1991

Phytoplankton Populations in Back Bay, Virginia

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Abstract: Cyanobacteria, diatoms and chlorophyceans dominated the seasonal assemblages of phytoplankton in a two year study of Back Bay, Virginia. Seasonal differences in composition and development were found between the two years, with highest concentrations occurring in summer and early fall when a pico-nanoplankton assemblage of cells was dominant.

Introduction

Back Bay is a shallow, oligohaline habitat of approximately 77.7 km^2. Lunar tides are not significant, but wind driven saline waters from Currituck Sound will enter the Bay, coming from the Pamlico Sound estuary located to the south. A pycnocline and stratification are rare because of the prevailing wind patterns that are present and the shallow nature (<2m) of Back Bay. Land drainage into the Bay also comes from several creeks and irrigation ditches. This area was once part of the Great Dismal Swamp and drainage through this system continues to contain tannin stained waters that are slightly acidic. Oaks *et al.* (1979) have discussed the geological history of this region and the relationship between Back Bay, the Great Dismal Swamp and the Pamlico Sound estuarine complex. Comegys (1977) described the phytoplankton in Back Bay as predominantly freshwater species dominated by cyanophyceans in summer, with chlorophyceans the major component of other times. He noted spring to fall production maxima, with the annual salinity range between 0.89 and 3.77 o/oo and a pH range from 6.3 to 9.2. The desmids were a common component, with diatoms having minor significance. Other regional phytoplankton studies have included those in the lower Chesapeake Bay, Elizabeth River and Nansemond River (Marshall, 1967; Marshall and Lacouture, 1986; Shomers, 1988). Flora from these sites are predominantly neritic and estuarine in composition, but differ significantly from assemblages in Back Bay. There are also different associations and dominant species in the freshwater phytoplankton of Lake Drummond, located within nearby Dismal Swamp. These lake species are dominated by diatoms and desmids, with cyanobacteria rare (Marshall, 1976, 1979).

The purpose of this study was to evaluate the seasonal composition and abundance of phytoplankton in Back Bay and to compare these populations to those reported by Comegys over a decade ago. During this period Back Bay has undergone major changes, which include the loss of its submerged vegetation, reduction in its freshwater fishery, increased turbidity and an intermittent policy where saltwater was being pumped into Back Bay.

Methods

Water samples for phytoplankton analysis were taken twice a month from March through October and once a month November through February from February 1986 to March 1988 at six stations in Back Bay (Fig. 1). A 500 ml sample was collected within the upper 0.5 meter at each station and preserved immediately with Lugol's solution. A settling and siphoning procedure followed to obtain a 20 ml concentrate that was placed in a settling chamber and later analyzed with an inverted plankton microscope. The entire concentrate was scanned at 125x for net phytoplankton. A random field-minimum count basis was used at 315x for microplankton (20-200 μ m), and at 500x for pico-nanoplankton (1.5-2.0 microns). Unidentified cells less than 1.5 microns in size were not counted since clear distinction could not be made between autotrophic and heterotrophic cells with the microscope used in this study. This analysis produced an 85% accuracy estimate for the species concentrations within these size ranges. Cell volume measurements were obtained by corresponding each phytoplankter to one or more geometric shapes and determining the cell volume in μ m^3. Salinity and temperature readings were obtained using a portable induction salinometer.

Results

The mean station temperatures for the two year period are given in Figure 2. The major difference between the two years was the timing of the spring temperature rise and subsequent decline into winter. The warming trend came earlier in 1986, with lowest surface water temperatures in January 1988 (0.5°C) and highest in July 1987 (32.1°C). The salinity range for this period was 1.9 to 4.9 o/oo for 1986 and 1.4 to 3.8 o/oo in 1987. Highest salinities were associated with summer and fall, with lowest values generally in late winter and spring, and in 1987 (Figure 2). This decrease was related to the regional precipitation totals for 1986 and 1987. The period for 1986 was considered a "dry" year, with a total precipitation of 26.4 inches compared to 44.6 inches for 1987. The salinity range in 1974-1975, noted by Comegys (1977) was 0.89 to 3.77 o/oo. The 1986 spring-summer temperature rise was associated with increased salinities. However, the temperature drop in 1986 preceded by two months lower salinity records for the station. In contrast, the temperatures and salinity patterns for 1987 and early 1988 were similar. These results indicated basic environmental differences were present over the two periods of study.

A total of 158 phytoplankton were identified (Table 1). These were represented by cyanobacteria (36), Chlorophyceae (35), Bacillariophyceae (49), Dinophyceae (14), Cryptophyceae (4), Euglenophyceae (10), Chrysophyceae (5), Xanthophyceae (3), and Prasinophyceae (2). In addition, several forms were placed under broader generic categories, with other unidentified cells placed in size categories of 1.5-3.0, 3-5 and 5-10 μ m, that included both picoplankton (0.2-2.0 microns) and nanoplankton (2.0-20.0 microns) size groups. The majority of the cells in these three size categories were cyanobacteria, chlorophyceans and microflagellates. The seasonal pattern for the total phytoplankton was a unimodal abundance period occurring in late summer-early fall for both 1986 and 1987, with winter lows each year (Fig. 3). There was greater abundance in the 1987 summer maximum due to increased numbers of cyanobacteria cells. In contrast, many of the other taxonomic groups were more abundant in 1986, and due to their larger cell sizes produced a greater biomass (cell volume) at this time (Fig. 3). Refer to Marshall (1988) for the monthly concentration patterns for the dominant species.

