SEABROOK ENVIRONMENTAL STUDIES, 1976-1977
MONITORING OF PLANKTON
AND RELATED PHYSICAL-CHEMICAL FACTORS
TECHNICAL REPORT VIII-3

Prepared for

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by

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1.0 INTRODUCTION

A plankton preoperational monitoring program was formally implemented, as of July 1975, to facilitate evaluation of the impact of Seabrook Station on composition and distribution of phytoplankton and zooplankton populations, particularly with regard to the intake and discharge of cooling water off Hampton Beach, New Hampshire.

In a previous report that 1) summarized plankton studies that began in the summer of 1969, and 2) presented results of the first formal year of preoperational monitoring, Normandeau Associates, Inc. (1977a) described coastal New Hampshire phytoplankton and zooplankton assemblages as resembling those found at most other near-coastal locations in the Gulf of Maine.

The net phytoplankton assemblage in the Gulf of Maine and specifically in coastal New Hampshire has been described as being largely composed of diatoms and armored dinoflagellates. Diatoms exhibit a typical semiannual cycle of spring and fall maxima, and winter and summer minima. Dinoflagellate population maxima tend to occur during the warmer months. Maximum concentrations of the key plant nutrients, nitrogen and phosphorous, were shown to have occurred in winter, when low light levels tend to limit phytoplankton growth.

Certain net phytoplankton species were selected for particular emphasis because they appeared consistently among the more common phytoplankton organisms collected year after year. Historically, these indicator species, and the seasonal preferences they exhibited have

been as follows: *Skeletonema costatum*, late summer and late fall; *Chaetoceros debilis*, spring; and *Ceratium longipes*, early summer.

Patterns of zooplankton abundance were found to be more complicated. Populations of holoplankton (planktonic animals which spend their entire life in the water column) tended to follow the phytoplankton peaks. Undoubtedly the reason for this was that most holoplankters collected have been herbivorous or omnivorous copepods. Four indicator species have historically exhibited the following distributional trends: *Oithona similis*, ubiquitous; *Eurytemora herdmani*, inshore and in summer; *Pseudocalanus minutus*, offshore, and in late summer and fall; and *Calanus finmarchicus*, offshore and from spring to midsummer.

Embryos and larval stages of animals not planktonic as adults have been termed meroplankton. Among the numerically more prominent members of this category are the larvae of bivalve molluscs, gastropods, barnacles and polychaete worms. Particular attention has been given to impact assessment with regard to meroplankton because this category includes the young of many economically important animals such as clams, mussels and decapod crustaceans (collectively known as "shellfish"), as well as finfish eggs and larvae (collectively termed "ichthyoplankton"). Details concerning the planktonic distribution of early life stages of clams and mussels (particularly those of the soft-shell clam, *Mya arenaria*), and of various finfish species, are contained in Technical Reports VIII-2 (NAI, 1978a) and VIII-4 (NAI, 1978b), respectively.

A third zooplankton life style category, tychoplankton, consists of organisms which temporarily inhabit the water column when they are swept from the sea bottom by currents or actively migrate up into the water column to feed (often at night). Harpacticoid copepods, nematodes, mysids, amphipods, cumaceans and juvenile decapod crustaceans, in part, comprise this group.

This report represents completion of the second annual period (July 1976 through June 1977) of preoperational monitoring of planktonic

organisms in coastal New Hampshire waters, and includes the following important study elements: 1) analysis and interpretation of spatial and temporal distribution of the more abundant phytoplankters and zooplankters; 2) phytoplankton related factors, including standing crop, primary productivity, and nutrients required for growth and 3) zooplankton biomass.

2.0 METHODS

2.1 FIELD COLLECTIONS

At the three stations shown in Figure 2.1-1, the following samples were taken each month from July 1976 to June 1977:

2.1.1 Net Tows: Meso (Mid-Sized) Zooplankton

Two dual-net oblique plankton tows were taken at night, using 333 μm mesh nets fitted to a 60 cm "bongo" frame. The tows were 5 to 10 minutes in duration, and were made from the surface to approximately 5 m off the bottom. The volume filtered through each net (approximately 70 to 120 m^3) was measured with a General Oceanics digital flow meter. Upon retrieval, the contents of each net were thoroughly removed by washing, and fixed in buffered 10% formalin.

2.1.2 Pumped Samples: Microzooplankton and Net Phytoplankton

Four replicate submersible pump samples were taken at night, 2 m below the surface and within 1 m of the bottom. Each pump discharged on deck into its own small, 76 μm mesh plankton net, set into a specially designed stand which filled with seawater to within 15 cm of the top of the net. Each net was fitted with an 8-dram (33-ml) vial on its cod end. Volume filtered was approximately 100 liters. Contents were thoroughly rinsed from the nets after pumping, and fixed in buffered 5% formalin.

2.1.3 Water Chemistry

Whole water samples were collected with a Kemmerer sampler from 1 m below the surface for chlorophyll *a* (3600 ml) and nutrient

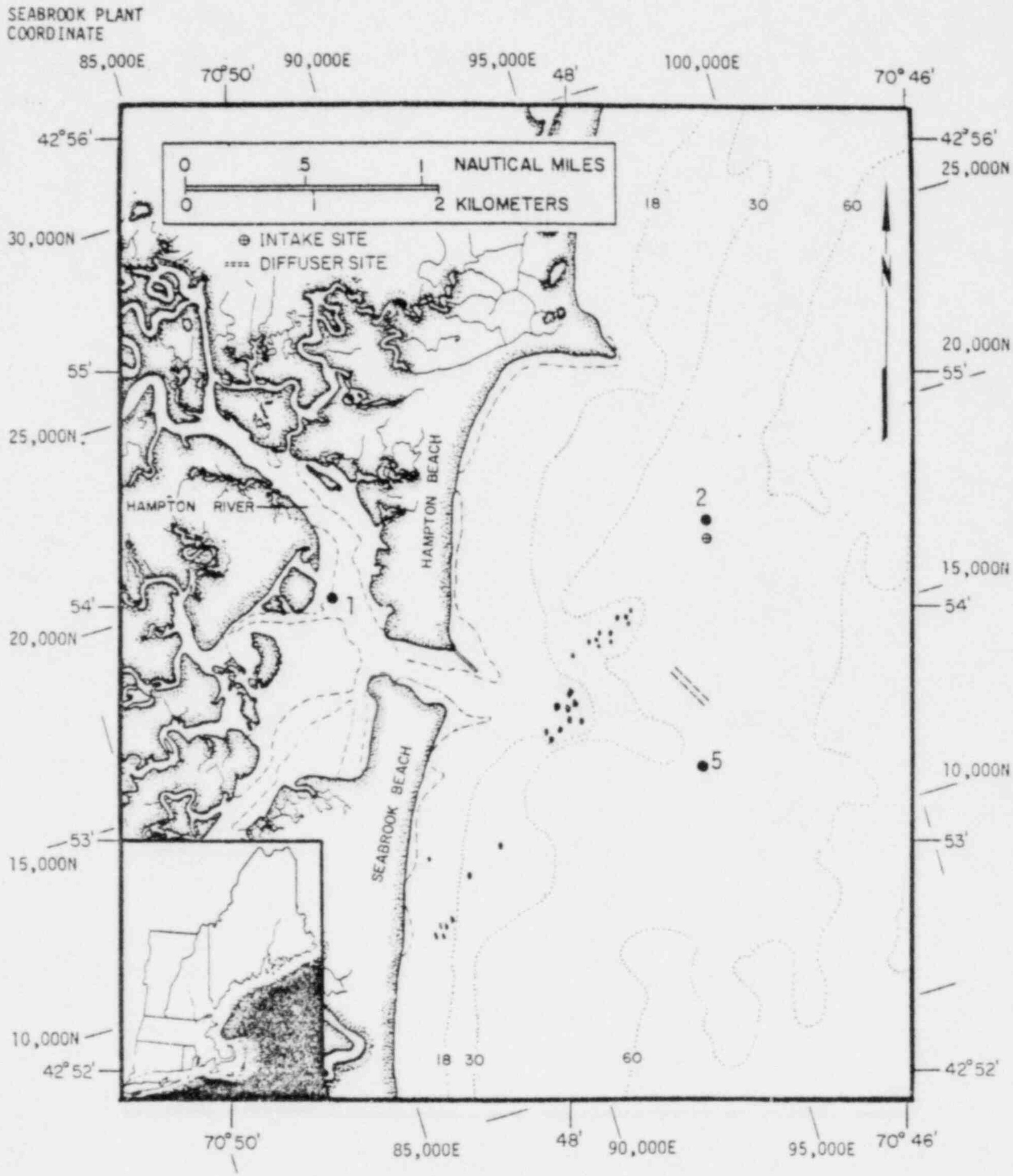

Figure 2.1-1. Plankton sampling stations. Seabrook Environmental Studies, 1976-1977.

analysis (250 ml). The nutrient samples were immediately frozen, while the chlorophyll *a* samples were immediately filtered.

At Station 5 only, during daylight hours, water samples were collected from 1 m below the surface with a Kemmerer bottle for primary productivity determinations. Four 250 ml BOD bottles (2 "light" and 2 "dark" bottles) were filled for ^{14}C uptake estimates and one 400 ml sample collected for pH analysis. On those dates when water samples were collected concurrently for both chlorophyll *a* and ^{14}C uptake determinations, the data were used to estimate phytoplankton growth rates using the procedure of Malone (1977).

Concurrent with the collection of water samples, temperature and conductivity measurements were obtained at 2 m intervals with a Beckman salinometer (Model RS5-3). The conductivity readings were later mathematically converted to salinity (^{o}/oo) based on the observed water temperature.

2.2 LABORATORY ANALYSIS

2.2.1 Net Phytoplankton

Phytoplankton species from pump samples were enumerated from two independent, one-ml subsamples in a Sedgewick-Rafter counting cell. Each subsample was placed under a compound microscope at 100X and three random passes across the width of the Sedgewick-Rafter cell examined. Net phytoplankton were identified to species as far as practical and enumerated on a cellular basis. Four replicate samples were analyzed.

2.2.2 Zooplankton

Microzooplankton from pump samples were analyzed as follows. The volume of the vial was concentrated to a known amount based upon the

relative settled volume of the plankton and detritus. The sample was agitated with a calibrated bulb pipette in an attempt to homogeneously distribute the contents. A 1 ml aliquot was quickly removed and placed in a Sedgewick-Rafter cell and examined under a compound microscope. Selected zooplankton taxa (Appendix 7.1) were identified using magnifications of 40X to 200X. Aliquoting and enumeration continued until 300 to 400 organisms had been counted; the entire sample was enumerated when less than 300 organisms were encountered.

Mesozooplankton samples from 333μm mesh net collections were split using a calibrated Folsom splitter. One half of the sample was used for biomass estimates and the other half was further subsampled for determination of species composition and abundance. Biomass was determined by drying in an oven at 40°C for approximately 12 hours. For taxonomic analysis, aliquots were quickly removed using a Stempel pipette and examined in a Sedgewick-Rafter cell. Selected zooplankton taxa (Appendix Table 7.1-3) were enumerated using a compound microscope at magnifications between 40X and 200X. Subsampling proceeded until 300 to 400 organisms (or at least 15% of the subsample) were counted.

2.2.3 Chlorophyll *a*

Water samples (3600 ml) were divided into four 900 ml replicates and filtered through a glass fiber filter (.45μm pore size). Near the end of the filtration, 2 ml of saturated $MgCO_3$ solution was added to retard sample degradation. Glass fiber filters were frozen pending laboratory extraction of pigment. Extraction of plant pigment consisted of macerating the filter in 90% aqueous acetone and centrifuging. Chlorophyll *a* determinations were accomplished using the *in vitro* fluorometric method (EPA, 1973).

2.2.4 Carbon-14 Uptake

Samples arriving at the laboratory were inoculated immediately with two microcuries of ^{14}C as sodium bicarbonate and incubated for four hours at ambient seawater temperature in a flow-through temperature box with 1000-1100 lux fluorescent illumination. Samples were then fixed with 2 ml of 40% formalin, filtered through a 25 mm Millipore membrane filter (.45 µm pore size) at about 15 psi, dried on a planchet in a dessicator and counted using a Nuclear Chicago Model 186 gas flow scintillometer. Primary production was calculated as mg $C/m^3/hr$ by using the formulae and tables described in Strickland and Parsons (1972).

2.2.5 Plant Nutrients

In the laboratory, water samples were analyzed for the following series of plant nutrients utilizing a Technicon Autoanalyzer system:

NUTRIENT	METHOD	REFERENCE(S)
total phosphorus	persulfate digestion in block digester, followed by automated colorimetric ascorbic acid reduction	EPA (1974)
orthophosphate	automated colorimetric ascorbic acid reduction	EPA (1974)
nitrite	automated cadmium reduction, without cadmium column in place	EPA (1974)
nitrate	automatic cadmium reduction	EPA (1974)

2.3 DATA ANALYSES

Mean values (phytoplankton cells per liter and zooplankton individuals per m^3) were computed for all taxa enumerated by sampling

location, collection date, and, in the case of pumped samples, also by collection depth. Replicate abundance estimates for historically representative species were transformed to $\log_{10}$ (x + 1) equivalent values; logarithmic means and standard deviations were then computed. The $\log_{10}$ (x + 1) transformation presumes a log normal relationship between replicate counts and sample collections. Among the more useful attributes of this procedure is reduction of the influence of one or two extremely high replicate values on the apparent overall density distribution.

Density data representing the 10 to 12 most abundant taxa in the phytoplankton, microzooplankton and mesozooplankton assemblages were used to produce three respective graphical displays, the purpose of which was to highlight probable differences in the distribution of these taxa with collection station and/or water depth. The graphical displays were constructed by specifying four mean density categories (combining all collection dates); for example, for zooplankton the categories $<100/m^3$, $100-500/m^3$, $501-5000/m^3$ and $>5000/m^3$ were chosen. In all three graphical displays, the most dense category was indicated by a completely filled (blackened) box intersecting the taxon (column) and collection site (row) in question. The least dense category was indicated by a completely open (blank) intersecting box (see: Figures 3.1-5, 3.2-7, 3.2-8 and 3.2-9).

3.0 RESULTS

3.1 NET PHYTOPLANKTON

3.1.1 Numerical Abundances

Total net phytoplankton abundance is given by collection date, station and depth in Table 3.1-1 and Figure 3.1-1. In general, cell densities were very low during the study period. Cell concentrations greater than 2000 per liter were recorded only under the following conditions: 1) in surface collections at Station 5, on 3 August 1976 and 13 April, 1977; and 2) in all collections made on 9 September 1976 except at Station 5 near bottom. The 9 September collections alone accounted for 48.5% of all the phytoplankton cells counted; August and December 1976 provided the next most abundant collections (Table 3.1-1).

3.1.2 Species Composition

A total of 107 phytoplankton taxa were identified over the course of the 12 month study. The 35 most prominent taxa are listed in Table 3.1-2. All taxa identified during the study period are listed systematically in Appendix Table 7.1-1. Five taxa each comprised more than 5% of the net phytoplankton over all collection dates; collectively, these five taxa accounted for approximately 70% of all the cells counted.

The most well-represented of the net phytoplankters were *Chaetoceros* spp.; in all, 18 *Chaetoceros* species were identified (Appendix Table 7.1-1). Collectively these 18 species, and the undifferentiated (but top-ranked) *Chaetoceros* spp. category*, accounted for approx-

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*This large category represents cells not identified to species because their cellular morphology was substantially altered due to compaction (e.g., on September 9, 1976) when very large quantities were present.

