30	2	21	26
Metridia lucens	3	90	3	54	71
Oithona atlantica	3	85	3	100	93
O. similis	3	95	3	100	98
Paracalanus parvus	3	45	3	75	61
Pleuromamma borealis	2	30	2	21	26
Pseudocalanus minutus	3	100	3	100	100
Temora longicornis	3	95	3	79	86
Tortanus discaudatus	0	0	3	21	11
Unidentified calanoids	3	60	3	38	49
Unidentified cyclopoids	2	5	0	0	3
Unidentified harpacticoids	3	55	1	21	36
Unidentified copepod nauplii	3	80	3	25	50
Unidentified copepods	0	0	1	4	2
Chaetognaths	3	70	3	100	86
Pteropods	3	95	3	79	86
Euphausids	3	80	3	62	70
Decapods	3	60	3	67	64
Appendicularians	3	45	3	50	48
Mollusc larvae	3	40	3	33	37
Polychaetes	1	35	3	38	37
Evadne	3	65	1	8	34
Fish eggs	3	40	3	21	30
Hyperiid amphipods	3	25	3	12	19
Podon	1	15	3	17	16
Medusae	3	10	1	12	11
Barnicle nauplii	1	5	1	8	7
Fish larvae	3	10	0	0	5
Pluteus	0	0	1	8	4
Ectoprocts	1	5	0	0	2
Isopods	0	0	1	4	2
Ostracods	0	0	2	4	2
Malacostroca	0	0	2	4	2

*zones: 0 = absent; 1 = Z < 50m only; 2 = > 50m only; 3 = < 50m plus > 50m

Comparisons of Mean Abundances

Due to the large sampling errors involved with zooplankton collections (Carpenter, et al., 1974), we did not attempt a station by station comparison except by contouring distributions which in itself tends to average station values. These contours revealed no systematic areal differences except those apparent in the regional analysis discussed below.

The use of identical gear and station locations for both years does permit a crude comparison of mean abundances using simple statistics like the Student's t test. Judkins et al., (1980) found major differences between shallower onshore waters (less than 50 meters) and deeper offshore waters (greater than 50 meter water depth). Therefore, differences between years for the two months were examined for mean abundance differences using the t test for these two regions as well as for all stations.

Total Copepods

Over all stations, there was no significant difference in total copepod abundance between May 1975 and May 1976. There was a greater abundance in May 1976 for the onshore region ($p<.05$), and a lower abundance for the offshore region ($p<.05$) than in May 1975. Copepods were more abundant in June of 1976 than June of 1975 ($p<.01$) over all stations, as well as in the onshore ($p<.1$) and offshore ($p<.025$) regions. This indicates a significant increase in total copepod abundance in the onshore region for both months during 1976.

In 1975, there was no statistically significant decrease in the total copepod count among all stations between May and June. There was a significant ($p<.05$) increase between May and June in the total copepod count among all onshore stations, and a significant ($p<.025$) decrease in the total copepod count among all offshore stations. In 1976, the total population of copepods among all stations increased ($p<.1$) between May and June. The difference in totals among onshore stations in May and June 1976 was not significant. The increase in total counts among offshore stations between May and June was significant ($p<.025$).

Examining onshore-offshore differences within months, the greater abundance offshore in May 1975 ($p<.005$) was not observed in May 1976, and the greater abundance onshore in June was also not significant.

Copepod Species Variations

The overall population structure was very similar for the two years. Spearman's rank correlation coefficient determined for the 12 most abundant species in the combined May and June data was 0.8, which was significant at $p<0.01$. There were variations in abundance of individual species. Besides the absence of *C. pergens* in 1976, as was mentioned earlier, *Calanus finmarchicus* was less abundant, as was *Paracalanus parvus* in some instances. *Centropages typicus* was significantly more abundant in 1976 for both months and both regions. These comparisons for the major copepod species are given as Tables II, III, and IV. Table VI is a compilation of the

TABLE II

MEAN COPEPOD ABUNDANCE FOR ALL STATIONS, n = 19

SPECIES	MAY '76			MAY '75		JUNE '76			JUNE '75	
	$\#m^{-2}$	s.e.*	p**	$\#m^{-2}$	s.e.*	$\#m^{-2}$	s.e.*	p**	$\#m^{-2}$	s.e*
P. minutus	83,000	17,200	NS	78,800	14,600	136,000	27,200	(5)	55,700	7,790
T. longicornis	21,600	7,820	NS	10,700	3,810	17,200	4,880	NS	31,300	14,700
O. similis	22,100	7,920	NS	25,500	6,900	19,200	4,510	NS	13,100	2,900
C. typicus	8,640	1,430	<0.025	3,818	1,290	51,600	11,300	<0.005	13,000	4,490
O. atlantica	3,580	856	NS	2,700	1,250	3,750	777	NS	2,780	1,550
C. finmarchicus	3,540	894	<0.025	42,233	17,900	7,180	3,090	< 0.05	20,300	7,250
P. parvus	586	219	<001	9,620	6,090	3,950	1,014	<0.1	2,100	802
A. longiremus	340	186	NS	373	120	3,320	1,840	<0.05	248	95.5
P. borealis	559	279	NS	1,880	1,100	1,372	1,210	NS	356	247
M. clausi	246	115	NS	1,120	564	259	142	NS	958	558
C. pergens	<20	--	<0.005	5,855	3,210	<20	--	<0.005	1,220	608
M. lucens	3,380	1,050	NS	5,530	2,530	4,190	1,620	NS	1,875	878
T. discandatus	<20	--	NS	237	111	126	60	NS	270	113
Others						7,200				
Total copepods	172,000	34,900		303,000	48,300	244,000	30,500		149,000	25,300

* s.e. = standard error of the mean

** p = level of significance of the difference in numbers of individuals per m^2 observed in 1976 and during the same month in 1975.