Cyanobacteria

The most abundant and characteristic phytoplankters in Back Bay were cyanobacteria. This group was divided into identifiable species composed of isolated cells, filaments or colonial forms and were included within the cyanobacteria category, and a second assemblage that was within the pico-nanoplankton category. The cyanobacteria were the major component in the size group 1.5-3 μ m, with most of the cells generally 1.5 to 2.0 μ m in size. Additional autotrophic cells, mainly cyanobacteria, within the picoplankton category were not counted because distinction between these and heterotrophic bacteria was not feasible with the light microscope. Thus, the counts given for picoplankton concentrations are considered underestimates of the pico-cyanobacteria component. Random samples taken over the study period and prepared for epifluorescent microscopic examination verified the vast majority of autotrophic cells in this category were cyanobacteria. Similar verification was noted in the 3-5 μ m cell size category, but the proportion of cyanobacteria cells to others was not as great as in the <3 μ m component. The larger cyanobacteria had one major pulse each year (Fig. 4). The cells in the < 3 μ m category were ubiquitous and abundant each year, but were more numerous in 1987 when a more distinct spring-summer pulse developed (Fig. 4). The greater diversity in composition of the 3-5 μ m cell size component produced larger numbers of cells throughout 1986, in comparison to 1987, which resulted in larger numbers of cyanobacteria.

With the exception of the pico-nanoplankton cells, the most abundant cyanobacteria in Back Bay were *Lyngbya limnetica, Lyngbya contorta, Chroococcus limneticus, Merismopedia elegans, Merismopedia tenuissima, Merismopedia glauca*, and *Gomphosphaeria aponina*. *Lyngbya limnetica* and *L. contorta* had peak production in mid-summer and fall, with a winter low (Table 1). These growth patterns were of shorter duration in 1987, with the decline more rapid and the peak production limited to summer. *Merismopedia glauca* and *M. tenuissima* had similar patterns, but *M. elegans* was generally a background species, with the exception of a spring 1986 pulse. *Gomphosphaeria aponina* and *Chroococcus limneticus* were also common, with a decline in winter.

Other Phytoplankton Categories

The Bacillariophyceae consisted of predominantly freshwater (e.g. *Melosira distans*) and to a lesser degree estuarine species (e.g. *Rhizosolenia setigera, Thalassiosira eccentrica*). *Cyclotella striata, Cyclotella meneghiania*, and *Cyclotella caspia* were dominant species throughout the year (Table 1), with their peak concentrations occurring during spring-summer months (Marshall, 1988). Higher numbers occurred in 1987 (than in 1986) when an early spring bloom began in late winter with a peak in January, followed by a decline, then a greater pulse in April, before dropping again into May (Fig. 3). There was no fall pulse, nor did any of the estuarine species reach high concentrations. These cells were more common at Station 22, the southern most site nearest to Currituck Sound. A diverse group of chlorophyceans were in the samples and in contrast to the diatoms had much higher concentrations during 1986 than in 1987. However, their greatest abundance occurred in spring and fall in 1986 and spring in 1987 and 1988 (Fig. 5). The group was mainly represented by desmids which included *Cosmarium costatum*, *Scenedesmus bijuga*, *S. dimorphus* and *S. quadricauda*. In addition, *Ankistrodesmus falcatus*, *Crucigenia tetrapedia*, and *Tetraedron regulare* were also common. Although not specifically recognized in the pico-nanoplankton category, there were also chlorophycean cells in these size groups. They often consisted of "chlorella like" cells, so their addition from that category would augment the significance of chlorophyceans in this habitat. Highest concentrations of chlorophyceans were consistently noted at Station 9, the most northern and least saline station sampled.

The cryptophyceans represented a major component within Back Bay with several generic groups common. These included *Cryptomonas*, *Chroomonas* and *Hemiselmis*, with *Cryptomonas* spp. most abundant. The greatest concentrations were in fall 1986 with other scattered pulses noted over the study period (Fig. 5). These cells were also common to the lower Chesapeake Bay and the regional sections of estuarine rivers (Marshall and Lacouture, 1986). These varied seasonal growth patterns indicated growth responses from several different components within the group. The dinophyceans consisted mainly of estuarine species, e.g. *Gymnodinium danicans*, *Katodinium rotundatum* and *Prorocentrum minimum*. Concentration levels were generally low, with the exceptions of pulses during winter 1986, summer 1987 and spring 1988 (Fig. 5). The spring 1988 pulse was limited to two northern stations (Stations 5, 9) and was dominated by *Gymnodinium danicans*. The different pulses of dinoflagellates were growth responses by an individual species, rather than a general growth response by numerous species. The dominant species were not unique for the region, but common constituents of local estuarine habitats (Marshall and Lacouture, 1988). Another prominent phytoflagellate category in Back Bay was the Euglenophyceae. Although never found in high concentrations the euglenophyceans were common at all stations. Representative species included *Euglena acus*, *E. proxima*, *E. pumila*, and *Eutreptia lanowii*. More rare were several *Phacus* spp. and *Trachelomonas hispida*, however, these genera were often noted at Station 9 and to a lesser degree at other stations. This group was most common in summer, with lowest concentrations during winter (Fig. 4).

In addition to the phytoplankton categories mentioned above, several other groups provided low concentrations and low diversity of species during the sampling period. These background species included chrysophyceans, prasinophyceans and xanthophyceans. The chrysophyceans are common estuarine species that were divided into two categories: 1) the silicoflagellates and 2) the other chrysophytes. The silicoflagellates included *Dictyocha fibula* and *Distephanus speculum*. They were generally rare but produced a small summer 1986 pulse. The other chrysophyceans consisted of *Calycomonas wulffie*, *Mallomonas* sp. and *Ochromonas* sp. The entry of these and other estuarine species into Back Bay was influenced by local wind patterns. Strong and prevailing winds from the southeast (or ESE, SSE) bring the more saline Currituck Sound water into the Bay. Depending upon wind direction, its duration and velocity, this water may move either into the entire lower portion of the Bay, or along the eastern margin. Other estuarine categories included the prasinophyceans which were represented by *Pyramimonas* sp. and *Tetraselmis* sp. and the xanthophyceans containing *Nephrochloris salina*, *Nephrochloris* sp. and *Olisthodisaus* sp. None of these three groups were major components of the Bay flora, but they produced several pulses over the two year period.