TABLE 3.1-1. TOTAL NET PHYTOPLANKTON ABUNDANCE (CELLS/LITER) MEANS OF FOUR REPLICATES, EACH STATION AND DEPTH. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

		1976						1977					
		J	A	S	O	N	D	J	F	M	A	M	J
Station 1:	Surface	80	1750	5940	492	178	1560	48	266	470	773	211	120
	Bottom	134	1180	6060	335	249	1500	36	136	454	836	114	76
Station 2:	Surface	76	843	5560	357	264	1710	52	34	340	471	74	172
	Bottom	131	922	3050	128	61	1085	37	67	208	161	2	223
Station 5:	Surface	162	2770	7260	508	234	923	34	38	536	2050	95	177
	Bottom	89	1240	836	585	71	1498	69	36	327	99	12	50
Percentage Representation of Annual Total Count		1.1	14.7	48.5	4.1	1.8	14.8	0.5	1.0	3.9	7.4	0.9	1.4

Bottom = 15 m below the surface

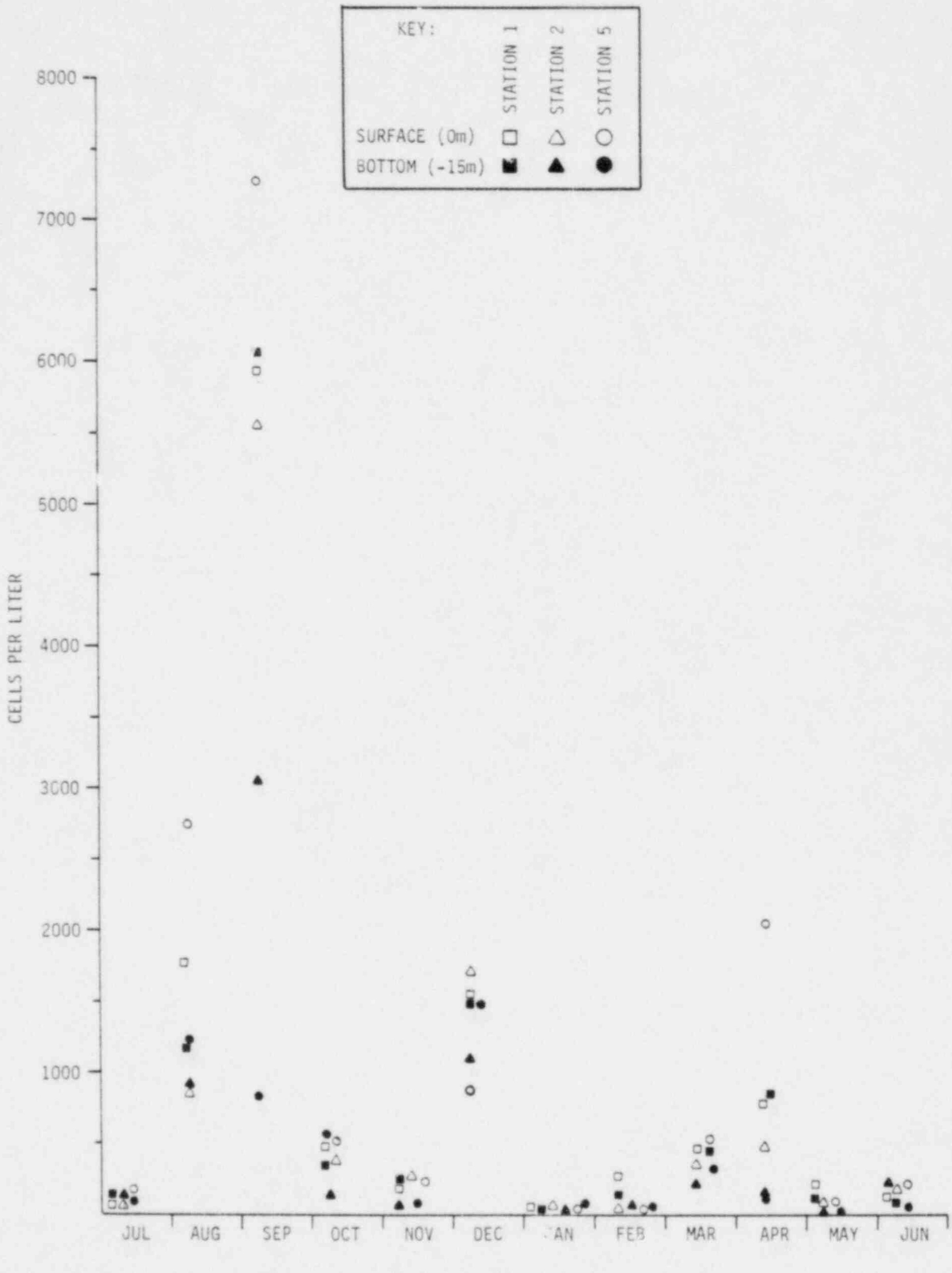

Figure 3.1-1. Total net phytoplankton abundance; means of four replicates each station and month. Seabrook Environmental Studies, 1976-1977.

TABLE 3.1-2. ABUNDANCE, RANK, ANNUAL PERCENTAGE COMPOSITION AND FREQUENCY OF OCCURRENCE OF NET PHYTO-PLANKTERS COLLECTED IN THE VICINITY OF HAMPTON, NEW HAMPSHIRE, JULY 1976 THROUGH JUNE 1977. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

TAXON	RANK	% COMPOSITION	COLLECTION DATES WHEN ORGANISM WAS PRESENT
Chaetoceros spp. (see section 3.1.2)	1	26.0	all, except 7 July and 8 February
Ceratium tripos	2	16.8	all 12
Skeletonema costatum	3	10.8	except 13 April through 9 June
Chaetoceros affinis	4	9.7	7 July, 9 Sept. through 6 Dec., 13 April
Chaetoceros debilis	5	6.8	all, except 8 February
Coscinodiscus spp.	6	4.3	all 12
Nitzschia seriata	7	3.3	3 August through 6 December
Rhizosolenia alata	8	2.9	except 3 January through 21 March
Chaetoceros decipiens	9	2.8	all, except 3 January and 8 February
Ceratium longipes	10	1.7	all, except 8 February
Chaetoceros didymus	11	1.4	7 July, 9 Sept. through 6 Dec., 21 March
Fragilaria spp.	12	1.1	all, except 9 September
Guinardia flaccida	13	1.0	3 August through 7 October, 6 December
Thalassiosira rotula	14	0.8	13 March and 21 April, only
Chaetoceros brevis	15	0.7	except 3 Aug., 7 Oct., 8 Feb. and 9 Jun
Chaetoceros teres	16	0.6	9 September through 6 December, only
Chaetoceros laciniosus	17	0.6	7 dates, but mostly fall and winter
Detonula confervacea	18	0.5	21 March and 4 May, only
Other Pennales	19	0.5	all, except 3 August
Cerataulina pelagica	20	0.5	4 dates, but mostly 9 Sept. and 21 March
Rhizosolenia delicatula	21	0.5	5 dates, but mostly in fall and 21 March
Ceratium bucephalum	22	0.5	7 July through 6 December
Nitzschia delicatissima	23	0.4	9 September and 7 October
Peridinium depressum	24	0.4	all, except 6 December and 8 February
Thalassiosira nordenskioldii	25	0.4	3 dates, but mostly 21 March and 13 April
Chaetoceros lorenzianus	26	0.4	6 dates, but mostly 9 September
Biddulphia aurita	27	0.4	all 12
Rhizosolenia spp. (other than above)	28	0.4	7 July through 6 December

(Continued)

TABLE 3.1-2. (Continued)

TAXON	RANK	% COMPOSITION	COLLECTION DATES WHEN ORGANISM WAS PRESENT
Thalassionema nitzschioides	29	0.4	7 dates, but mostly 21 March
Licmophora spp.	30	0.3	7 July through 7 October, 6 December
Leptocylindrus minimus	31	0.3	7 July, 9 September, 7 October
Navicula crucigera	32	0.2	8 February, only
Chaetoceros compressus	33	0.2	4 dates, mostly 21 March
Chaetoceros concavicornis	34	0.2	13 April and 9 June, only
Melosira moniliformis	35	0.2	except 9 September and 3 January

all others, less than .2%

imately half of all the phytoplankton cells counted. The category *Chaetoceros* spp. resulted not from occurrence of some unknown species but was comprised almost entirely of several of the 18 species listed in Appendix Table 7.1-1.

3.1.3 Seasonal Differences in Species Composition

Cell concentrations are given in Table 3.1-3 for those phytoplankters which comprised 10% or more of samples from at least one collection date. The prominence of the 9 September collections can be seen from Table 3.1-3 to be due to relatively large concentrations of *Chaetoceros* spp., particularly those in the top-ranked category which were not differentiated to species. Other taxa which predominated on other dates included: *Ceratium tripos*, on 3 August; *Skeletonema costatum* on 6 December; and *Chaetoceros debilis*, on 13 April. For species considered to be historically representative (see Introduction, Section 1.0) details pertaining to seasonal distribution are shown in Figures 3.1-2 through 3.1-4.

3.1.4 SPATIAL DISTRIBUTION

Graphic representation of cell concentrations for ten of the more abundant phytoplankton taxa is given in Figure 3.1-5 by station and depth. Distributional patterns exhibited in this figure appear to be complex, suggesting no clearly definable trends encompassing more than one species. In general, when cell densities were expressed logarithmically (Figures 3.1-2 through 3.1-4) there appeared to be few dates on which there were clear-cut concentration differences with station or depth. Notable exceptions include: 1) *Chaetoceros debilis* (Figure 3.1-3), higher cell concentrations near the surface at Station 5, on 13 April 1977; and 2) *Ceratium longipes* (Figure 3.1-4), higher cell concentrations near the surface at Stations 2 and 5, on 4 May and 9 June 1977.

TABLE 3.1-3. NUMERICAL ABUNDANCE (CELLS/LITER) OF NET PHYTOPLANKTON DOMINANTS (COMPRISING 10% OR MORE OF TOTAL CELL COUNT, ON ONE OR MORE COLLECTION DATES), AVERAGED OVER ALL STATIONS AND DEPTHS. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

	COLLECTION DATE											
TAXON	7 JUL 1976	3 AUG 1976	9 SEP 1976	7 OCT 1976	9 NOV 1976	6 DEC 1976	3 JAN 1977	8 FEB 1977	21 MAR 1977	13 APR 1977	4 MAY 1977	9 JUN 1977
Chaetoceros spp. (See Section 3.1.2)	0	6	2320	33	<1	27	<1	0	12	33	<1	1
Ceratium tripos	63	1300	156	17	6	9	14	1	<1	<1	<1	<1
Skeletonema costatum	2	1	104	233	4	1050	1	2	4	0	0	0
Chaetoceros affinis	1	0	893	1	2	18	0	0	0	<1	0	0
Chaetoceros debilis	1	0	64	<1	5	124	1	2	24	450	<1	11
Coscinodiscus spp.	<1	<1	23	5	117	155	21	45	37	39	1	3
Nitzschia seriata	0	1	257	49	<1	<1	0	0	0	0	0	0
Chaetoceros decipiens	0	0	132	<1	1	16	5	6	41	47	4	14
Ceratium longipes	15	49	26	1	<1	<1	1	0	1	<1	20	43
Fragilaria spp.	6	1	0	5	6	7	0	6	1	6	18	36
Thalassiosira rotula	0	0	0	0	0	0	0	0	68	11	0	0
Detonula confervacea	0	0	0	0	0	0	0	0	50	0	1	0
Peridinium depressum	2	<1	10	<1	<1	0	<1	0	<1	<1	21	5
Navicula crucigera	0	0	0	0	0	0	0	19	0	0	0	0
Melosira nummuloides	1	0	0	0	0	2	0	0	1	<1	11	0

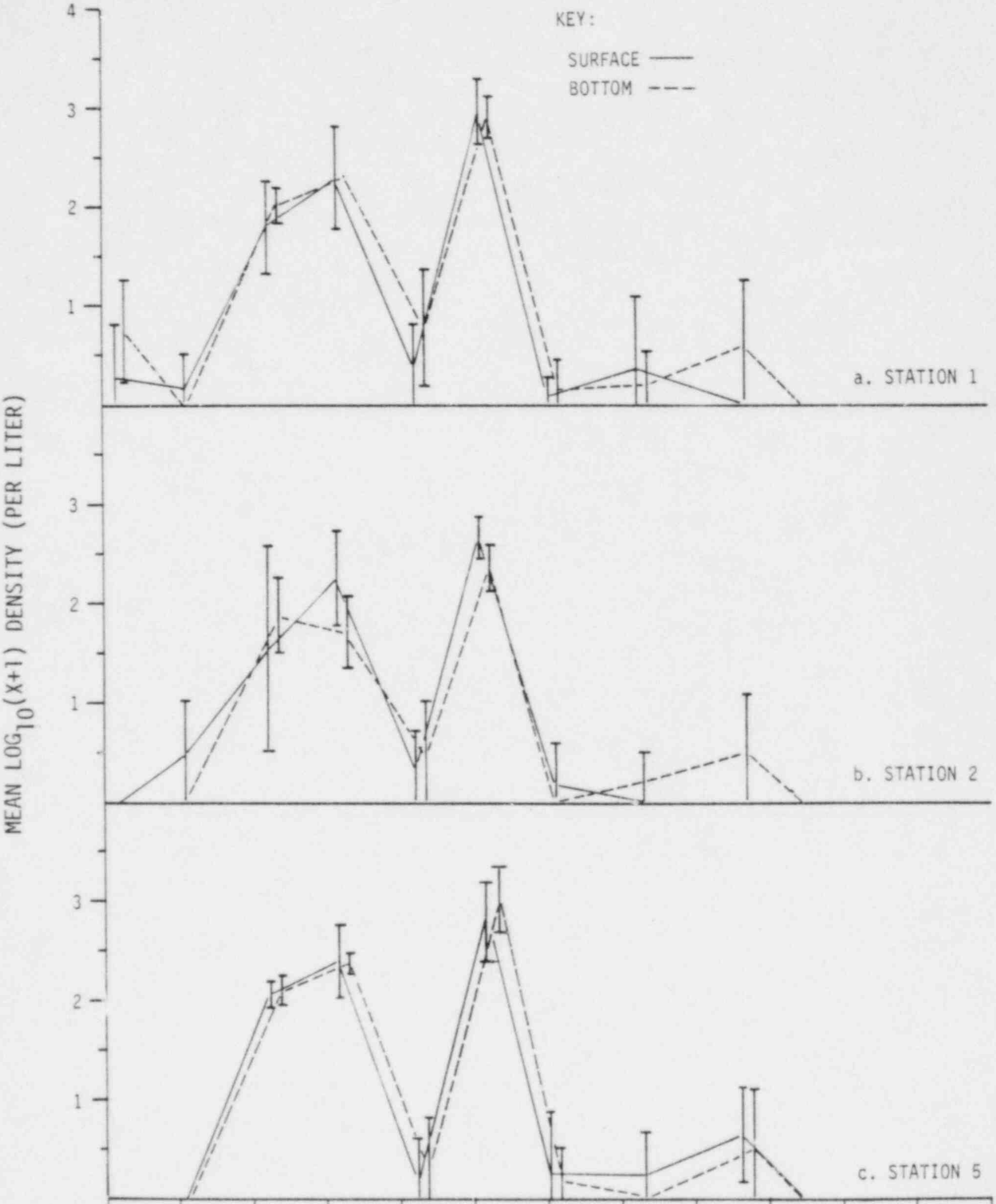

Figure 3.1-2. Numerical abundance of *Skeletonema costatum*, means of four replicates. Standard deviations shown except where less than .10. Seabrook Environmental Studies, 1976-1977.

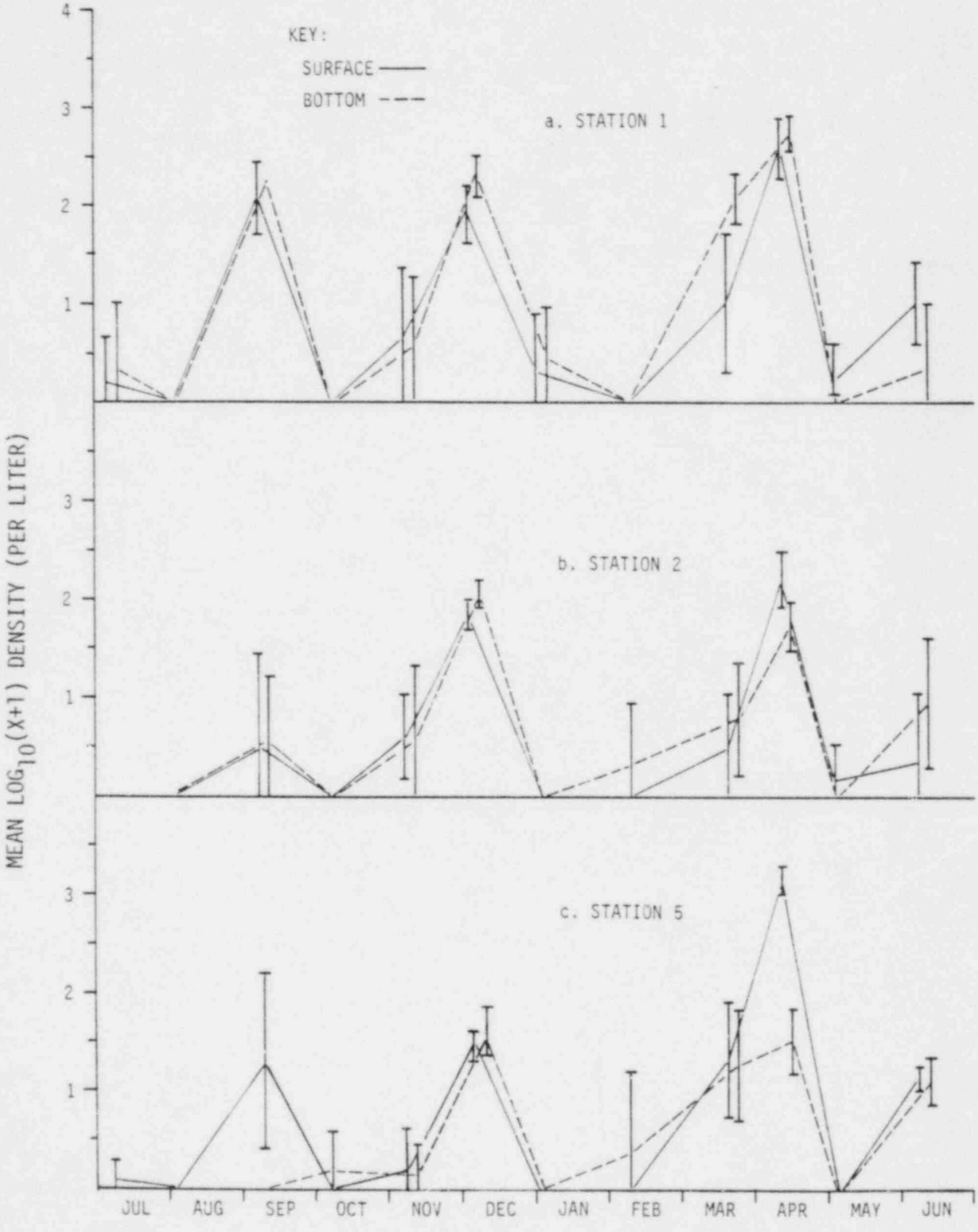

Figure 3.1-3. Numerical abundance of *Chaetoceros debilis*, means of four replicates. Standard deviations shown except where less than .10. Seabrook Environmental Studies, 1976 - 1977.