TABLE III

MEAN COPEPOD ABUNDANCE FOR ONSHORE STATIONS, n = 10

SPECIES	MAY '76			MAY '75		JUNE '76			JUNE '75	
	$\#m^{-2}$	s.e.*	p**	$\#m^{-2}$	s.e.	$\#m^{-2}$	s.e.*	p**	$\#m^{-2}$	s.e.*
P. minutus	71,700	12,100	<0.1	52,600	6,340	65,700	6,760	NS	56,300	10,200
T. longicornis	34,800	13,600	NS	17,700	6,370	30,500	6,930	NS	58,200	25,600
O. similis	34,700	14,000	<0.05	5,780	1,230	25,400	8,000	<0.1	13,500	4,110
C. typicus	6,160	1,820	<0.01	1,254	334	66,300	17,800	<0.01	15,700	7,850
M. lucens	1,810	654	<0.025	132	47	120	69	NS	--	--
O. atlantica	1,390	543	<0.025	116	77	1,680	363	NS	--	--
C. finmarchicus	1,300	573	NS	2,470	750	1,850	585	<0.1	5,320	1,920
P. parvus	527	262	NS	---	---	1,470	295	<0.005	32	0
Acartia	256	81	<0.1	682	273	323	153	NS	833	430
Other species	----	---	NS	<20	---	---	---	NS	69	---
C. hamatus	150	---	NS	209	68	49	---	NS	369	255
T. discandatus	----	---	NS	255	171	191	101	<0.1	513	187
copepods unid.	314	135	<0.025	2,120	813	2,240	2,000	NS	3,330	1,160
Naupli unid	43,100	29,100	NS	---	---	11,100	6,650	NS	---	---
Total copepods	196,000	60,000		83,300	11,700	207,000	23,300		154,000	40,400

*s.e. = standard error of the mean

**p = level of significance of the difference in numbers of individuals per m^2 observed in 1976 and during the same month in 1975.

TABLE IV

MEAN COPEPOD ABUNDANCE FOR OFFSHORE STATIONS, n = 9

SPECIES	MAY '76			MAY '75		JUNE '76			JUNE '75	
	$\#m^{-2}$	s.e.*	p**	$\#m^{-2}$	s.e.*	$\#m^{-2}$	s.e.	p**	$\#m^{-2}$	s.e.*
P. minutus	95,500	34,400	NS	107,000	27,700	213,000	44,900	<0.005	54,900	12,600
T. longicornis	7,000	2,990	NS	2,980	2,000	2,455	1,090	NS	1,524	530
O. similis	8,100	2,240	<0.005	47,400	10,500	12,200	2,280	NS	12,600	4,340
C. typicus	11,400	1,950	<0.1	6,670	2,400	35,300	12,110	<0.05	9,970	4,060
M. lucens	5,130	1,990	NS	11,500	4,680	8,715	2,770	<0.1	3,960	1,622
O. atlantica	6,010	1,300	NS	5,560	2,340	6,056	1,203	NS	5,870	3,030
C. finmarchicus	6,030	1,380	<0.025	86,400	32,600	13,101	6,054	<0.1	36,900	13,400
P. parvus	652	376	< 0.1	20,300	12,200	6,713	1,724	NS	4,400	1,342
A. longiremus	459	143	NS			6,660	3,660	<0.05	143	74
P. borealis	1,180	528	NS	3,960	2,180	2,900	2,540	NS	752	503
M. clause	519	214	<0.1	2,370	1,070	548	276	NS	2,020	1,100
Copepods unid.	1,500	760	<0.01	19,300	7,060	1,230	950	<0.01	6,650	1,840
C. pergens	<20		<0.005	12,400	6,230	<20		<0.005	2,580	1,150
Other species				9,330		293		NS	2,147	
Total	148,000	37,700		337,000	81,900	281,000	55,600		144,000	31,700

*s.e. = standard error of the mean

**p = level of significance of the difference in numbers of individuals per m^2 observed in 1976 and during the same month in 1975.