Discussion

Comegys (1977) described the phytoplankton flora of Back Bay as predominantly cyanobacteria (blue green algae) and chlorophycean, with diatoms, cryptomonads and others as non-dominant components. The results of this present study indicate the cyanobacteria remain the dominant flora, but show a changing contribution to the total assemblage by the chlorophyceans and the greater significance of diatoms and the cryptomonads. In addition, there were interannual differences in the seasonal abundance of the various phylogenetic groups and total phytoplankton concentrations between 1986 and 1987.

There have been major environmental events that have impacted Back Bay since Comegys's study in 1974-1975, which represent only a portion of the total changes that have taken place within this drainage basin. Their total scope is too vast to discuss in this report. However, they include: 1) the intermittent pumping of salt water into Back Bay; 2) the changing land use patterns bordering Back Bay, which includes the transition of woodland and marsh sites to agriculture and housing developments; 3) increased turbidity levels; 4) the loss of submerged vegetation; and 5) the reduction of the freshwater fishery. In addition, there are likely seasonal and annual deviations of algae growth patterns that cannot be fully identified in short-term studies. Normal ranges of seasonal fluctuations need to be identified before many of the algal responses to "normal" and/or adverse environmental conditions can be fully recognized.

Alden and Ewing (1990) have also reviewed water quality data for Back Bay over the past two decades and identified several concerns. One involves the tributaries along the western border that are major sources for nutrients into the Bay. In addition, the main Bay waters have a high suspended solid load, with high TKN concentrations. Their data infers a reduction in productivity (based on pH and oxygen levels), with elevated TKN values indicating a positive trend, going from means of 1.14 to 1.97 mg/l over this period. They associate a reduced productivity with the loss of submerged aquatic vegetation, increased suspended solids and a change in the phytoplankton population. A significant feature of the TKN is that they are above the 0.9 mg/1 level "used as a benchmark for nitrogen over-enrichment." It should be noted the present phytoplankton populations contain potential bloom producers among its procaryote and eucaryote species. Greater development, or bloom production is considered imminent if nutrient levels, specially phosphates, were to increase in the Bay waters. Sites most vulnerable for increased growth would be those located near, or along the western margin of the Bay. With a submerged vegetation practically absent in the Bay, there would be little competition for increased nutrient loadings, resulting in rapid uptake by the phytoplankton community. However, a major deterrent to this utilization and growth, may be the high suspended solid load within the Bay waters and the possible impact this has on reducing light availability to the cells.

The present algal assemblages in Back Bay are unique among regional habitats. The nearby estuaries of the Elizabeth and Nansemond Rivers have predominantly an estuarine-neritic flora dominated by diatoms and a pico-nanoplankton component (Marshall, 1967; Shomers, 1988). These assemblages are comparable to those in the lower James River (Hampton Roads) and the lower Chesapeake Bay (Marshall and Lacouture, 1986). Common components that were dominant in these different habitats was the diatom *Cyclotella striata* and the ubiquitous pico-nanoplankton cells. However, other diatoms such as *Skeletonema costatum*, *Leptocylindrus minimus* and *Asterionella glacialis* were major dominants and these were not common in Back Bay. The acidic, brown water Lake Drummond, located in nearby Dismal Swamp, has a floral assemblage that is dominated by another diatom group consisting of *Asterionella formosa*, *Melosira granulata* and *Melosira herzogii* (Marshall, 1976).

The phytoplankton flora at Back Bay is characterized as predominantly composed of cyanobacteria, bacillariophyceans and chlorophyceans. A very prominent pico-nanoplankton community of cells is ubiquitous and composed of mainly cyanobacteria, with chlorophyceans in less abundance. The major period of algal growth is summer, when each of these categories obtained maximum development. The dominant species within each category are small cells. Even *Cyclotella striata*, or *Cyclotella caspia* are represented by a cell size of less than 10 μ m. The cryptomonads are also prominent, but to a lesser degree. The other taxonomic groups were not major contributors to the local productivity. However, within each of the taxonomic categories individual pulses of growth were common, with a larger number of background species intermittently present, but in lower concentrations during the sampling period.

In summary, the phytoplankton assemblages have changed since 1974-75 when they were evaluated by Comegys (1977). Comegys considered Back Bay was in an advanced mesotrophic or eutrophic stage. The present species composition in Back Bay would be considered more mesotrophic than eutrophic, with the changes in species compositon that have occurred over the past decade due to modified water quality conditions that favored the presence and growth of the existing assemblages. The return to a lower salinity range, increased nutrient input and reduced salt water entry (from either pumping activities, or its natural entry from the south) would enhance eutrophication and initiate another composition change of future phytoplankton assemblages.

Acknowledgement

Special appreciation is given to Ronald Southwick and Mitchell Norman from the Virginia Department of Game and Inland Fisheries for assistance in the collection of the water samples. Special thanks is given to Cindy Shomers for processing the raw data for statistical analysis. This study was funded by the Virginia Department of Game and Inland Fisheries.

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Table 1. Phytoplankton species observed in Back Bay. Mean annual cell concentrations and mean annual volume measurements are given for each species. Less than 1 values are indicated by a zero. Cell concentrations given in no.'s per liter, cell volume in cubic microns per microliter.