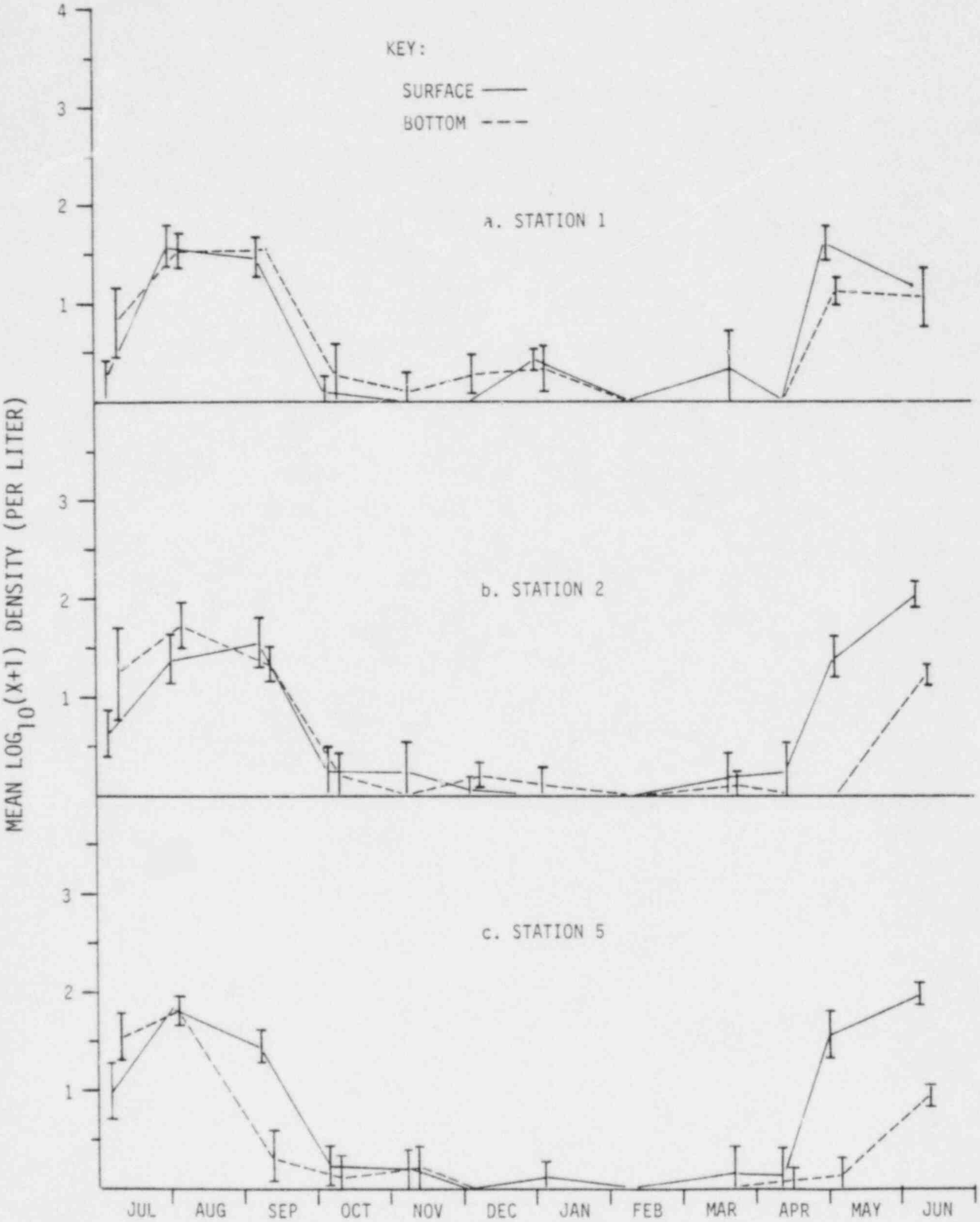

Figure 3.1-4. Numerical abundance of *Ceratium longipes*, means of four replicates. Standard deviations shown except where less than .10. Seabrook Environmental Studies, 1976-1977.

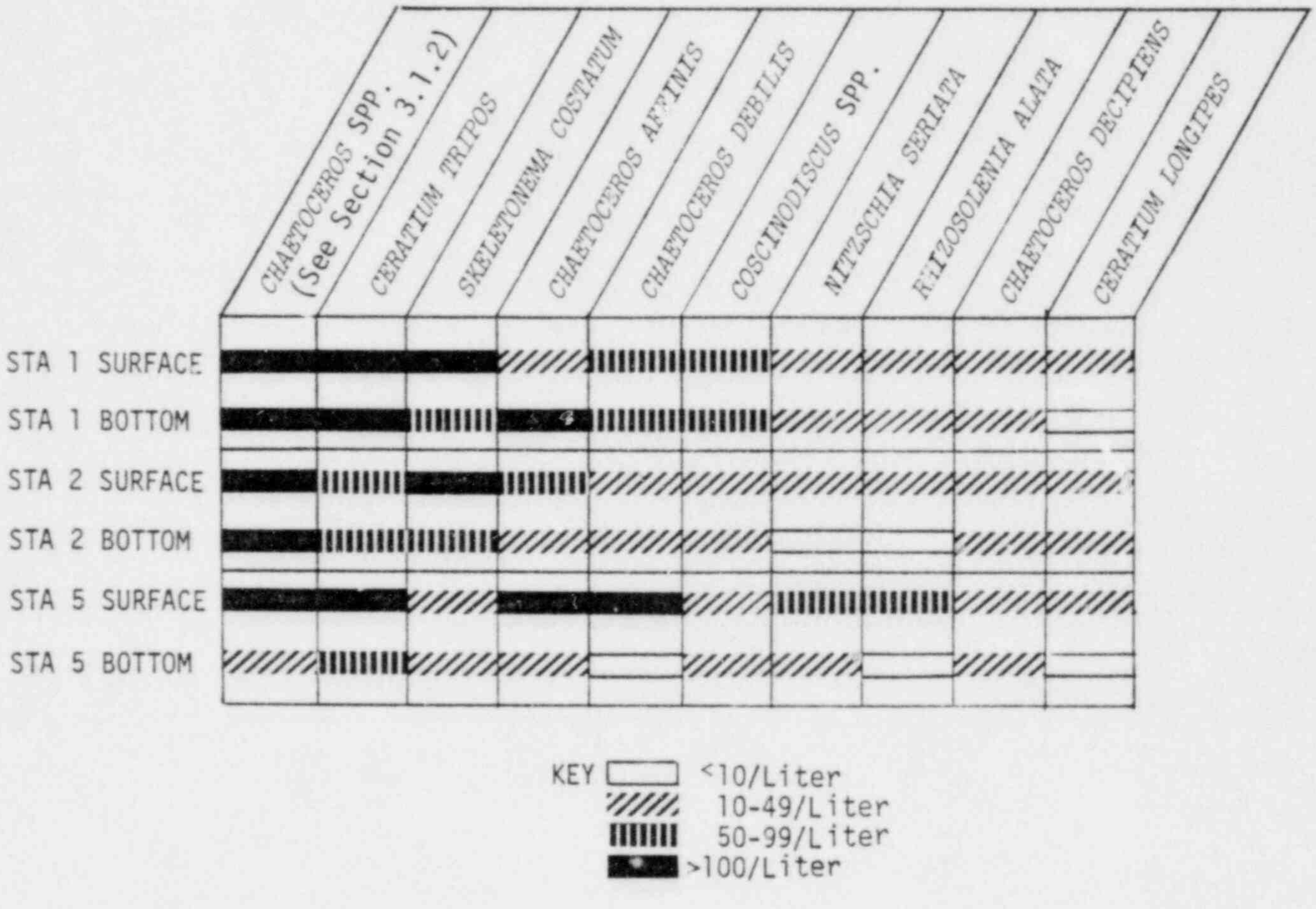

Figure 3.1-5. Mean densities by station and depth of 10 taxonomic components of net phytoplankton assemblages in the vicinity of Hampton Beach, New Hampshire. Seabrook Environmental Studies, 1976 - 1977.

3.2.5 Chlorophyll *a*

Means and standard deviations of chlorophyll *a* measurements are presented in Figure 3.1-6 and in Appendix Table 7.1-2. In general, the seasonal pattern of chlorophyll *a* concentration closely resembled that of total net phytoplankton cell concentration (cf. Figures 3.1-1 and 3.1-6). Similarities included the occurrence of: 1) maximum concentrations on 9 September, 2) relatively modest spring values, and 3) very low concentrations in January and February. A dissimilarity was that the relative cell concentration peak on 6 December 1976, was not reflected in the chlorophyll *a* concentration data. This may be explained in part by the fact that the principal species involved, *Skeletonema costatum*, has very small cells.

3.2.6 Primary Productivity

Table 3.1-4 presents estimates of Carbon 14 uptake rate at Station 5, and relates these to concurrent values of chlorophyll *a* concentration. Highest carbon uptake rates were obtained for 9 June 1977, followed by rates obtained for 7 September 1976, and 14 April 1977. Very low uptake estimates were obtained on 8 July 1976 and 4 January and 7 February 1977. Highest ratio of carbon uptake to chlorophyll *a* concentration (5.0 ^{14}C/Chl *a* per hour) was recorded for 4 May 1977, followed by the ratio for 9 June 1977 (4.0 ^{14}C/Chl *a* per hour). Assuming an internal carbon to chlorophyll *a* ratio of 30 for phytoplankton cells in general (Malone, 1977), estimates of the time required for populations to double their numbers ranged from as briefly as approximately 10.5 hours, on 4 May 1977, to 30 hours on 5 October and 6 December 1976 and 21 March 1977 (Table 3.1-4).

3.2.7 Plant Nutrients

Table 3.1-5 presents concentration data for forms of nitrogen and phosphorus which promote phytoplankton growth. Nitrate concentra-

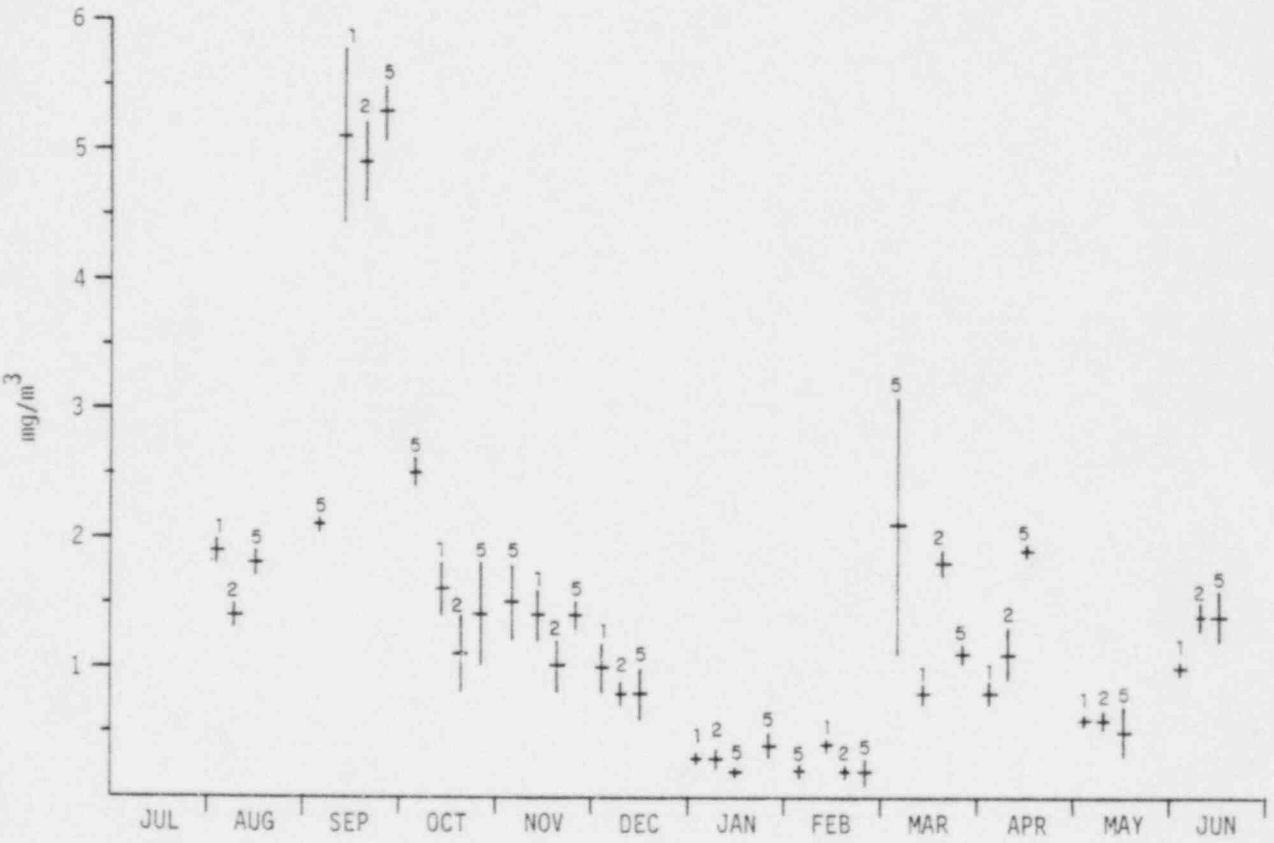

Figure 3.1-6. Chlorophyll *a* concentration (means and standard deviations) at Stations 1, 2 and 5. Seabrook Environmental Studies, 1976 - 1977.

TABLE 3.1-4. PRIMARY PRODUCTIVITY, RATIO OF PRODUCTIVITY TO BIOMASS AND CARBON SPECIFIC PHYTOPLANKTON GROWTH RATES AT STATION 5. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

DATE	TEMPERATURE (°C)	SALINITY[b] (°/oo)	PRIMARY PRODUCTIVITY ($mgC/m^3/hr$) REPLICATE 1	REPLICATE 2	BIOMASS: CHLOROPHYLL *a* (mg/m^3)	RATIO OF PRODUCTIVITY TO BIOMASS (C/CHL/HR)	CARBON SPECIFIC GROWTH RATE (DOUBLINGS/DAY[a])
8 Jul 76	15.9	31.0-31.5	0.46	0.59	--- [b]		
5 Aug 76	16.1	31.1-31.6	2.26	1.78	--- [b]		
7 Sep 76	10.6	30.8-32.2	3.65	4.65	2.1±0.5	1.98	1.4
5 Oct 76	12.9	32.5-32.8	2.20	2.80	2.5± .1	1.00	0.8
8 Nov 76	9.0	32.7-33.2	2.31	1.98	1.5± .3	1.43	1.1
6 Dec 76	6.2	31.6-31.9	0.66	0.82	0.8± .2	0.92	0.8
4 Jan 77	3.0	33.5-33.7	0.58	0.57	0.4± .1	1.44	1.1
7 Feb 77	0.5	34.0-34.4	0.50	---	0.2± .02	2.50	1.6
21 Mar 77	1.9	32.2-32.4	2.29	2.27	2.5± 1.0	0.91	0.8
14 Apr 77	4.4	30.7	4.11	3.80	1.9± .05	2.08	1.4
4 May 77	9.2	29.9-30.9	2.36	2.59	0.5± .2	4.95	2.3
9 Jun 77	9.2	30.7-31.6	5.68	5.47	1.4± .2	3.98	2.1

[a] Calculated using the expression 3.32 $\log_{10}$ (30 + C:Chl)/30; 30:1 is assumed to be the ratio of carbon to chlorophyll *a* in a normal phytoplankton cell (Malone, 1977).

[b] Chlorophyll *a* samples not collected concurrently with primary productivity (See Appendix Table 7.1-2)

TABLE 3.1-5. PLANT NUTRIENT CONCENTRATIONS BY STATION AND SAMPLING DATE. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

	STATION	ORTHOPHOSPHATE PO_4-P (μg/l)	TOTAL PHOSPHORUS TOTAL P (μg/l)	NITRATE NO_3-N (μg/l)	NITRITE NO_2-N (μg/l)	AMMONIA NH_3-N (μg/l)
July						
7	1	30	66	5	2	39
	2	12	27	<1	1	NA
	3	8	20	<1	1	NA
	4	7	21	<1	<1	NA
	5	10	25	<1	1	NA
August						
3	1	9	24	<1	1	<10
	2	2	27	<1	1	<10
	5	2	21	<1	1	<10
September						
9	1	13	35	5	2	239
	2	9	33	<1	1	NA
	5	10	35	<1	1	16
October						
7	1	11	43	10	5	14
	2	9	51	5	4	16
	5	7	51	2	3	10
November						
9	1	28	52	108	2	NA
	2	17	40	66	2	NA
	5	22	40	92	3	NA
December						
6	1	2	34	55	6	NA
	2	12	35	62	4	NA
	5	8	32	34	3	NA
January						
3	1	20	29	8	<1	NA
	2	23	42	5	<1	NA
	5	38	53	6	<1	NA

(Continued)

TABLE 3.1-5. (Continued)

STATION		ORTHOPHOSPHATE PO -P (μg/l)	TOTAL PHOSPHORUS TOTAL P (μg/l)	NITRATE NO_3-N (μg/l)	NITRITE NO_2-N (μg/l)	AMMONIA NH_3-N (μg/l)
February						
8	1	21	44	21	16	NA
	2	17	38	12	<1	NA
	5	18	30	17	<1	NA
March						
21	1	15	20	11	3	NA
	2	12	19	8	2	NA
	5	19	24	12	4	NA
April						
13	1	14	20	8	3	NA
	2	18	21	8	3	NA
	5	18	26	10	4	NA
May						
4	1	13	16	1	<1	NA
	2	15	16	2	<1	NA
	5	10	16	1	<1	NA
June						
9	1	12	11	13	2	NA
	2	7	10	8	1	NA
	5	8	13	6	1	NA

NA = Water sample not analyzed for ammonia

tion values exceeded 15 μg/l only during late fall and winter (November through February) with peak values recorded for 9 November 1976. During the summer months, values were usually below detectable limits. Nitrite concentrations exceeded 5 μg/l only at Station 1, on 6 December 1976 and 8 February 1977. Analyses for ammonia were not routinely carried out until July 1977.