TABLE V

MEAN ABUNDANCE ALL STATIONS, n = 19

Taxon	May '76 $\#m^{-2}$	May '76 s.e.*	p**	May '75 $\#m^{-2}$	May '75 s.e.*	June '76 $\#m^{-2}$	June '76 s.e.*	p**	June '75 $\#m^{-2}$	June '75 s.e.*
Chaetognaths	4,150	880	NS	4,520±	828	5,840±	1,010	<0.1	4,029	888
Evadne	988	305	<0.005	23,900±	6,490	441±	411	<0.01	7,460	2,710
Pteropods	52,900	38,800	NS	17,800±	4,470	73,100±	43,900	<0.1	13,300	4,750
Appendicularia	1,390	726	<0.005	7,500±	1,490	595±	444	<0.005	3,930	1,200
ONSHORE, n = 10										
Chaetognaths	4,590	1,080	NS	4,760	1,290	4,190	566	NS	5,960	1,270
Evadne	1,170	417	<0.005	39,500	9,640	839	777	<0.05	10,500	4,913
Pteropods	10,800	4,360	<0.05	24,800	5,840	44,300	23,300	<0.1	5,720	2,510
Appendicularia	142	52.5	<0.005	7,010	2,000	108	56.4	<0.005	2,460	735
OFFSHORE, n = 9										
Chaetognaths	3,720	1,470	NS	4,350	1,080	7,670	1,910	<0.005	1,610	471
Evadne	791	464	<0.025	6,660	2,680	-----	-----	NS	3,990	1,360
Pteropods	94,900	79,100	NS	10,061	6,160	105,000	90,800	NS	21,700	9,100
Appendicularia	3,100	1,500	<0.05	8,030	2,330	1,140	929	<0.05	5,570	2,350

* s.e. = standard error of the mean

** p = level of significance of the difference in number of individuals per m^2 observed in 1976 and during the same month in 1975.

TABLE VI

Number of Significant Differences in Abundance Between 1975 and 1976

	Greater Than 1975	Lesser than 1975
C. typicus	6	-
C. finmarchicus	-	5
P. parvus	2	2
P. minutus	3	-
A. longiremus	3	-
O. similis	3	-
M. lucens	2	-
O. atlantica	1	-
T. discandatus	-	1
M. clausii	-	1
	20	9

Total 29

observed species which showed any significant differences between years. For example, *P. minutus* was about 4 times more abundant offshore in June of 1976 than June 1975. The population apparently doubled from May to June, 1976. *C. finmarchicus* was nearly an order of magnitude less abundant in May 1976 compared to May 1975, and one third as abundant in June 1976 compared to June 1975.

In terms of percent abundance, *Pseudocalanus minutus* formed a much higher fraction of animals in 1976 than in 1975, except in the onshore region. Offshore, the percent of this species was nearly double the 1975 percent (70 vs. 36%). *Centropages typicus* showed similar but less drastic increases in 1976.

Other Zooplankton

Chaetognaths were distributed fairly uniformly over the Bight during both years, and because of the low sampling variance, a slight significant ($p<.1$) increase for June 1976 over June 1975 was noted. The absolute difference was only about 45% (Table V). Evadne and Appendicularians were less abundant in 1976 for both months than in 1975. Due to the extremely large variations in pteropod abundances, no significant variations were found, although the mean biomass for 1976 appeared to be 5-10 times the 1975 levels.

Relation to Areas of Anoxia

The anoxic conditions developed in the waters of the western half of our onshore region (stations A2, A4, B3, B5, C4). There were no significant differences in total copepod or total zooplankton abundance or biomass between the eastern and western onshore sections in 1976. We also examined the data for a relationship between copepods and zooplankton with the number density of *Ceratium tripos*, and found a very slightly positive but low correlation ($r^2 = 0.17$).

DISCUSSION

These results show no clear trends which might relate the abundance and composition of the zooplankton to the subsequent development of anoxia, since there are few differences apparent in the zooplankton data between 1976 and 1975. The differences which do exist between the years, while sometimes apparently large, are typical of annual variations within the zooplankton community. In this sense, the data base is much too small. Sears and Clarke (1940), for instance, found very similar results over the period 1929 - 1932 in the region south of Montauk Point, N.Y. They noted a general increase in zooplankton displacement volumes during springs and summers following warm winters, especially 1932, but by May and June 1932 the plankton was sparse. Over the 1929-1932 period *Calanus finmarchicus* varied annually by a factor of 600, being least abundant in the spring of 1932. Changes in the displacement volume of *Centropages* were the inverse of *C. finmarchicus* and reached a maximum in 1932. Sears and Clarke (1940) discounted temperature per se, and mixing of offshore water, as a causative factor in these variations in distributions.

For many of the species discussed here, the period of

May - June is a transitional time (Judkins et al., 1980), and slight variations in the timing of cruises or in biological seasonality could drastically alter the comparisons made here. Two months of data is insufficient to determine the timing of the seasonal cycle. We did not explore comparisons of May with June, or May and June 1976 with June and July 1975, for example, and do not feel the data warrants such comparisons.

In summary, there were a few differences in the zooplankton community in 1976 compared to 1975 but it is difficult to relate these to phytoplankton dynamics or to the events which followed our last collection, and without invoking highly controversial assumptions. For example, perhaps the overall increase in smaller copepods in June 1976 might imply greater transport of carbon to sub-pycnocline layers via sinking of fecal pellets, but total primary production and particulate carbon levels appeared normal in 1976 with the exception of added *Ceratium* biomass (Malone et al., 1979).

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