Species	Cell Concentration	Cell Volume
BACILLARIOPHYCEAE		
Achnanthes clevei Grunow	270	0
Achnanthes longipes Agardh	234	6
Achnanthes sp.	270	1
Amphiprora alata (Ehrenberg) Kutzing	590	43
Amphiprora costata (W. Smith) Hustedt	284	7
Amphiprora sp.	234	14
Amphora proteus Gregory	0	0
Amphora sp.	248	5
Bacteriastrum hyalinum Lauder	12194	63
Biddulphia longicruris Greville	2144	19
Centric diatoms (Unid.) <20u diameter	5920	5
Centric diatoms (Unid.) 20u-100u diameter	53980	1831
Chaetoceros sp.	3	0
Cocconeis sp.	9923	60
Coscinodiscus centralis Ehrenberg	35	28
Cyclotella glomerata Bachmann	41182	23
Cyclotella meneghiniana Kutzing	578509	909
Cyclotella sp.	250125	85
Cyclotella sp. I	27909	1
Cyclotella caspia Grunow	35753	2
Cyclotella striata (Kutzing) Grunow	743306	2627
Cymbella sp.	2698	1
Diploneis crabro Ehrenberg	625	15
Diploneis gruendleri (Schmidt) Cleve	270	1
Fragilaria sp.	7836	2
Frustulia rhomboides (Ehrenberg) deToni	0	0
Frustulia sp.	248	2
Gomphonema sp.	866	8
Gyrosigma hippocampus (Ehrenberg) Hassall	319	4
Licmophora paradoxa (Lyngbye) Agard	319	5
Licmophora flabellata (Carmichael) Agardh	0	0
Melosira distans (Ehrenberg) Kutzing	26411	72
Melosira granulata (Ehrengerg) Ralfs	11783	64
Melosira nummuloides (Dillwyn) Agardh	1	0
Melosira sp.	16843	331
Navicula arenaria Donkin	0	0
Navicula sp.	2314	17
Nitzschia angularis var. *affinis* Grunow	10292	100
Nitzschia clausii Hantzsch	319	0
Nitzschia sigma (Kutzing) W. Smith	951	36
Nitzschia sp.	5636	51
Nitzschia vermicularia (Kutzing) Hantzsch	0	0
Pennate Diatoms (Unid.) <20u apical axis	53611	10
Plagiogramma staurophorum (Gregory) Heilberg	27228	3
Pleurosigma sp.	271	10
Pleurosigma strigosum W. Smith	468	30
Porosira gracialis (Gran) Jorgensen	1774	94
Rhizosolenia setigera Brightwell	319	15
Striatella sp.	248	5
Surirella fastuosa Ehrenberg	319	28
Surirella striatula Turpin	2	0
Thalassiosira eccentrica (Ehrenberg) Cleve	3	0

Species	Cell Concentration	Cell Volume
DINOPHYCEAE		
Amphidinium sp.	1107	4
Amphisolenia bidentata Schroeder	539	90
Ceratium sp.	248	7
Dinoflagellate cysts (Unid.)	589	25
Glenodinium sp.	1455	10
Gymnodinium danicans Campbell	22659	33
Gymnodinium nelsonii Martin	284	11
Gymnodinium sp.	1810	142
Gyrodinium aureolum Hulburt	1704	10
Gyrodinium sp.	284	10
Katodinium asymmetricum (Massart) Loeblich III	305	0
Katodinium rotundatum (Lohmann) Loeblich III	2456	2
Oblea rotunda (Lebour) Balech	0	0
Prorocentrum minimum (Pavillard) Schiller	2371	1
Protoperidinium sp.	1604	23
CYANOBACTERIA		
Agmenellum quadruplicatum (Heneghini) Brebisson	3407	0
Anabaena confervoides Reinsch	298	0
Anabaena sp.	6445	0
Anacystis cyanea (Kutzing) Drouet & Dailey	468	0
Blue Green single cells (Unid.)	19768	1
Blue Green trichomes (Unid.)	539	1
Calothrix sp.	327	0
Chroococcus dispersus (Keissler) Lemmerman	11321	0
Chroococcus limneticus Lemmerman	5799735	655
Chroococcus sp.	13969	3
Chroococcus turgidus (Kutzing) Naegeli	78546	932
Dactylococcopsis fascicularis Lemmerman	639	0
Gomphosphaeria aponina Kutzing	3081428	1384
Gomphosphaeria sp.	213	0
Johannesbaptistia pellucida (Dickie) Taylor & Drouet	2002	0
Lyngbya contorta Lemmerman	1114301	309
Lyngbya limnetica Lemmerman	15446130	9468
Lyngbya sp.	497	0
Merismopedia elegans Braun	3121613	28728
Merismopedia v. *major* G. Smith	6090	4
Merismopedia glauca (Ehrenberg) Naegeli	6390852	217
Merismopedia punctata Meyen	453107	546
Merismopedia sp.	5494	3
Merismopedia tenuissima Lemmerman	3531559	32
Microcystis aeruginosa Kutzing	7354521	2809
Microcystis incerta Lemmerman	1740863	2
Nodularia sp.	270	0
Nostoc commune Vaucher	454143	30
Nostoc sp.	47344	3099
Oscillatoria limnetica Lemmerman	479205	158
Oscillatoria sp.	3024	35
Oscillatoria tenuis Agardh	51702	69
Raphidiopsis curvata Fritsch & Rich	573872	1333
Rhabdoderma lineare Schmidle & Lauterborn	5196	0
Rhabdoderma sigmoidea f. *minor* Moore & Carter	60588	0
Rhabdoderma sp.	1164	0
Schizothrix sp.	284	0
Spirulina subsalsa Oersted	284	0