Lowest total phosphorus concentrations were recorded for 9 June 1977, coinciding with highest primary productivity levels observed (see Section 3.2.6). The highest total phosphorus levels (66 μg/l) were recorded for Station 1, on 7 July 1976. In general, however, total phosphorus concentrations tended to be higher by a factor of 2 or 3 during the fall and winter months than during the summer or spring months. Ortnophosphate (the most rapidly assimilable form of phosphorus) followed a similar seasonal pattern although differences between warmer and colder months were not as pronounced as in the case of total phosphorus. With one exception, orthophosphate values were 15 μg/l or less from 7 July through 7 October 1976 and on 4 May and 9 June 1977. The one exception was an orthophosphate concentration value of 30 μg/l recorded for Station 1 on 7 July 1976. Often, concentrations of most of the nutrients investigated were higher at Station 1 than at either Station 2 or Station 5 (Table 3.1-5), suggesting contributions from anthropogenic sources (e.g., sewage effluent, septic tank leachate, etc.).

3.2 ZOOPLANKT^N

3.2.1 Species Composition

Approximately 73 zooplankton taxa were designated and enumerated during the 12 month study period from July 1976 through June 1977. The 27 most prominent taxa are shown in Table 3.2-1. All taxa are listed systematically in Appendix Table 7.1-3. Overall, the numerically most important taxa included: copepod nauplii, *Oithona* spp., *Pseudocalanus* spp., bivalve veligers, *Eurytemora* spp. and *Centropages* spp.

TABLE 3.2-1. ABUNDANCE, RANK, ANNUAL PERCENTAGE COMPOSITION AND FREQUENCY OF OCCURRENCE OF ZOOPLANKTERS COLLECTED IN THE VICINITY OF HAMPTON, NEW HAMPSHIRE, JULY 1976 THROUGH JUNE 1977. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

TAXON	RANK	% COMPOSITION	COLLECTION DATES WHEN ORGANISM WAS PRESENT
Copepod nauplii (predominantly Ca)	1	34.6	all 12
Oithona spp. (Cy)	2	29.8	all 12
Pseudocalanus spp. (Ca)*	3	10.8	all 12
Bivalve veligers	4	7.6	all 12
Eurytemora spp. (Ca)	5	3.1	all, except 3 Jan
Centropages spp. (Ca)	6	2.4	all, except 4 May
Gastropod veligers	7	1.9	all 12
Cirripedia (Barnacle) larvae	8	1.5	except 6 Dec through 8 Feb
Microsetella norvegica (H)	9	1.4	all 12
Acartia spp. (Ca)	10	1.1	all 12
Polychaete nectochaete larvae	11	1.0	all 12
Temora longicornis (Ca)	12	0.7	all 12
Bryozoan cyphonautes larvae	13	0.7	7 July through 6 Dec
Calanus finmarchicus (Ca)	14	0.5	all 12
Harpacticoida	15	0.5	all 12
Polychaete eggs	16	0.4	6 (principally Spring and Fall)
Paracalanus parvus (Ca)	17	0.3	except 8 Feb through 9 Jun
Gastropod eggs	18	0.2	except 6 Dec and 3 Jan
Metridia spp. (Ca)	19	0.2	all 12
Evadne spp. (Cl)	20	0.2	except 9 Nov through 8 Feb
Podon spp. (Cl)	21	0.2	except 6 Dec through 13 Apr
Echinoderm larvae	22	0.2	6 (principally Spring and Fall)
Nematodes	23	0.1	all 12
Tortanus discaudatus (Ca)	24	0.1	all 12
Rotifera	25	0.1	6 (principally in Spring)
Paracalanus crassirostris (Ca)	26	0.1	9 Nov through 3 Jan
Brachyuran (Crab) larvae	27	0.1	except 9 Nov through 13 Apr

All others less than 0.1%

* includes individuals identified as *P. minutus* and *Pseudocalanus* "Type A"

Holoplankton Codes: Ca = Calanoid copepod
Cl = Cladoceran
Cy = Cyclopoid copepod
H = Pelagic harpacticoid copepod

Together these six taxonomic categories comprised approximately 88% of the total number of organisms enumerated. The Copepoda accounted for approximately 85% of the total number of organisms.

3.2.2 Seasonal Distribution

3.2.2.1 General

Results of the two collection methods (76 μm pump samples and 333 μm net tows) are presented in terms of mean total zooplankton density (per m^3) by collection date in Figure 3.2-1 and Appendix Table 7.1-4. Animals collected by pumping seawater into a 76 μm mesh net far outnumbered larger forms captured by the 333 μm mesh bongo net. Enormous numbers of horse mussel (*Modiolus modiolus*) straight-hinge veligers (less than 48 hours old) were enumerated from the 7 October 1976 pump samples. For reasons explained in more detail in the discussion (Section 4.0), it was considered appropriate to regard the occurrence of these early veligers as a chance anomaly when considering overall patterns of seasonal abundance of total zooplankton. Discounting the straight-hinge *M. modiolus*, both microzooplankton and mesozooplankton collections exhibited peak densities on 9 June 1977 (44,100/m^3 and 3660/m^3, respectively). Second highest levels of abundance (30,400/m^3 for microzooplankton; 1280/m^3 for mesozooplankton) were also recorded for the same date (7 July 1976). The highest late summer/fall densities occurred on 9 September 1976, for the microzooplankton (28,600/m^3) and on 9 November 1976, for the mesozooplankton (1160/m^3).

Of the three categories based on zooplankton life style, holoplankters contributed by far the greatest percentage to total numbers collected and tychoplankters the smallest percentage (Figure 3.2-2). Mean abundances by life style category are shown for each collection date in Appendix Table 7.1-4b. Highest densities of holoplankters were recorded on 7 July, 3 August and 9 September 1976, and 9 June 1977,

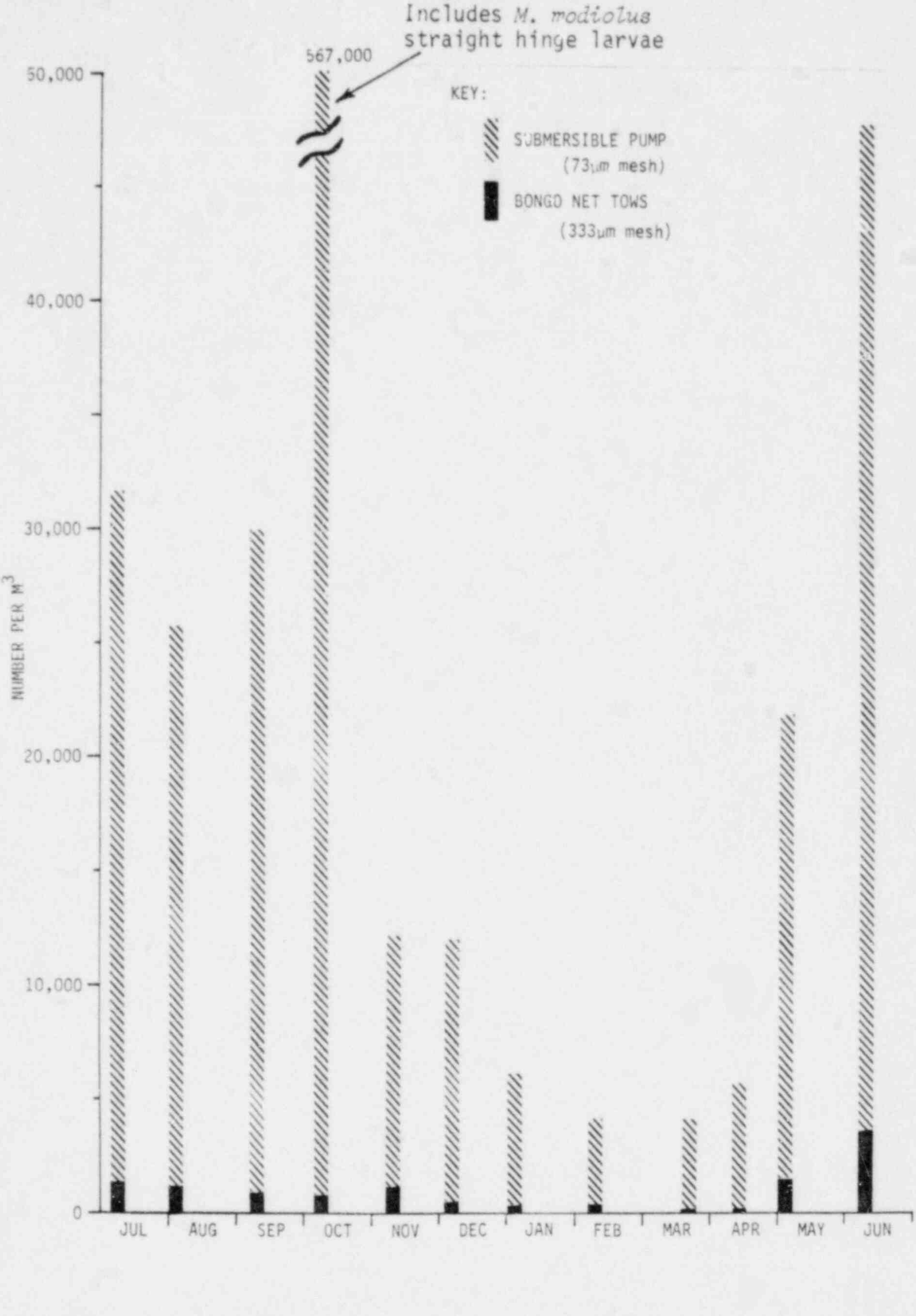

Figure 3.2-1. Mean zooplankton abundance (no./m^3) by collection date. Seabrook Environmental Studies, 1976-1977.

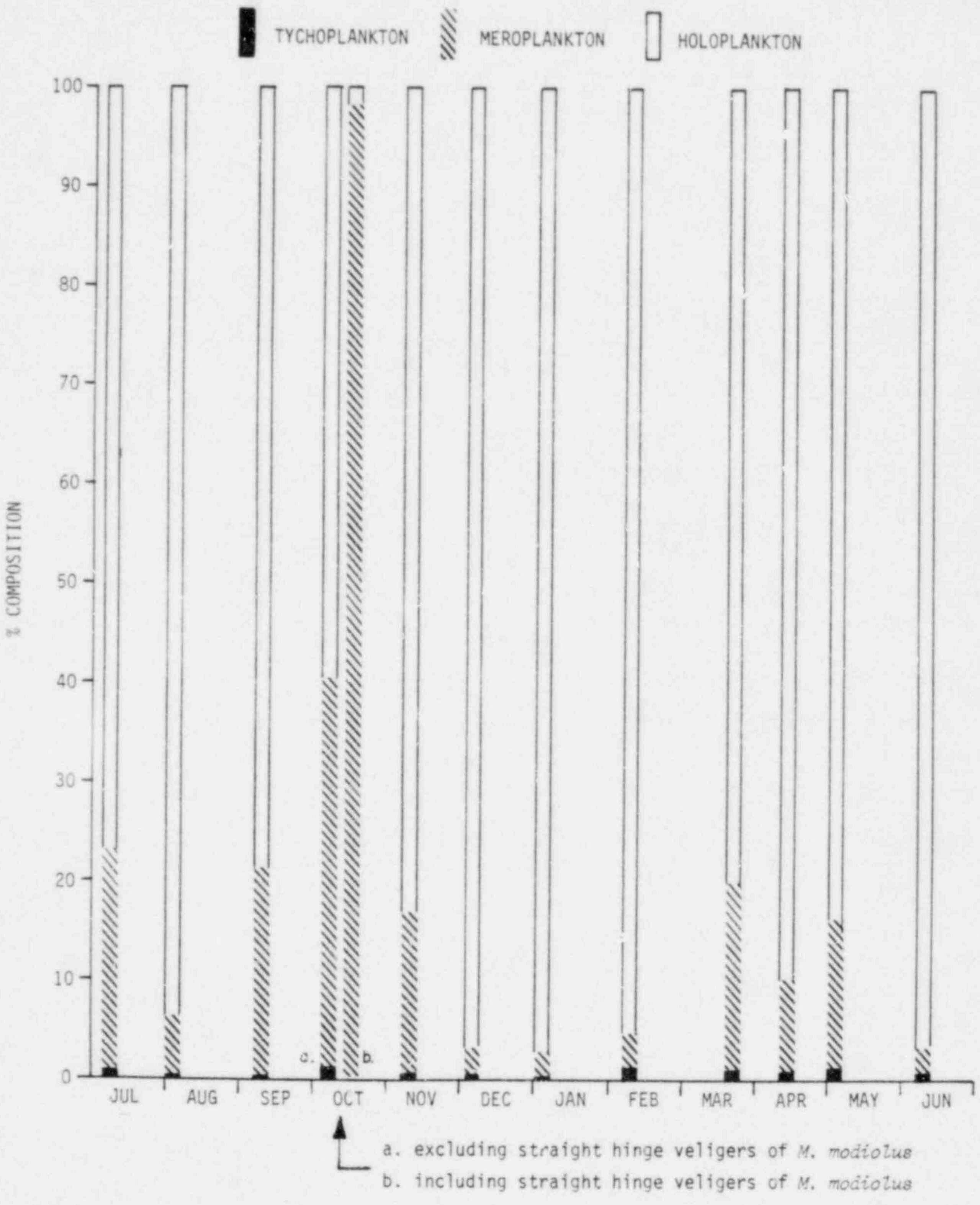

Figure 3.2-2. Percentage contribution to total abundance by holoplanktonic, meroplanktonic and tychoplanktonic forms for each collection date. Seabrook Environmental Studies, 1976-1977.

each collection exceeding a mean density of 20,000/m^3. Highest densities of meroplankters occurred on 7 July, 9 September and 7 October, 1976, each collection exceeding a mean density of 6000/m^3. Tychoplankton mean densities exceeded 200/m^3 in collections from 7 July 1976 and 4 May and 9 June 1977.

3.2.2.2 Holoplankton

Most of the holoplankters listed in Table 3.2-1 were represented throughout the study period or were absent only during some of the colder months. A few exceptions were *Centropages* spp., which were absent in spring and *Paracalanus parvus*, which was not present in collections after 8 February 1977.

Copepod nauplii were most abundant on 9 September 1976 (12,300/m^3), and 9 June 1977 (21,940/m^3) (Appendix Table 7.1-4c). Lowest densities were recorded for 3 January and 8 February 1977 (1980 and 1930/m^3, respectively). These nauplii represent the earliest post embryonic life stages of calanoid (Ca) copepod species listed in Table 3.2-1. Seasonal abundances of the next major developmental stage, the copepodite stage, are represented in Figure 3.2-3 for the six principal calanoid species present. Further detail regarding seasonal distribution characteristics can be seen in Figures 3.2-4 and 3.2-5 for copepodites and adult males and females of the two most abundant calanoid species, *Pseudocalanus minutus* and *Eurytemora herdmani*.