Species	Cell Concentration	Cell Volume
EUGLENOPHYCEAE		
Euglena acus Ehrenberg	2472	82
Euglena ehrenbergii Klebs	319	12
Euglena proxima Dangeard	2633	73
Euglena pumila Campbell	2243	88
Euglena sp.	13025	177
Eutreptia lanowii Steuer	319	0
Eutreptia sp.	284	2
Phacus sp.	355	0
Trachelomonas hispida (Perty) Stein	589	130
Trachelomonas sp.	958	197
CHLOROPHYCEAE		
Ankistrodesmus falcatus Beijerinck	66515	130
Ankistrodesmus sp.	7204	197
Botryococcus protuberans West & West	3577	0
Chlamydomonas sp.	365256	164
Chlorella sp.	355	0
Cosmarium costatum West & West	1682	24
Cosmarium sp.	9916	143
Crucegenia sp.	20570	2
Crucegenia quadrata Morren	3549	0
Crucegenia tetrapedia (Kirchner) West & West	17773	2
Dictyophaerium planctonicum Tiffany & Ahlstrom	3748	2
Dictyophaerium pulchellum Wood	1874	0
Euastrum sp.	355	4
Kirchneriella lunaris (Kirchner) Moebius	50147	2
Kirchneriella obesa major (Bernard) G. Smith	6118	1
Kirchneriella sp.	31898	
Microasterias sp.	234	30
Pediastrum boryanum (Turpin) Meneghini	4863	69
Pediastrum duplex Meyen	2023	1059
Pediastrum duplex var. *rotundatum* Meyen	3	1715
Pediastrum simplex (Meyen) Lemmerman	319	167
Scenedesmus abundans (Kirchner) Chodat	3407	0
Scenedesmus bernardii G. Smith	3975	1
Scenedesmus bijuga (Turpin) Lagerheim	115498	125
Scenedesmus dimorphus (Turpin) Kutzing	88355	4
Scenedesmus hystrix Lagerheim	3407	1
Scenedesmus quadricauda (Turpin) Brebisson	253633	431
Scenedesmus sp.	6558	9
Staurastrum grande Bulnheim	7098	21
Staurastrum sp.	3159	15
Tetraedron lobulatum (Naegeli) Hansgirg	284	3
Tetraedron minimum (Braun) Hansgirg	10008	20
Tetraedron muticum (Braun) Hansgirg	284	1
Tetraedron regulare Kutzing	1519	28
Tetraedron sp.	5728	8
CRYPTOPHYCEAE		
Chroomonas sp.	8979	2
Cryptomonas sp.	394197	253
Cryptomonas sp. 2	44767	12
Hemiselmis sp.	132283	2

Species	Cell Concentration	Cell Volume
XANTHOPHYCEAE		
Nephrochloris salina Carter	9029	1
Nephrochloris sp.	710	0
Olisthodiscus sp.	1363	0
CHRYSOPHYCEAE		
Calycomonas wulffii Conrad & Kufferath	355	0
Mallomonas sp.	270	0
Ochromonas sp.	81527	7628
CHRYSOPHYCEAE: SILICOFLAGELLATES		
Dictyocha fibula Ehrenberg	270	2
Distephanus speculum (Ehrenberg) Haekel	41253	314
PRASINOPHYCEAE		
Pyramimonas sp.	3748	0
Tetraselmis sp.	4827	1
OTHER TAXA		
Micro-phytoflagellates (Unid.) <10 Microns	11186	0
Micro-phytoflagellates (Unid.) >10 Microns	72300	10
Green cells (1.5-3 microns)	61664095	123
Green cells (3-5 microns)	6505887	221