With the exception of copepod nauplii, cyclopoid copepods of *Oithona* spp. were the most abundant of all taxa. Although it was possible to distinguish *Oithona* spp. from any other copepod genus at all life stages, only adult females could be unequivocally identified as belonging to one of two congeneric species, *O. similis* or *O. plumifera*. On the basis of the ratio observed among the adult females, *O. similis* was about 20 times as abundant in the collections as *O. plumifera*. Distributional characteristics of *Oithona* spp. nauplii, copepodites,

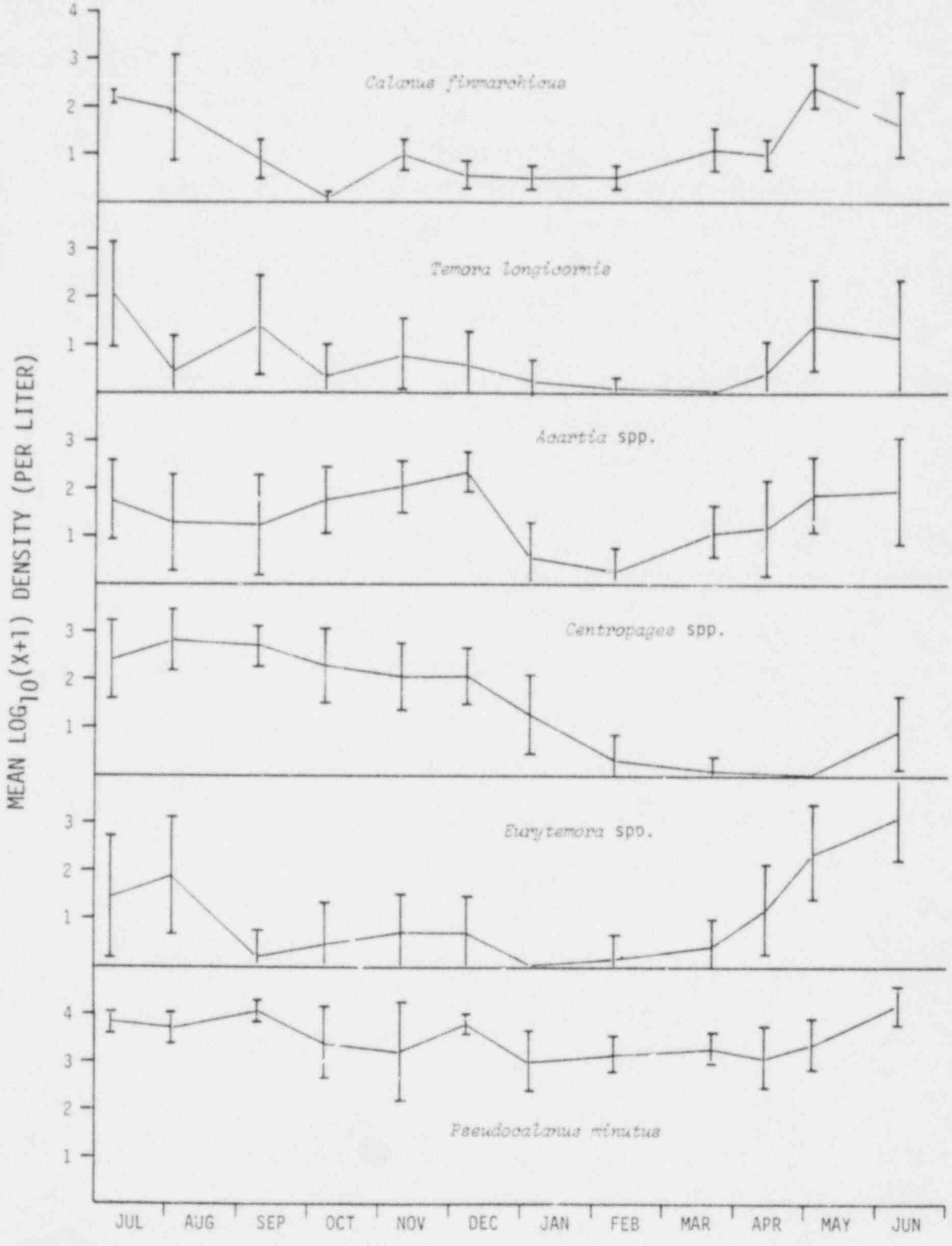

Figure 3.2-3. Seasonal abundance of copepodites representing six species of calanoid copepods. Seabrook Environmental Studies, 1976-1977.

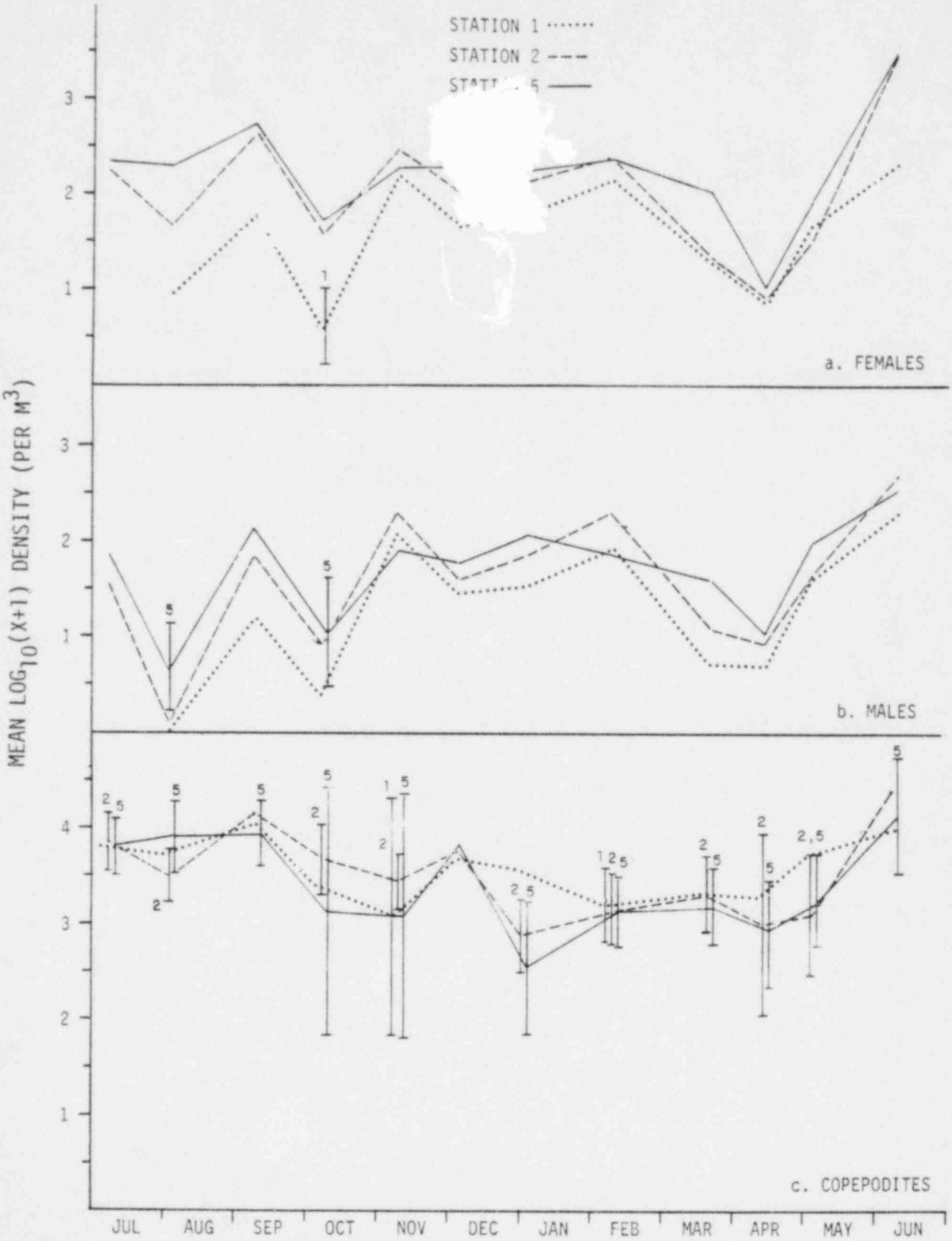

Figure 3.2-4. Mean abundance of *Pseudocalanus minutus* life stages by station. Standard deviations shown except where less than .25. Seabrook Environmental Studies, 1976-1977.

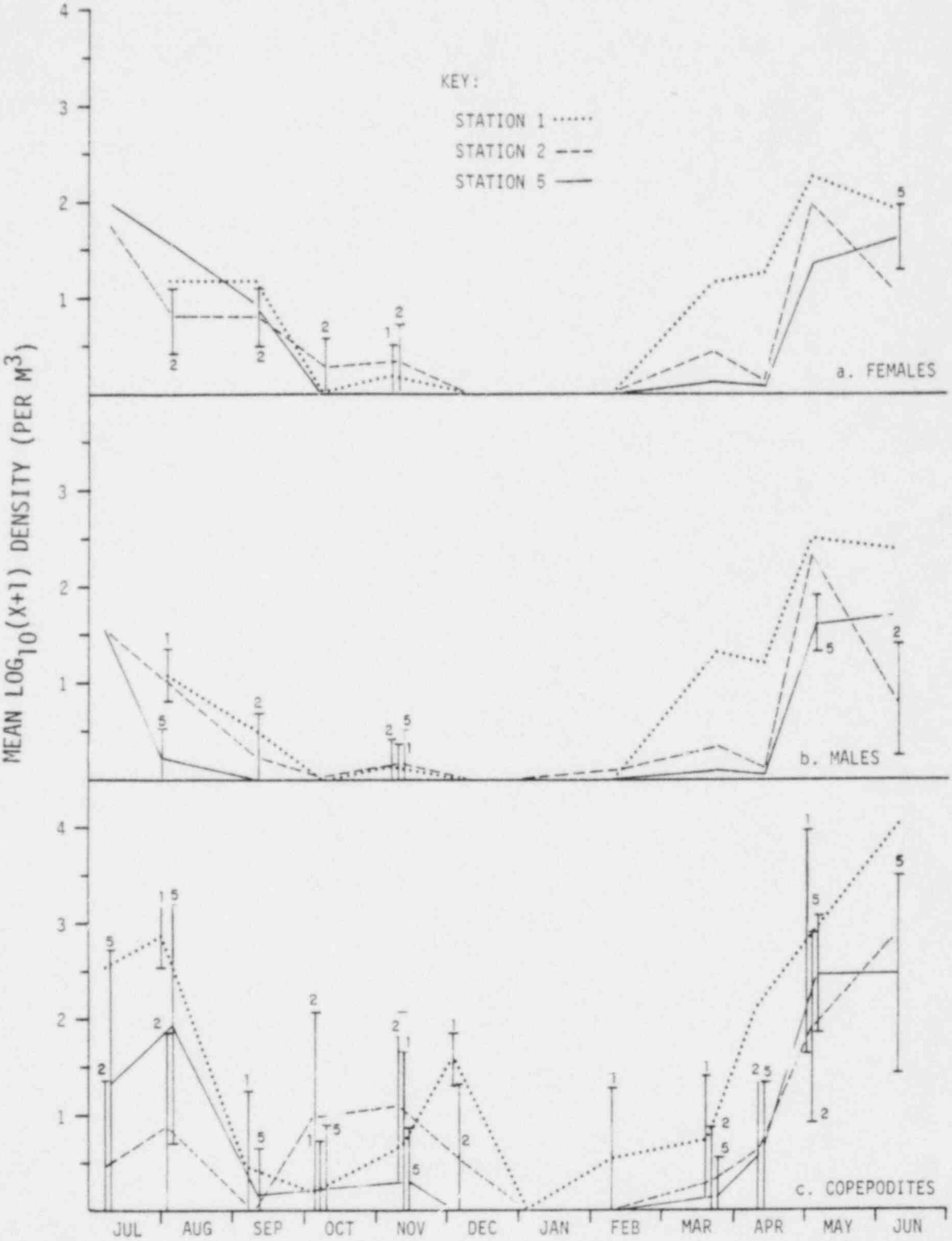

Figure 3.2-5. Mean abundance of *Eurytemora herdmani* life stages by station. Standard deviations shown except where less than .25. Seabrook Environmental Studies, 1976-1977.

males and females are given in Figure 3.2-6. A similar pattern of gradual decline in abundance, from summer 1976 to spring 1977, followed by a relatively rapid increase by late spring, appeared to apply to all four life stages.

3.2.2.3 Meroplankton

Invertebrate taxa at the suborder level or above which were generally well-represented in the meroplankton are listed in Table 3.2-2. Collectively these eight groups comprised approximately 14% of the total zooplankton collected (76% if the 7 October 1976 count of *M. modiolus* straight-hinge larvae were included), and all but a fraction of a percent of the meroplankton. Bivalve veligers, the most abundant meroplankton component, exhibited densities in excess of $1500/m^3$ on 7 July, 9 September, 7 October and 9 November 1976. Overall, bivalve larvae densities were much higher in the last half of 1976 than in the first half of 1977 (Table 3.2-2). Gastropod embryonic and larval forms exhibited a similar trend. The highest density of polychaete embryos and larvae was recorded for 9 September 1976 ($1310/m^3$); an apparent secondary peak ($668/m^3$) occurred on 4 May 1977. Cirripedes (i.e., barnacles) were most abundant in early spring, with the apparent peak ($2390/m^3$) occurring with the 4 May 1977 collection. Bryozoan larvae were present only in the 1976 collections, with peak density values recorded for 9 September and 7 October. Both decapod and echinoderm larvae exhibited seasonal patterns of abundance, with the former group appearing to favor the summer months, and the latter group exhibiting bimodality centering on the September-October 1976, and April-May 1977 collections. Isopoda (epicaridean larvae) occurred sporadically in the collections, with the apparent peak density recorded for 7 July 1976.

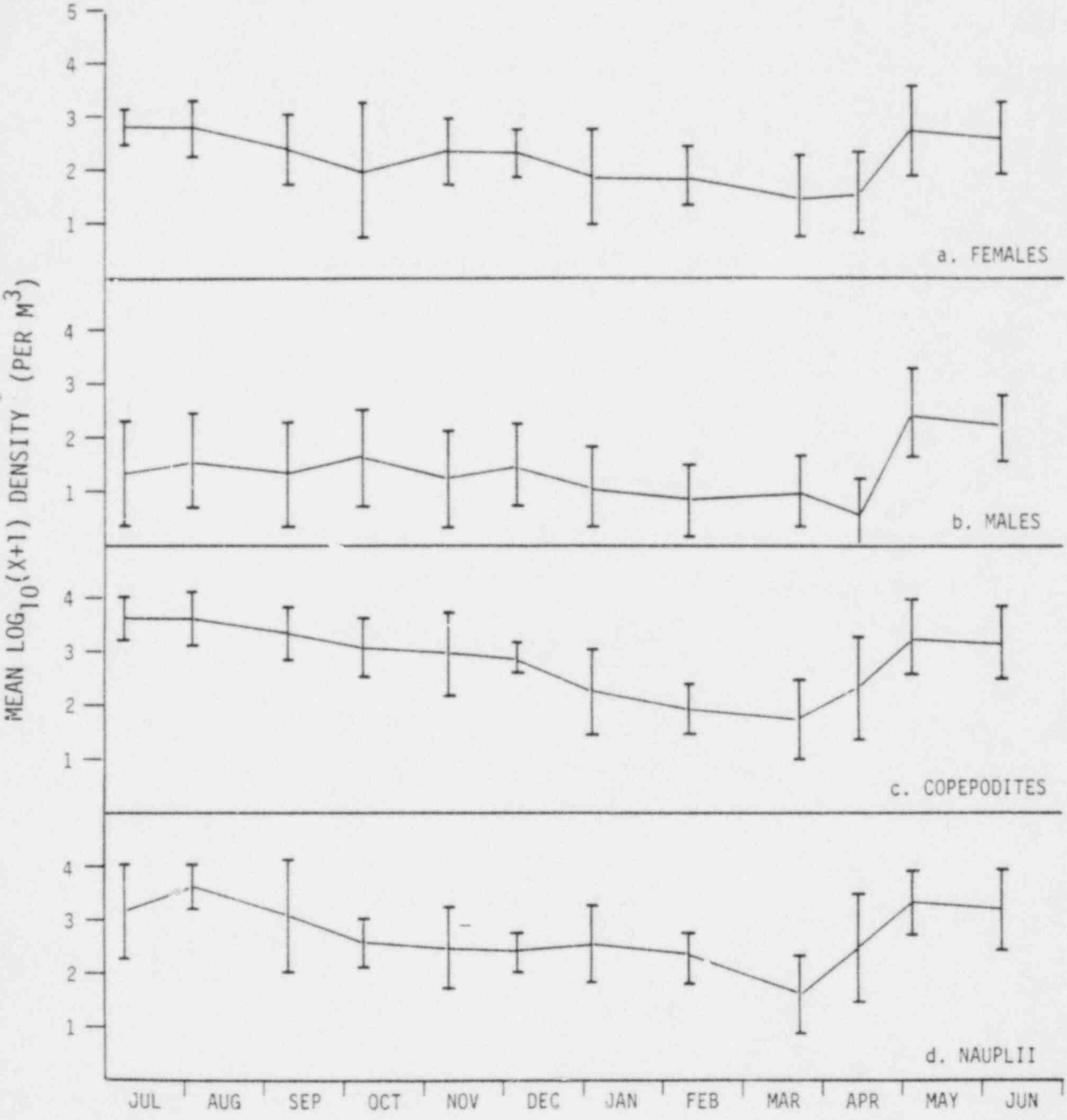

Figure 3.2-6. Seasonal abundance of four life stages of *Oithona* spp. Seabrook Environmental Studies, 1976-1977.

TABLE 3.2-2. MEAN ABUNDANCE (PER M^3) OF IMPORTANT INVERTEBRATE TAXONOMIC GROUPS IN THE MEROPLANKTON, BY COLLECTION DATE. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

COLLECTION DATE	GROUPS: BIVALVIA	GASTROPODA	POLYCHAETA	CIRRIPEDIA	BRYOZOA	DECAPODA	ECHINODERMATA	ISOPODA
7 July 1976	5,650	1,110	108	65	15	68	0	20
3 August 1976	328	957	129	16	4	89	0	1
9 September 1976	2,680	1,270	1,310	32	796	16	119	1
7 October 1976	[a]5,020 [b]556,000	374	287	4	637	1	115	6
9 November 1976	1,800	97	13	3	42	2	0	1
6 December 1976	165	38	16	4	9	0	2	1
3 January 1977	147	7	1	0	0	1	0	1
8 February 1977	128	8	4	0	0	1	0	3
21 March 1977	9	39	144	568	0	1	5	1
13 April 1977	139	103	157	100	0	0	40	0
4 May 1977	77	128	668	2,390	0	2	44	0
9 June 1977	354	458	223	40	0	73	0	3
Percentage representation of total meroplankton, on an annual basis	43.2[a] 94.9[b]	21.9	13.1	14.4	3.0	1.2	1.2	1.5

[a] excluding straight hinge veligers of *M. modiolus*

[b] including straight hinge veligers of *M. modiolus*

3.2.3 Spatial Distribution

Graphic representations of taxonomic mean density spatial distributions (all collection dates combined) are shown in Figures 3.2-7 through 3.2-9. Several of the taxa listed appeared to exhibit a distributional pattern consisting of an affinity for surface waters in the open coastal area (Stations 2 and 5) and dispersal (i.e., no depth affinity) within Hampton Harbor (Station 1). This distributional pattern was best exemplified by bivalve veligers and barnacle larvae (Figure 3.2-8), and by *Oithona* spp. copepodites and nauplii (Figure 3.2-9). Adult *Oithona* spp. appeared to be associated more strongly with surface waters whatever the station location (Figure 3.2-9). *Acartia hudsonica (= A. clausi)* and *Eurytemora herdmani* exhibited evidence of an affinity for harbor waters; *Pseudocalanus minutus*, *Calanus finmarchicus* copepodites, *Centropages typicus*, *Metridia* spp. copepodites, *Podon* spp., *Temora longicornis* and *Tortanus discaudatus* exhibited affinities for open coastal waters (Figures 3.2-7 and 3.2-8). Figures 3.2-7 and 3.2-8 suggest that inshore/offshore distribution trends tended to be more demonstrable for sexually mature than for sexually immature individuals.

Gastropod veligers and the pelagic harpacticoid, *Microsetella norvegica*, appeared to be well dispersed throughout the study area (i.e., no depth or station affinities indicated). Polychaete larvae appeared to be concentrated in the surface waters of Hampton Harbor. The only taxon exhibiting indication of bottom water affinities was *Temora longicornis* copepodites (Figure 3.2-8).

3.2.4 Biomass

Results of mesozooplankton biomass measurements from oblique bongo net tow collections are presented in Figure 3.2-10a, and Appendix Table 7.1-5. Seasonal and spatial distribution trends appear similar to trends exhibited by the numerical abundance data (Figure 3.2-10b) with a few notable exceptions. These exceptions relate to the difficulty of

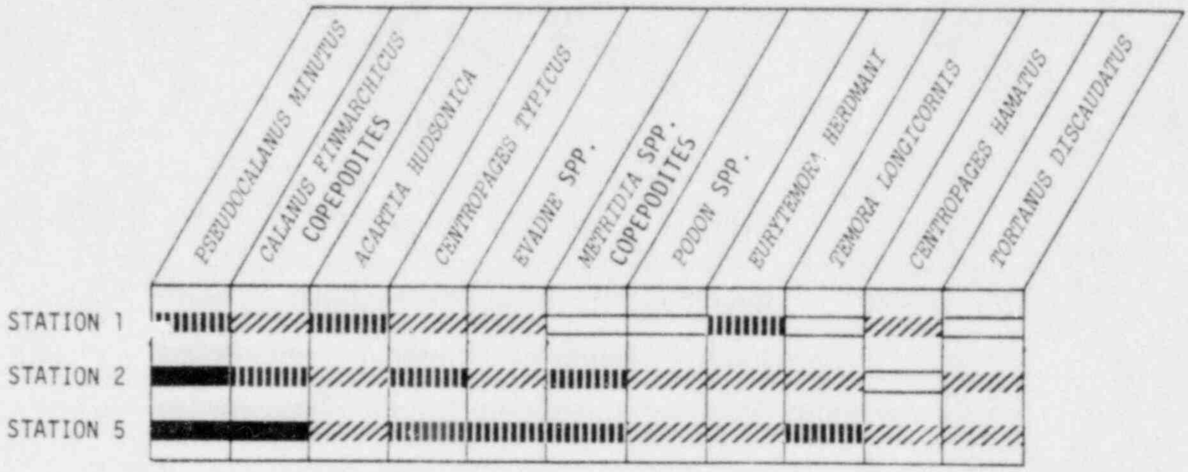

Figure 3.2-7. Mean densities by station of 11 zooplankters in bongo net tows from the vicinity of Hampton Beach, New Hampshire. Data represent sexually mature adults except where otherwise indicated. Seabrook Environmental Studies, 1976 - 1977.

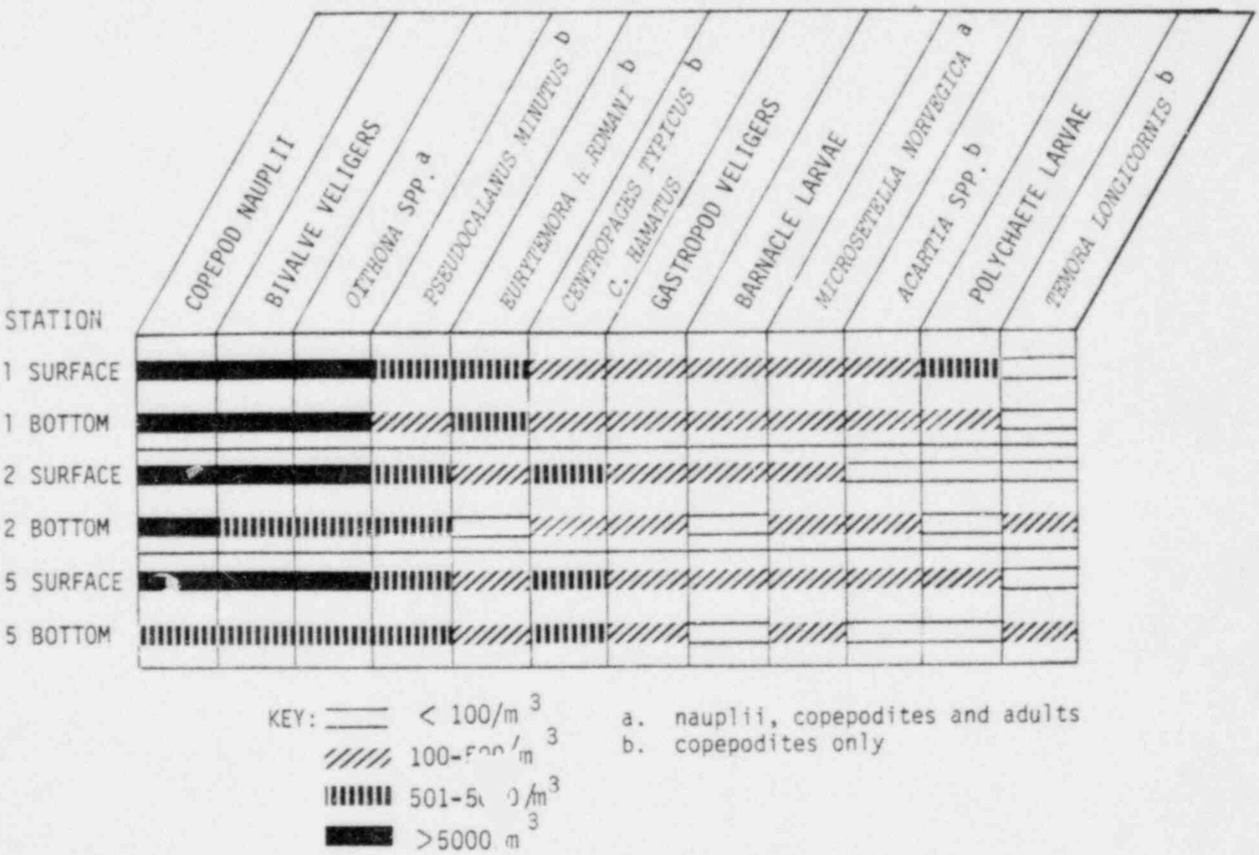

Figure 3.2-8. Mean densities by station and depth of 12 taxonomic components of pump zooplankton assemblages in the vicinity of Hampton Beach, New Hampshire. Seabrook Environmental Studies, 1976 - 1977.

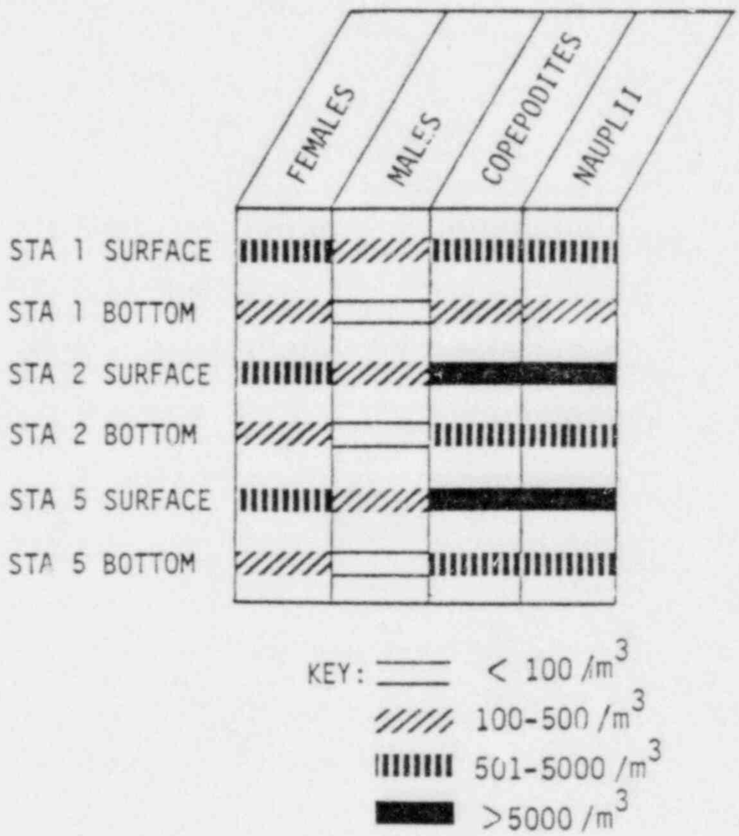

Figure 3.2-9. Mean density, by station and depth, of various life stages of *Oithona* spp. Seabrook Environmental Studies, 1976 - 1977.

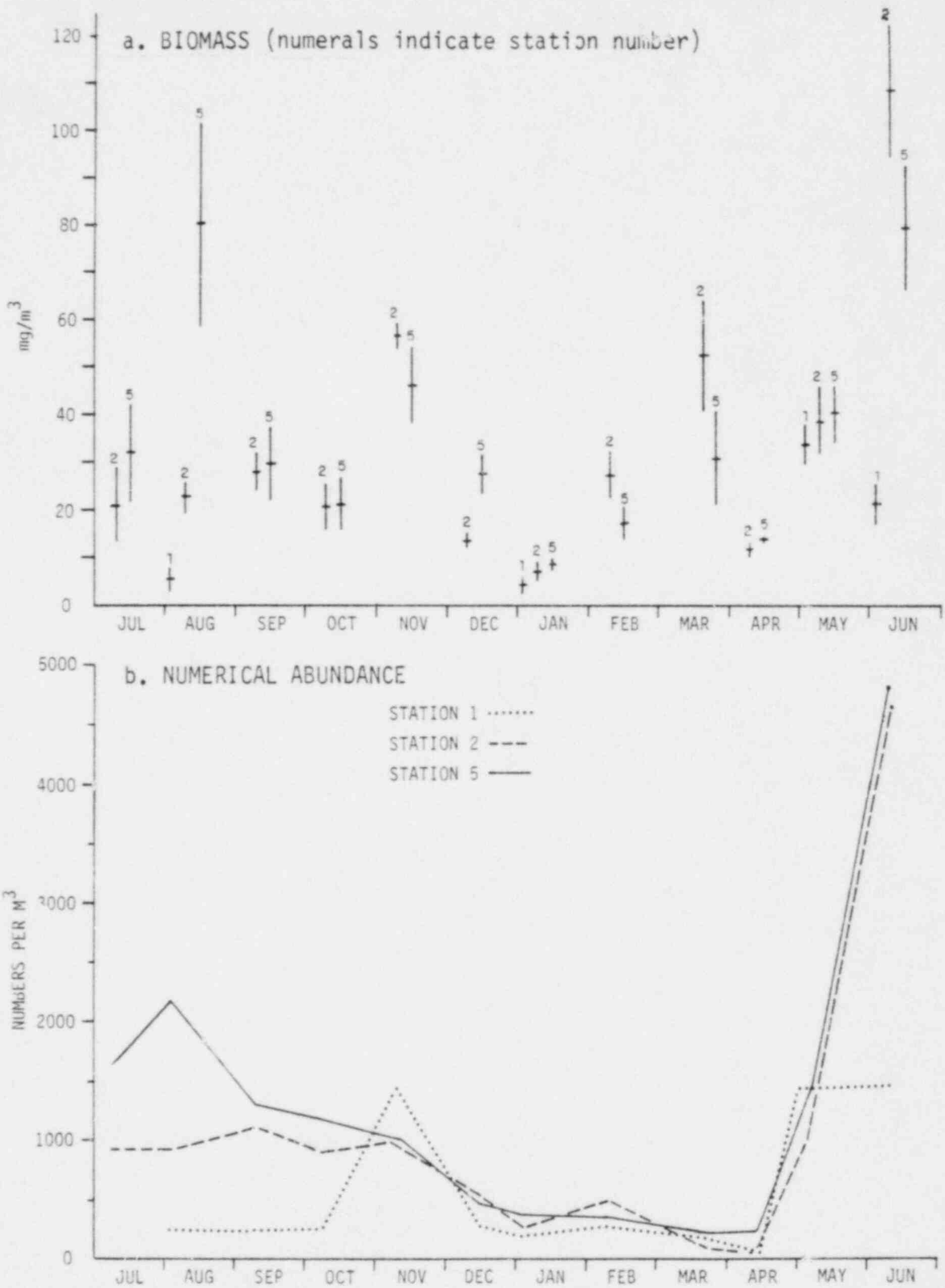

Figure 3.2-10. Means and standard deviations of mesozooplankton biomass (mg/m^3 dry weight), and mean numerical abundance (per m^3) by station and collection date for bongo net tows. Seabrook Environmental Studies, 1976 - 1977.

accounting for the moderately high biomass values shown for Stations 2 and 5 on 9 November, 1976, and 21 March 1977. Numerical abundances (Figure 3.2-10b) recorded for those same dates were not of comparable value, particularly on 21 March 1977. The most plausible explanation is that, on those dates, the bongo nets captured substantial masses of organisms not enumerated for the purposes of this particular study. Cursory re-examination of the collections indicated that these organisms were various life stages of mysids (opposum shrimps), euphausiids (krill) and, to a lesser extent, cumaceans.

4.0 DISCUSSION

4.1 PHYTOPLANKTON

4.1.1 General

During the present study period (July 1976 through June 1977), total net phytoplankton cell densities were usually found to be less than 2000/liter, even during the spring (Table 3.1-1). Such values appear remarkably low with respect to observations from previous studies (NAI, 1973; 1974; 1975; 1977a) which recorded cell concentrations in excess of 10^5/liter during spring blooms. The implication is that the 1976-1977 period was one of relatively sparse phytoplankton density. This supposition is supported by the historical record of chlorophyll *a* measurements (Table 4.1-1) which shows that chlorophyll *a* concentration values for collection dates from October 1976 through May 1977 established new monthly low records. Over that same period of time, however, primary productivity (as measured by Carbon 14 uptake) was not substantially lower than on comparable sampling dates one year earlier (Table 4.1-2).

Historical records of nutrient availability (Table 4.1-3) indicate much lower concentrations of nitrate in the early months (January through April) of 1977 than in previous years. This might have adversely affected the development of a "normal" spring bloom by making it more difficult for larger (net collectible) species, with their low surface-to-volume ratios, to assimilate nitrate at rates sufficient to produce large populations. Such a relationship between phytoplankton cell size and nutrient uptake has been reported by Parsons and Takahashi (1973).

4.1.2 Indicator Species

Species considered representative of the New Hampshire coastal phytoplankton assemblage were not very abundant relative to densities

TABLE 4.1-1. MONTHLY CHLOROPHYLL *a* CONCENTRATION DATA (mg/m^3) FROM VARIOUS PERIODS OF STUDY IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	0.3	0.2	1.8	1.1	0.6	1.4						
1976	1.1	0.6	7.8	1.5	3.9	0.9	---	1.4	4.9	1.1	1.0	0.8
1975	0.5	1.3	10.6	2.3	4.9	---	1.2	1.2	2.0	3.5	1.8	1.3
1974	1.2	1.2	2.3-5.8	2.3-2.8	2.3	0.4	1.3	5.7	7.0	2.5	7.0	1.4
1973	0.4	---	---	---	---	0.8-1.3	0.7-2.2	1.0-2.8	0.6	4.5	1.4	1.3-2.5

TABLE 4.1-2. ^{14}C UPTAKE MEASUREMENTS ($mgC/m^3/hr$) IN THE VICINITY OF THE PROPOSED DISCHARGE SITE. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	0.5	0.5	2.3	4.0	2.5	5.6						
1976	0.4	0.3	2.2	0.3	2.3	0.5	0.5	2.0	4.2	2.6	2.1	0.7
1975							4.5	0.7	1.4	9.8	0.7	1.1

TABLE 4.1-3. MONTHLY NUTRIENT DATA FROM VARIOUS PERIODS OF STUDY IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

a. ORTHOPHOSPHATE (µg P/l)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1977	23	17	12	18	15	7						
1976	27	7	2	13	9	8	12	2	9	9	17	12
1975	34	27	16	16	5	---	13	9	12	20	15	34
1974	29	30	20-29	7-14	7	4	9	5	20	12	21	31
1973	30	---	---	---	---	9-12	6-8	5-9	12	17	15-28	24-34

b. TOTAL PHOSPHATE (µg P/l)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1977	42	38	19	21	16	10						
1976	33	40	10	25	30	12	27	27	33	51	40	35
1975	49	36	23	24	17	---	21	17	22	27	22	40
1974	31	---	23-29	15-22	27	7	18	11	43	16	40	37
1973	32	---	---	---	---	10-14	7-12	9-19	18	25	25-32	33-36

c. NITRATE (µg N/l)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1977	5	12	8	8	2	8						
1976	85	20	---	24	<1	<1	<1	<1	<1	5	66	62
1975	47	57	7	14	6	---	5	4	3	17	11	125
1974	44	56	25-39	10-17	1	8	10	17	8	9	23	45
1973	39	---	---	---	---	4-6	2-4	2	16	27	30	41-82

d. NITRITE (µg N/l)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D
1977	<1	<1	2	3	<1	1						
1976	4	1	---	3	2	<1	1	1	1	4	2	4
1975	3	2	2	3	1	---	<1	<1	2	3	2	6
1974	2	1	1-2	0-1	0	<1	<1	<1	[illegible]	1	5	3
1973	2	---	---	---	---	<1-2	<1	<1	2	20	3	3

recorded for previous years (Table 4.1-4). Maximum densities recorded in 1977 for *Chaetoceros debilis*, historically most abundant in New Hampshire coastal waters from March through May, were less than 1000 cells per liter, less than previously recorded peaks. *Skeletonema costatum* was barely evident in samples collected after the December 1976 bloom. Population densities of *Ceratium longipes*, usually most abundant from May through August, appeared least reduced compared to previous records.