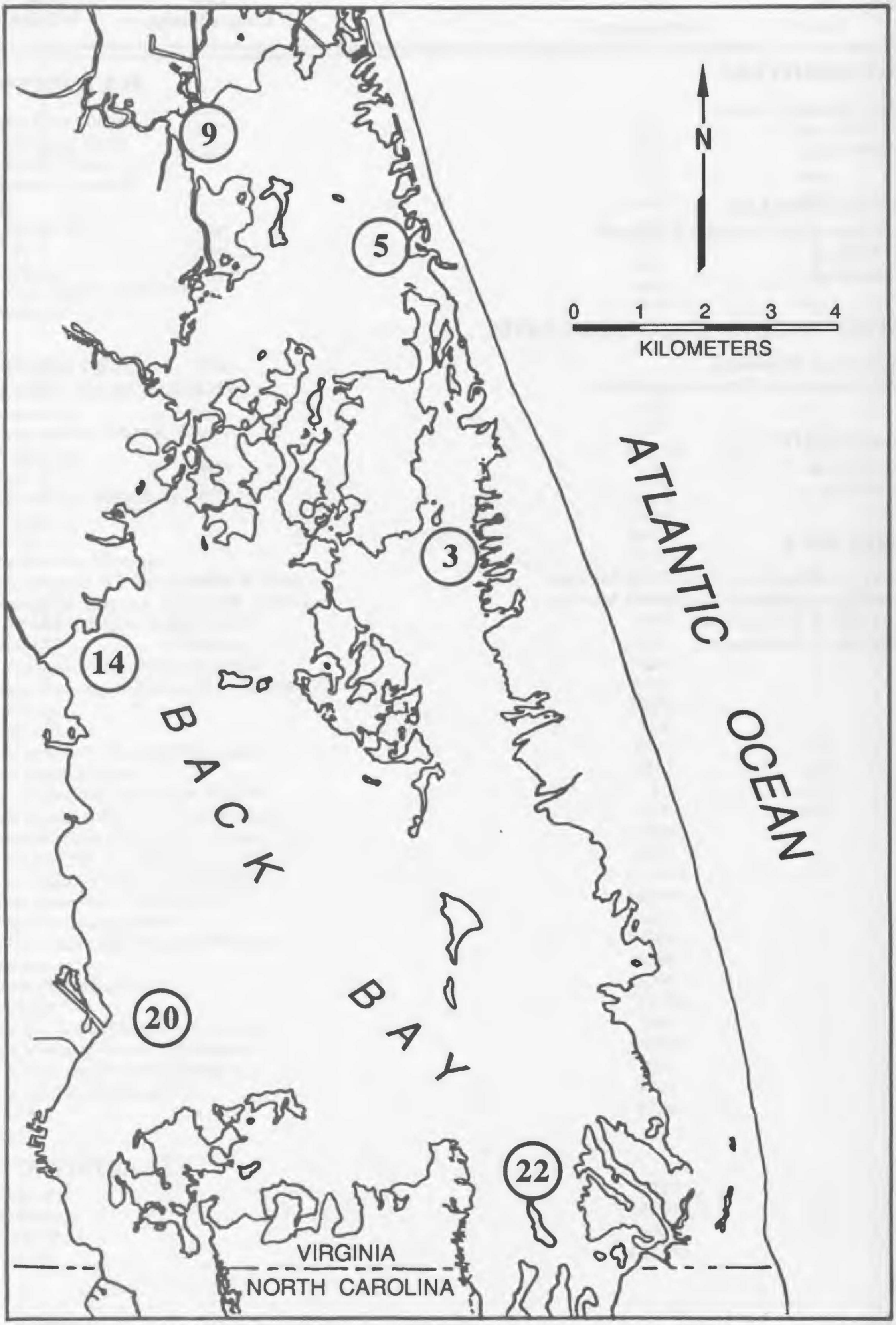

Figure 1. Station locations in the Back Bay collection area.

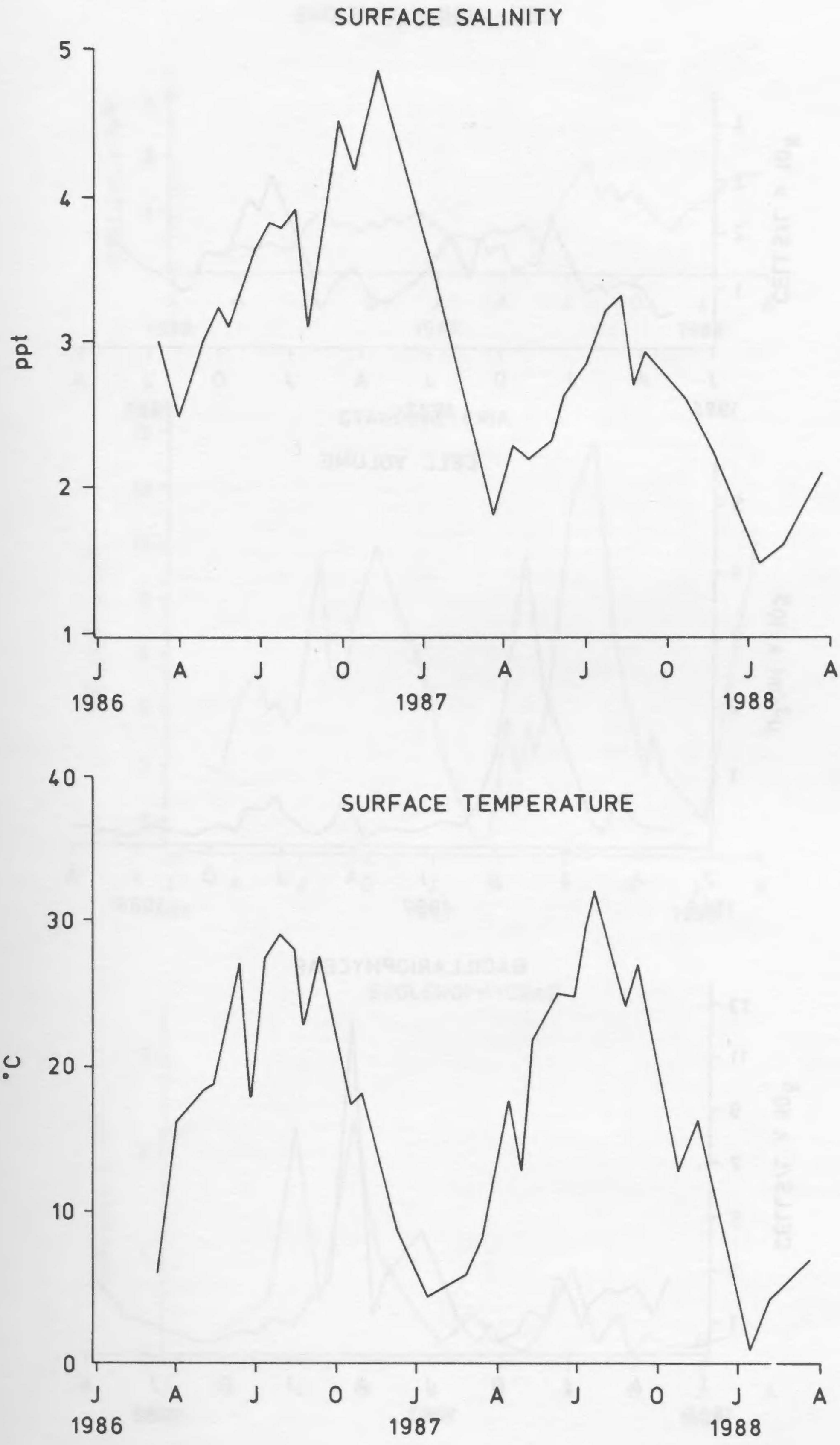

Figure 2. Mean surface salinity and temperature records from all stations in the Back Bay collections from February 1986 through March 1988.

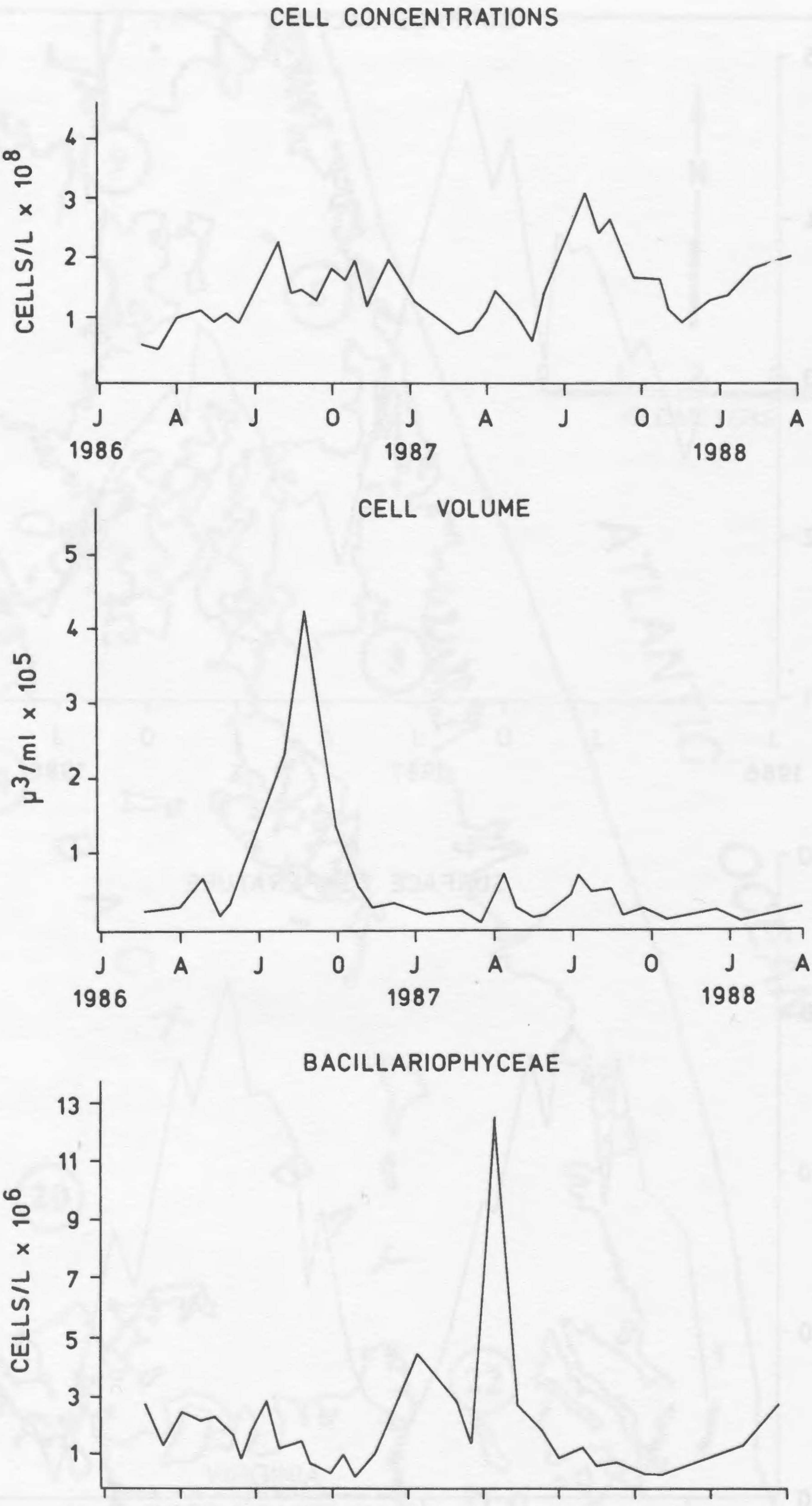

Figure 3. Mean values for total cell concentrations, total cell volume and concentrations of diatoms (Bacillariophyceae) from all stations in the Back Bay collections from Feburary 1986 through March 1988.