Monitoring the larger (net) plankton since 1972 has produced a data set which is of primary use in describing long term changes regarding taxa such as *Chaetoceros* and *Ceratium* which consistently have larger cells. Because of the large sample volumes, the historical presences of rarer species have also been monitored. With respect to short term fluctuations and population changes which affect the smaller-celled organisms, however, the cell count data is of limited use. General historical perspective on changes affecting the community as a whole can be obtained from the chlorophyll *a* data which constitute a measure of total phytoplankton biomass.

In July 1977 the phytoplankton program was augmented to include whole water sampling and weekly sampling frequency; frequency of laboratory analysis has been made contingent on the occurrence of short-lived "blooms". Results from these program additions should be of increased benefit in assessment of power plant impact.

4.2 ZOOPLANKTON

4.2.1 General

Unlike net phytoplankton cell densities, total zooplankton abundance did not appear to be substantially reduced from densities recorded for the previous 12 month study period (NAI, 1977a). Disregarding enumeration of *Modiolus modiolus* straight-hinge veligers on 7

TABLE 4.1-4. MONTHLY DATA ON THREE PHYTOPLANKTON INDICATOR SPECIES IN THE VICINITY OF THE PROPOSED INTAKE SITE[a] FOR SEABROOK STATION, 1972-1977. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977[b].

a. *CHAETOCEROS DEBILIS* (CELLS PER LITER)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	0	2	7	122	<1	10						
1976	3	5	36,700	35,700	169,000	28	0	0	14	0	7	23
1975	0	30	261	6,020	3		0	0	1	1	41	3
1974	0	365	762	22	185	10	0	0	0	0	1	0
1973			88		217,000	<1	1,560	1	0	2	0	0
1972[c]				18,300	1,950		2	0		0		<1

b. *SKELETONEMA COSTATUM* (CELLS PER LITER)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	1	1	2	0	0	0						
1976	0	6	0	27	23	135	0	2	4	161	3	1,154
1975	0	28	19	229	0		0	18	1,620	18	114	1
1974	0	13	3	60	19	3	0	50	1,700	9	5	2
1973			1		0	252	3,540	8,700	0	164	38	1,090
1972[c]				0	0		2,160	1,040		5		<1

c. *CERATIUM LONGIPES* (CELLS PER LITER)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	<1	0	1	<1	13	63						
1976	2	<1	2	0	25	99	18	42	30	1	1	<1
1975	1	<1	2	96	252		76	32	31	7	<1	9
1974	<1	0	<1	0	0	10	106	21	5	25	32	8
1973			<1		92	206	427	75	1	6	3	1
1972				<1	12		59	51		6		<1

[a] Data represents means across all replicates surface and bottom, except in 1974-1975 when only surface data were collected.

[b] Note: In previous report (NAI, 1977a) cell densities were incorrectly reported as per m^3.

[c] Cell counts determined by counting chains and multiplying number of chains by average number of cells in chains.

October 1976, the 1976-1977 data indicated a summer zooplankton population peak similar to one which was evident in the 1975-1976 data. However, in 1975, August collections represented a prominent peak (approaching a density of 57,000/m^3), while in 1976, August densities (at 25,700/m^3) were slightly exceeded by both July and September values (Appendix Table 7.1-4).

Mesozooplankton biomass estimates tended to follow a seasonal cycle consisting of a winter minimum and a summer maximum. Biomass estimates for November 1976 and March 1977, which could not be correlated to mesozooplankton numerical density (Section 3.2.4), were high relative to comparable monthly estimates from previous years (Table 4.2-1). However, Table 4.2-1 also indicates relatively high biomass estimates in September 1975 and April 1976. Perhaps the explanation given for the November and March values (Section 3.2.4) may also hold true for other values of similarly high magnitude which occurred in months other than June or July.

Numerically, holoplankters were the dominant influence on general patterns of zooplankton distribution. This, however, does not diminish the ecological importance of meroplanktonic forms which, while occurring briefly as members of the plankton community, constitute a rather vulnerable stage in the life of many marine invertebrates. Both the present and previous (1975-76) preoperational studies have found bivalve veligers to rank highest among the meroplankton groups, comprising approximately 8 to 12% of the total zooplankton count. Gastropod veligers ranked second (and noticeably lower) with approximately 2 to 3% of the total zooplankton count. Polychaete nectochaete and barnacle larvae have consistently comprised from 1 to 2% of total zooplankton abundance during the past two years of the preoperational survey.

With regard to general patterns of zooplankton abundance and distribution, counts of *Modiolus modiolus* straight-hinge veligers were treated as an anomaly. This was deemed necessary due to two factors:

TABLE 4.2-1. MONTHLY ESTIMATES OF ZOOPLANKTON BIOMASS (mg/m^3 DRY WEIGHT) VARIOUS PERIODS OF STUDY IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	7.0	27	52	12	38	108						
1976	5.0	3	16	46	---	65	20	22	28	20	56	13
1975	---	9	3	3	18	---	81	28	50	39	17	15
1974	0.3	2	2-10	3	2	22	48	11	9	7	11	5
1973						22-61	23-31	27-75	18	10	6-20	3-17

1) the once-monthly sampling frequency, which may leave gaps in knowledge concerning the occurrence of such a short-lived event (30 hours) and 2) the extremely high density of the event in question which would tend to obscure seasonal trends attributable to other species, including other bivalve molluscs. Concurrent studies with a much higher sampling frequency (twice weekly) are being carried out for definition of bivalve larvae seasonality; 1977 results are reported in Technical Report VIII-2 (NAI, 1978a). It must be regarded as coincidental that the immediate products of a spawning episode, involving this particular species, occurred concurrently with the 4 October 1976, collection date. Based on evidence from Technical Report VIII-2 (NAI, 1978a) such an event could have co-occurred with any of the sampling dates from July through October.

Ranking present and past holoplankton collections in order of decreasing species abundance (Table 4.2-2) provides some perspective on the representation over time of particular species in the New Hampshire coastal zooplankton assemblage. Because of the once-monthly sampling, importance should be attached only to the larger shifts in rank order. Changes in order of numerical abundance which appear to be worthy of attention involve: 1) *Centropages hamatus* and *Acartia hudsonica*, which appear to have recovered from a population decline of undetermined duration; 2) *Paracalanus parvus* which appears to be increasing in abundance from the previous study period, when it was first recorded and 3) *Acartia longiremis* which appears to have declined in abundance from the previous year. All of these apparent trends are undoubtedly a composite of true long-term population cycles and various types of sampling variability.

4.2.2 Indicator Species

A species for which population estimates appear least affected by sampling frequency is the ubiquitous cyclopoid copepod, *Oithona* spp. Both the present study and a previous report (NAI, 1977a) are consistent

TABLE 4.2-2. RELATIVE REPRESENTATION OF HOLOPLANKTERS IN THE VICINITY OF HAMPTON BEACH, NEW HAMPSHIRE. COMPARISON OF 1976-1977 ABUNDANCE RANKING WITH PREVIOUS YEARS. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

TAXON	1976-77	1975-76	1974-75	1973-74	1972-73
Oithona spp. (Cy)	1	1	1	1	1
Pseudocalanus minutus (Ca)	2	2	3	3	6
Eurytemora herdmani (Ca)	3	7	7	2	3
Microsetella norvegica (H)	4	3	ND	ND	8
Centropages typicus (Ca)	5	4	2	4	5
Centropages hamatus (Ca)	6	14	ND	ND	9
Acartia hudsonica (Ca)	7	15	ND	ND	7
Temora longicornis (Ca)	8	5	8	6	4
Calanus finmarchicus (Ca)	9	6	4	10	10
Paracalanus parvus (Ca)	10	17	ND	ND	ND
Metridia lucens (Ca)	11	12	ND	ND	ND
Evadne spp. (Cl)	12	8	6	8	2
Podon spp. (Cl)	13	10	9	7	ND
Tortanus discaudatus (Ca)	14	13	10	9	ND
Paracalanus crassirostris (Ca)	15	16	ND	ND	ND
Acartia longiremis (Ca)	16	9	ND	ND	ND

ND = not determined
Ca = calanoid copepod
Cl = cladoceran
Cy = cyclopoid copepod
H = Harpacticoid copepod

in indicating little difference in distribution between Hampton Harbor (Station 1) and the open coastal area (Stations 2 and 5). Another point of agreement between the present and previous study is that *Oithona* spp. have a demonstrable affinity for surface waters (Figure 3.2-9). *Oithona* spp. are abundant at all times of the year, but particularly so from late spring to early fall. Table 4.2-3 indicates that populations have been reasonably stable over the past five to six years.

The indication given by data in the present study (Figure 3.2-7) that *Pseudocalanus minutus* is more abundant in open coastal areas than in Hampton Harbor is consistent with earlier findings (NAI, 1977a; Sherman, 1965, 1966, 1968, 1970; TRIGOM-PARC, 1974). Over at least the past five years (Table 4.2-4), *P. minutus* population densities have been reasonably stable, taking into consideration that *P. minutus* is less abundant than *Oithona* spp. and exhibits slightly larger variation in seasonal abundance. Highest densities in more than six years of study were those recorded for 9 June 1977 (Table 4.2-4).

Preference of *Eurytemora herdmani* for inshore areas has been demonstrated in the present study (Figures 3.2-7 and 3.2-8) as well as in previous investigations of New Hampshire coastal waters (NAI, 1974a, 1977). Historical data indicate a pronounced seasonality in abundance, favoring the mid-summer period, and also suggest that populations may experience a cyclical fluctuation in abundance with perhaps a five to six year period of recurrence (Table 4.2-5). However, this thesis remains in the realm of speculation pending accumulation of more years of data.

Calanus finmarchicus is even more evident than *P. minutus*, an offshore species, where it is the dominant copepod of the Gulf of Maine (Bigelow, 1926; Fish and Johnson, 1937; Sherman, 1965, 1966, 1968, 1970). During the present study period, sexually mature individuals were infrequently caught in bongo tows (maximum occurrences: 3 males and 3 females/m^3 at Station 5, on 8 February 1977). Copepodites, on the other hand, were frequently encountered, most abundantly in spring and

TABLE 4.2-3. MONTHLY DATA ON *OITHONA* SPP. NUMERICAL DENSITY (INDIVIDUALS/m^3) IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
a. ADULTS												
1977	168	88	72	132	1,369	1,502						
1976	90	53	206	132	157	1,687	1,164	1,666	400	918	310	274
1975	38	40	44	234	364	---	1,033	404	590	516	783	155
1974	25	37	115	11	43	1,522	896	0	150	2,132	1,162	44
1973			58		136	1,034	941	1,034	310	224	697	184
1972				117	776	---	606	1,982	---	1,936	---	131
b. COPEPODITES												
1977	214	67	110	907	2,550	5,348						
1976	423	77	556	567	808	9,480	10,178	7,793	3,984	4,334	2,585	957
1975	---	---	---	---	---	---	3,556	17,387	5,517	5,693	2,059	565
1974	0	0	31	20	0	---	---	---	---	---	---	---
1973					492	936	913	653	115	162	162	15
c. NAUPLII												
1977	456	213	129	1,577	2,151	6,570						
1976	405	108	1,018	86	583	4,623	10,672	7,037	4,929	440	594	433
1975	---	---	---	---	---	---	1,202	6,446	2,168	1,352	1,046	903
1974	59	126	181	530	425	---	---	---	---	---	---	---
1973					590	1,760	2,185	2,079	306	1,511	113	470

TABLE 4.2-4. MONTHLY DATA ON *PSEUDOCALANUS MINUTUS* ADULT NUMERICAL DENSITY (INDIVIDUALS/m^3) IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	210	438	31	12	78	3577						
1976	73	29	23	68	106	192	225	49	485	46	491	144
1975	27	71	14	9	315	---	935	23	146	154	37	121
1974	1	---	12	43	---	256	1433	10	13	81	225	17
1973	---	---	2	---	0	486	1917	1233	---	---	0	0
1972				2	19		48	54		134		19

TABLE 4.2-5. MONTHLY DATA ON *EURYTEMORA HERDMANI* NUMERICAL DENSITY (INDIVIDUALS/m^3) IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

a. ADULTS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	0	1	4	1	418	31						
1976	0	1	1	1	3	150	114	9	2	3	2	0
1975	0	10	1	0	45	---	2	2	1	0	0	0
1974	0	0	0	0	0	1040	0	0	0	0	0	0
1973	---	---	1	---	125[illegible]	2156	683	944	48	0	0	0
1972				3	148	872	---	508	---	24	---	0

b. COPEPODITES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	0	0	5	10	291	746						
1976	1	0	0	0	0	77	20	38	0	51	25	11
1975	---	---	---	---	---	---	9	35	0	0	0	14
1974	0	0	0	0	0	---	---	---	---	---	---	---
1973					248	1085	209	230	0	0	0	0

summer (Figure 3.2-3). Historical data (Table 4.2-6) appear to suggest that *C. finmarchicus* copepodites were somewhat more abundant prior to 1975 than in more recent years. As with *E. herdmani*, this may turn out to represent a natural long-term population cycle.

TABLE 4.2-6. MONTHLY DATA ON *CALANUS FINMARCHICUS* COPEPODITE NUMERICAL DENSITY (INDIVIDUALS/m^3) IN THE VICINITY OF THE PROPOSED INTAKE SITE FOR SEABROOK STATION. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	3	3	8	5	84	137						
1976	1	<1	2	3	9	157	97	272	8	1	10	2
1975	0	0	0	44	157	---	194	44	48	16	5	3
1974	1	8	17	1416	72	0	2753	148	0	1	0	0
1973	---	---	4	---	2440	650	850	1740	48	90	4	40
1972				6	31	10	---	9	---	0	---	1

5.0 SUMMARY

This report has presented results of plankton surveys undertaken as part of the second annual preoperational monitoring program for Seabrook Station. Specifically investigated were seasonal cycles of abundance and species composition of net phytoplankton, and macro- and microzooplankton, collected monthly from three coastal New Hampshire sampling stations, from July 1976 through June 1977. The study also included monitoring of ^{14}C uptake (primary productivity), chlorophyll *a* concentration, and concentrations of the plant nutrients: orthophosphate, total phosphorus, nitrate, nitrite and ammonia.

A total of 107 phytoplankton taxa were identified from water pumped through 76 μm mesh nets. In general, total net phytoplankton cell densities were found to be unusually low (seldom exceeding 2000 cells per liter) compared to previous years. Chlorophyll *a* concentrations were also found to be relatively low, exceeding 2 mg/m^3 only during a *Chaetoceros* spp. bloom which occurred in early September 1976. Nitrate levels which in previous years have ranged from 20 to 85 μg/liter during early winter ranged from 8 to 17 μg/liter in January and February, 1977, raising the possibility that a scarcity of this nutrient may have inhibited the full development of the spring bloom. Carbon 14 uptake ranged from 0.5 mg C/m^3/hr in mid winter to 5.7 mg C/m^3/hr during blooms, and did not appear appreciably lower than rates reported in previous years.

Approximately 73 zooplankton taxa were identified from pump and bongo net collections. As in previous years, holoplankters were chiefly represented by copepods of which the most important were *Oithona* spp., *Pseudocalanus* spp., *Eurytemora herdmani*, *Centropages* spp. and *Microsetella norvegica*. Bivalve and gastropod veligers and barnacle and polychaete larvae were the most numerous representatives of the meroplankton. On 7 October 1976, straight-hinge veligers of the horse mussel, *Modiolus modiolus*, a principal habitat former on subtidal hard substrates in the immediate vicinity of the plankton sampling stations, was collected in densities averaging more than half a million per m^3.

Of seven planktonic species given special attention as "indicator" organisms, two diatoms, *Skeletomema costatum* and *Chaetoceros debilis*, exhibited evidence of population decline from the previous annual preoperational monitoring period, while an armored dinoflagellate, *Ceratium longipes*, and three copepods, *Oithona* spp., *Pseudocalanus minutus*, and *Calanus finmarchicus* appeared to have maintained reasonably stable populations. A fourth "indicator" copepod, *Eurytemora herdmani*, appeared to be returning to a level of abundance not observed since 1973.

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7.0 APPENDICES

TABLE 7.1-1. TAXONOMIC LIST OF NET PHYTOPLANKTON IDENTIFIED FROM 73 μm PLANKTON PUMP SAMPLES JULY 1975-JUNE 1976. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

CLASS: BACILLARIOPHYCEAE

ORDER: Centrales

Actinoptychus spp.
Biddulphia alternans
Biddulphia aurita
Biddulphia spp.
Cerataulina spp.
Cerataulina pelagica
Chaetoceros affinis
Chaetoceros atlanticus
Chaetoceros borealis
Chaetoceros brevis
Chaetoceros compressus
Chaetoceros concavicornis
Chaetoceros convolutus
Chaetoceros danicus
Chaetoceros debilis
Chaetoceros decipiens
Chaetoceros diadema
Chaetoceros didymus
Chaetoceros furcellatus
Chaetoceros gracilis
Chaetoceros laciniosus
Chaetoceros lorenzianus
Chaetoceros lorenzianus f. *forceps*
Chaetoceros socialis
Chaetoceros teres
Chaetoceros spp.
Corethron hystrix
Coscinodiscus centralis
Coscinodiscus spp.
Ditylum brightwellii
Detonula confervacea
Guinardia flaccida
Guinardia spp.
Leptocylindrus danicus
Leptocylindrus minimus

(Continued)

TABLE 7.1-1. (Continued)

CLASS: BACILLARIOPHYCEAE (Continued)

ORDER: Centrales (Continued)

Melosira moniliformis
Melosira nummuloides
Melosira spp.
Paralia sulcata
Rhizosolenia alata
Rhizosolenia delicatula
Rhizosolenia fragilissima
Rhizosolenia hebetata
Rhizosolenia setigera
Rhizosolenia spp.
Skeletonema costatum
Stephanopyxis spp.
Thalassiosira nordenskioldii
Thalassiosira rotula
Thalassiosira spp.

ORDER: Pennales

Achnanthes spp.
Amphora spp.
Asterionella formosa
Asterionella glacialis
Campylodiscus echineis
Campylodiscus spp.
Cocconeis scutellum
Cylindrotheca closterium
Fragilaria oceanica
Fragilaria spp.
Grammatophora angulosa
Grammatophora marina
Gyrosigma balticum
Gyrosigma fascicla
Gyrosigma/Pleurosigma spp.
Isthmia nervosa
Licmophora abbreviata
Licmophora flabellata
Licmophora spp.
Navicula crucigera
Navicula cf. *interrupta*
Navicula spp.
Nitzschia delicatissima

(Continued)

TABLE 7.1-1. (Continued)

CLASS: BACILLARIOPHYCEAE (Continued)

ORDER: Pennales (Continued)

Nitzschia seriata
Nitzschia spp.
Rhabdonema arcuatum
Rhabdonema spp.
Striatella spp.
Surirella spp.
Synedra spp.
Thalassionema nitzschioides
Thalassionema spp.
Thalassiothrix frauenfeldii

CLASS: CHRYSOPHYCEAE

ORDER: Dictyochales

Dichtyocha fibula
Distephanus speculum
Ebria tripartita

CLASS: DINOPHYCEAE

ORDER: Prorocentrales

Ceratium arcticum
Ceratium bucephalum
Ceratium fusus
Ceratium horridum
Ceratium lineatum
Ceratium longipes
Ceratium macroceros
Ceratium tripos
Ceratium spp.
Peridinium depressum
Peridinium ovatum
Peridinium spp.
Prorocentrum micans
Prorocentrum spp.

(Continued)

TABLE 7.1-1. (Continued)

CLASS: DINOPHYCEAE (Continued)

ORDER: Dinophysiales

Dinophysis norvegica

CLASS: CHLOROPHYCEAE

ORDER: Chlorococcales

Pediastrum spp.
Scenedesmus spp.

CLASS: CRYPTOPHYCEAE

ORDER: Cryptomonadales

Cryptomonadaceae

CLASS: CYANOPHYCEAE

ORDER: Chroococcales

Merismopedia (Agmenellum) spp.

ORDER: Oscillatoriales

Spirulina subsalsa

INCERTAE SEDIS:

Polyasterias problematica

TABLE 7.1-2. CHLOROPHYLL *a* VALUES (mg/m^3) AT STATIONS IN THE VICINITY OF HAMPTON BEACH, NEW HAMPSHIRE. MEANS AND STANDARD DEVIATIONS REPRESENT FOUR REPLICATES EXCEPT WHEN OTHERWISE INDICATED. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

	STATION 1	STATION 2	STATION 5	PERCENTAGE OF 11 MONTH TOTAL[c]
7 Jul 76[a]	-	-	-	
2 Aug 76	1.9 ±.1	1.4 ±.1	1.8 ±.1	11.4
7 Sep 76			2.1 ±.05[b]	
9 Sep 76	5.1 ±.7	4.9 ±.3	5.3 ±.2[b]	34.2
5 Oct 76			2.5 ±.1	
7 Oct 76	1.6 ±.2	1.1 ±.3	1.4 ±.4	9.2
8 Nov 76			1.5 ±.3	
9 Nov 76	1.4 ±.2	1.0 ±.2	1.4 ±.1	8.5
6 Dec 76	1.0 ±.2	0.8 ±.1	0.8 ±.2	5.8
3 Jan 77	0.3 ±.03	0.3 ±.05	0.2 ±.02	1.8
4 Jan 77			0.4 ±.1	
7 Feb 77			0.2 ±.02	
8 Feb 77	0.4 ±.02	0.2 ±.02	0.2 ±.1	1.8
21 Mar 77			2.5 ±1.0	
22 Mar 77	0.8 ±.05	1.8 ±.1	1.1 ±.06	8.3
13 Apr 77	0.8 ±.1	1.1 ±.2	1.1 ±.2	6.7
14 Apr 77			1.9 ±.05	
4 May 77	0.6 ±.02	0.6 ±.06	0.5 ±.2	3.8
9 Jun 77	1.0 ±.05	1.4 ±.1	1.4 ±.2	8.5

[a]values not reported due to suspected contamination during handling

[b]mean & std. dev. of <u>two</u> replicates

[c]computed only for dates when all three stations were sampled.

TABLE 7.1-3. TAXONOMIC LIST OF SPECIES OR TYPES OF ZOOPLANKTON IDENTIFIED FROM OBLIQUE 333 μm BONGO TOWS (Ω) AND 76 μm PLANKTON PUMP SAMPLES (*), JULY 1976-JUNE 1977. SEABROOK ENVIRONMENTAL STUDIES, 1976-1977.

KEY: * = Microplankton
Ω = Mesoplankton
H = Holoplanktonic
M = Meroplanktonic
T = Tychoplanktonic

PHYLUM: PROTOZOA		
SUBPHYLUM: CILIOPHORA		
ORDER: TINTINNIDA	H	*
PHYLUM: ROTIFERA	H	*
Brachionus spp.	H	*
Notholea striata	H	*
Polyarthra spp.	H	*
PHYLUM: NEMATODA	T	*
PHYLUM: ANNELIDA		
CLASS: POLYCHAETA		
Polychaete eggs	M	*
Polychaete trochophore	M	*
Polychaete nectochaete larvae	M	*
Tomopteris spp. larvae	T	Ω
PHYLUM: MOLLUSCA		
CLASS: GASTROPODA		
Gastropod egg	M	*
Gastropod veliger	M	*
SUBCLASS: OPISTHOBRANCHIA (VELIGER)	M	*
SUBCLASS: PROSOBRANCHIA		
Littorina littorea eggs	M	*
CLASS: BIVALVIA		
Bivalve veliger	M	*
Anomia spp. veliger	M	*
Ensis directus veliger	M	*
Modiolus modiolus veliger	M	*
Mytilus edulis veliger	M	*
Placopecten magellanicus veliger	M	*

(Continued)

TABLE 7.1-3. (Continued)

PHYLUM: ARTHROPODA		
CLASS: CRUSTACEA		
SUBCLASS: BRANCHIOPODA		
SUBORDER: CLADOCERA		
Podon spp.	H	Ω
Evadne spp.	H	Ω
SUBCLASS: OSTRACODA		
SUBCLASS: COPEPODA		
Copepoda nauplii	H	*
ORDER: CALANOIDA		
Calanus finmarchicus copepodite	H	Ω
Calanus finmarchicus female	H	Ω
Calanus finmarchicus male	H	Ω
Paracalanus crassirostris copepodite	H	*
Paracalanus crassirostris female	H	*
Paracalanus crassirostris male	H	*
Paracalanus parvus copepodite	H	*
Paracalanus parvus female	H	Ω
Paracalanus parvus male	H	Ω
Pseudocalanus minutus copepodite	H	*
Pseudocalanus minutus female	H	Ω
Pseudocalanus minutus male	H	Ω
Pseudocalanus Type A copepodite	H	*
Pseudocalanus Type A female	H	*
Pseudocalanus Type A male	H	*
Rhincalanus nasutus	H	Ω
Aetideus armatus copepodite	H	Ω
Aetideus armatus female	H	Ω
Aetideus armatus male	H	Ω
Euchaeta spp. copepodite	H	Ω
Centropages spp. copepodite	H	*
Centropages typicus female	H	Ω
Centropages typicus male	H	Ω
Centropages hamatus female	H	Ω
Centropages hamatus male	H	Ω
Pseudodiaptomus coronatus copepodite	T	Ω
Pseudodiaptomus coronatus female	T	Ω
Pseudodiaptomus coronatus male	T	Ω
Temora spp. copepodite	H	*
Temora longicornis female	H	Ω
Temora longicornis male	H	Ω
Eurytemora spp. copepodite	H	*
Eurytemora herdmani copepodite	H	Ω
Eurytemora herdmani male	H	Ω
Eurytemora herdmani female	H	Ω

(Continued)

TABLE 7.1-3 (Continued)

ORDER: CALANOIDA (CONTINUED)		
Eurytemora americana female	H	Ω
Eurytemora americana male	H	Ω
Eurytemora affinis female	H	Ω
Metridia spp. copepodite	H	Ω
Metridia lucens female	H	Ω
Metridia lucens male	H	Ω
Candacia armata copepodite	H	Ω
Candacia armata female	H	Ω
Candacia armata male	H	Ω
Acartia spp. copepodite	H	*
Acartia tonsa	H	Ω
Acartia hudsonica (= clausi)	H	Ω
Acartia longiremis	H	Ω
Tortanus discaudatus copepodite	H	Ω
Tortanus discaudatus female	H	Ω
Tortanus discaudatus male	H	Ω
Anomalocera opalus copepodite	H	Ω
ORDER: HARPACTICOIDA	T	*
Alteutha spp.	T	*
Clytemnestra spp.	T	*
Microsetella norvegica	H	*
Tegastidae	T	*
Tisbe (Idya) spp.	T	*
ORDER: CYCLOPOIDA		
Cyclopoid copepodite	H	*
Halicyclops spp. copepodite	H	*
Halicyclops spp. adult	H	*
Oithona spp. nauplii	H	*
Oithona spp. copepodite	H	*
Oithona similis male	H	*
Oithona similis female	H	*
Oithona plumifera female	H	*
Oithona plumifera male	H	*
Saphirella spp.	H	*
Oncaea spp.	H	*
Macrocheiron spp.	T	*
ORDER: MONSTRILLOIDA		
Monstrillidae	M	*
SUBCLASS: CIRRIPEDIA		
Cirripedia nauplii	M	*
Cirripedia cypris	M	*
Hansen's nauplii	M	*
SUBCLASS: MALACOSTRACA		
SUPER ORDER: PERACARIDA		
ORDER: ISOPODA		
Epicaridean larvae	M	*

(Continued)

TABLE 7.1-3. (Continued)

ORDER: AMPHIPODA		
SUPER ORDER: Hyperiidea	H	Ω
SUPER ORDER: EUCARIDA		
ORDER: EUPHAUSIACEA		
Euphausid nauplii	H	Ω
Euphausid metanauplii	H	Ω
Calyptopis larva	H	Ω
Furcilia larva	H	Ω
ORDER: DECAPODA		
Decapod megalopa	T	Ω
Caridea zoea	M	Ω
Crangon septemspinosa zoea	M	Ω
Crangon septemspinosa post larva	M	Ω
Brachyura zoea	M	Ω
Brachyura megalopa	T	Ω
Carcinus maenas zoea	M	Ω
Cancer spp. zoea	M	Ω
Pagurus spp. zoea	M	Ω
PHYLUM: BRYOZOA		
Bryozoan cyphonautes larva	M	*
PHYLUM: ECHINODERMATA		
Echinoderm larva	M	Ω
PHYLUM: CHORDATA		
CLASS: LARVACEA	H	Ω
CLASS: ASCIDIACEA		
Appendicularian type larvae	M	*
PHYLUM: CHAETOGNATHA		
Sagitta spp.	H	Ω

TABLE 7.1-4. MEAN ABUNDANCE (PER M^3) OF SELECTED ZOOPLANKTON GROUPS BY COLLECTION DATE. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

	1976						1977					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Microzooplankton	30,400	24,600	28,900	15,700[a] 566,000[b]	11,000	11,600	5,860	3,770	3,930	5,630	20,700	44,100
Mesozooplankton	1,280	1,120	892	777	1,160	420	274	364	155	118	1,280	3,660

b. HOLOPLANKTON, MEROPLANKTON AND TYCHOPLANKTON.

	1976						1977					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Holoplankton	24,400	24,200	23,000	9,820	10,100	11,600	5,970	3,940	3,270	5,160	18,360	46,400
Meroplankton	7,040	1,520	6,220	6,450[a] 557,000[b]	1,960	313	154	145	767	540	3,310	1,150
Tychoplankton	247	44	108	186	75	65	10	49	43	41	257	267

c. COPEPOD NAUPLII.

1976						1977					
JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
7,590	6,630	12,300	4,240	3,490	6,640	1,980	1,930	2,390	2,430	3,690	21,940

a = excluding straight hinge veligers of *M. modiolus*

b = including straight hinge veligers of *M. modiolus*

TABLE 7.1-5. ZOOPLANKTON DRY WEIGHT BIOMASS (mg/m^3) FROM 333μm MESH PAIRED BONGO NET TOWS OFF HAMPTON BEACH, NEW HAMPSHIRE. SEABROOK ENVIRONMENTAL STUDIES, 1976 - 1977.

STATION	7 JULY 1976 SAMPLE REPLICATE 1	2	3	4	$\bar{x}$ & STD. DEV.	3 AUGUST 1976 SAMPLE REPLICATE 1	2	3	4	$\bar{x}$ & STD. DEV.	9 SEPTEMBER 1976 SAMPLE REPLICATE 1	2	3	4	$\bar{x}$ & STD. DEV.
1			*			6.5	7.3	4.4	3.0	5.3 ±2.0			*		
2	20.7	10.0	27.7	23.5	20.5 ±7.6	21.0	18.8	24.5	25.2	22.4 ±3.0	29.4	26.7	30.9	23.1	27.5 ±3.4
5	24.6	21.6	41.4	39.8	31.8 ±10.2	91.9	103.9	58.2	65.9	80.0 ±21.5	30.2	18.8	32.9	36.4	29.6 ±7.6

STATION	7 OCTOBER 1976 SAMPLE REPLICATE 1	2	3	4	$\bar{x}$ & STD. DEV.	9 NOVEMBER 1976 SAMPLE REPLICATE 1	2	3	4	$\bar{x}$ & STD. DEV.	6 DECEMBER 1976 SAMPLE REPLICATE 1	2	3	4	$\bar{x}$ & STD. DEV.
1			*					*					*		
2	24.4	24.6	15.2	17.6	20.4 ±4.8	55.0	59.7	54.3	56.9	56.5 ±2.4	13.3	14.8	11.8	12.6	13.1 ±1.3
5	26.8	24.2	15.2	17.5	20.9 ±5.5	40.2	38.2	55.9	48.7	45.8 ±8.2	26.4	30.4	22.6	29.4	27.2 ±3.5

TABLE 7.1-5. (Continued)

STATION	3 JANUARY 1977 Sample Replicate 1	2	3	4	x̄ & STD. DEV.	8 FEBRUARY 1977 Sample Replicate 1	2	3	4	x̄ & STD. DEV.	21 MARCH 1977 Sample Replicate 1	2	3	4	x̄ & STD. DEV.
1	4.2	4.1	4.6	3.7	4.2 ±0.4			*					*		
2	9.5	7.5	5.8	4.9	6.9 ±2.0	28.8	33.0	22.8	23.4	27.0 ±4.8	59.1	65.1	42.4	41.8	52.1 ±11.8
5	10.1	8.2	7.1	8.2	8.4 ±1.2	15.3	19.1	13.6	19.7	16.9 ±3.0	41.4	37.6	21.3	23.0	30.8 ±10.2

STATION	13 APRIL 1977 Sample Replicate 1	2	3	4	x̄ & STD. DEV.	4 MAY 1977 Sample Replicate 1	2	3	4	x̄ & STD. DEV.	9 JUNE 1977 Sample Replicate 1	2	3	4	x̄ & STD. DEV.
1			*			28.5	35.6	32.9	38.4	33.8 ±4.2	18.6	16.3	26.1	23.8	21.2 ±4.5
2	11.5	12.0	13.5	10.4	11.8 ±1.3	28.4	42.5	43.5	39.1	38.4 ±6.9	123.5	116.9	95.1	98.3	108.4 ±13.9
5	14.2	13.0	14.1	13.4	13.7 ±0.6	33.2	37.0	45.9	44.6	40.2 ±6.1	74.0	64.9	82.7	95.4	79.2 ±13.0

* Samples heavily contaminated with silt