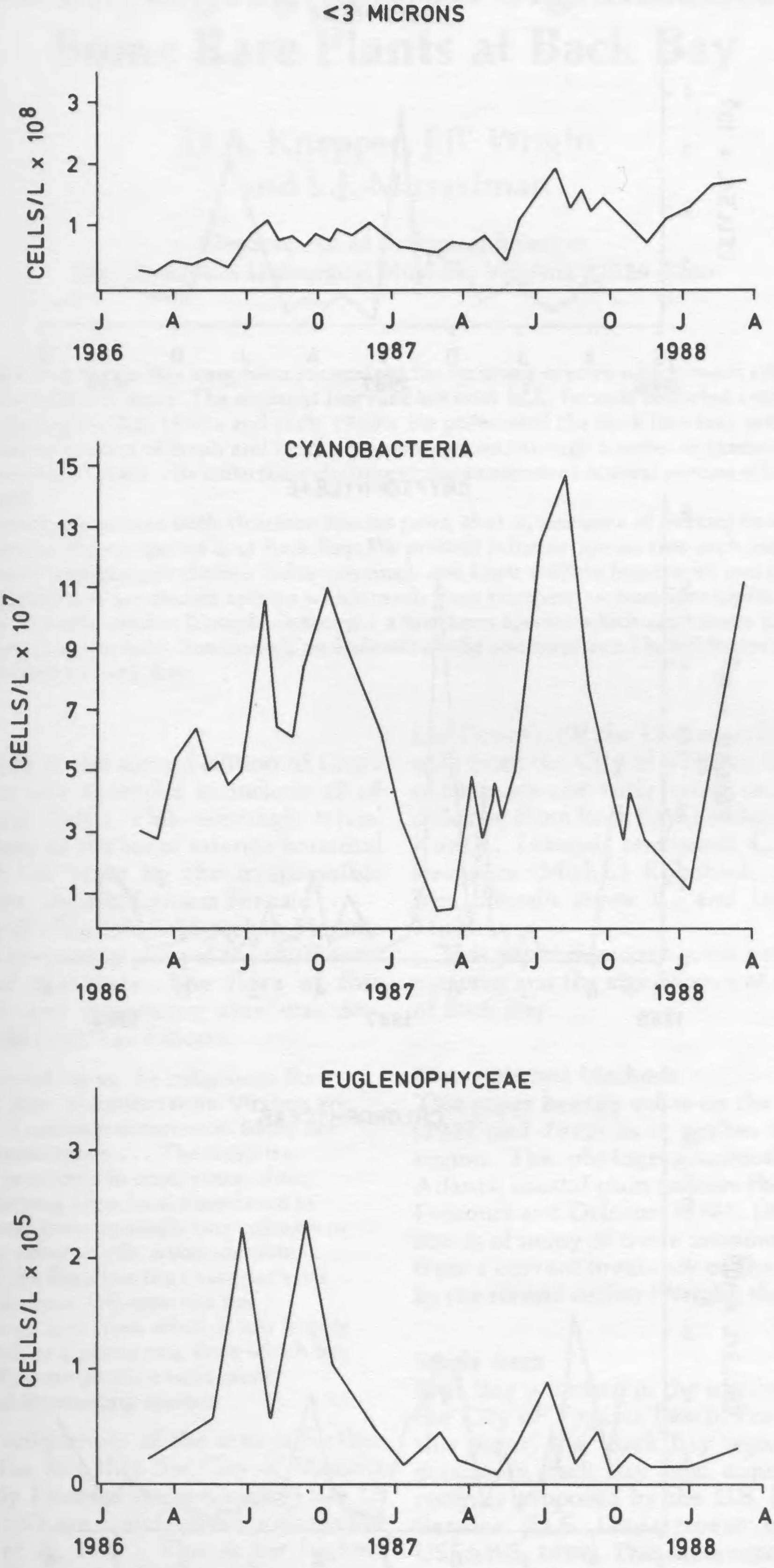

Figure 4. Mean cell concentrations for pico-nanoplankton cells less than 3 microns, cyanobacteria and euglenophyceans from all stations in the Back Bay collections from Feburary 1986 through March 1988.

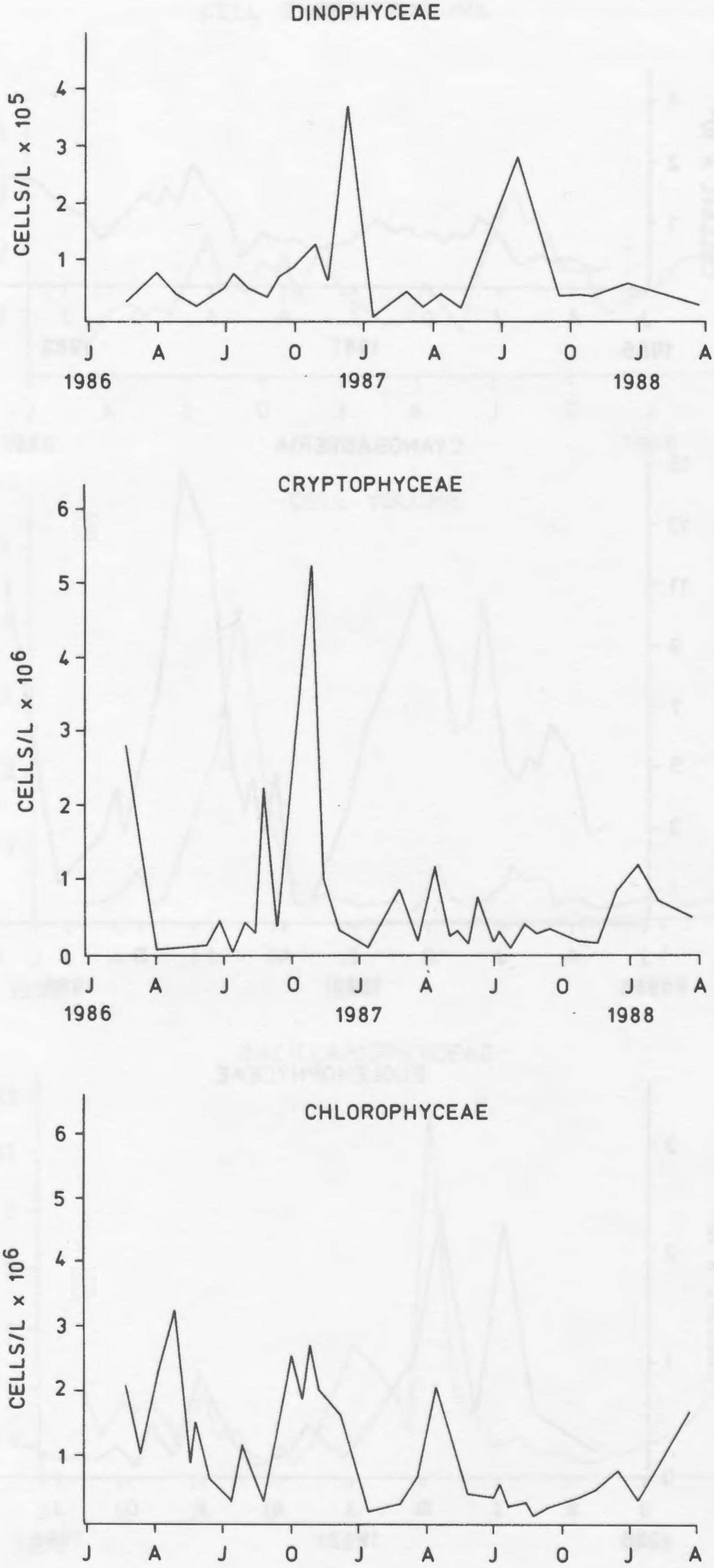

Figure 5. Mean cell concentrations for dinophyceans, cryptophyceans and chlorophyceans from all stations in the Back Bay collections from Feburary 1986 through March 1988.