STUDIES OF THE HORIZONTAL AND VERTICAL DISTRIBUTIONAL PATTERNS OF DIATOMS EPIPHYTIC ON EEL GRASS, ZOSTERA MARINA L.

by

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INTRODUCTION

Many studies have been made on planktonic diatoms but little work has been done on bottom diatom communities, especially with emphasis on epiphytic forms. Chapman (1957) emphasized that any contribution dealing with the distribution of littoral marine diatoms represented an advance into what was virtually a new field, and Cannon (1961) stated: "At the present time nearly all the experimental work (on diatoms) with an ecological viewpoint is concerned with plankton algae."

A good source of epiphytic diatoms is eel grass, Zostera marina L., one of the most widely distributed and abundant salt water seed plants in temperate regions (Newcombe, 1948). The erect segments of this plant are annuals lending themselves to yearly examination with no confusion from the preceding year's growth. The eel grass bed studied was in the sublittoral region as defined by Hedgpeth (1957), a region in which few diatom studies have been conducted.

An examination of epiphytic diatoms on eel grass was made to determine horizontal and vertical distributional patterns, and to demonstrate the population fluctuation of these organisms during the "stable period" of summer growth. It is hoped that this study will serve as a point of departure for others interested in marine epiphytic diatom communities.

The epiphytic diatoms studied are a component of the "aufwuchs" community which is composed typically of an assortment of unicellular and filamentous algal forms found on a submerged substrate (Reid, 1961:307). This group of organisms is also considered as a component of the periphyton (Welch, 1948:327). Periphyton is the assemblage of organisms which forms a slimy coating on submerged plants, wood, stones, and other objects.

This study was conducted with the cooperation of the personnel at Virginia Institute of Marine Science at Gloucester Point, Virginia. Sampling sites were located immediately adjacent to the institute near the mouth of the York River in the estuarine system of Chesapeake Bay.

LITERATURE REVIEW

Apparently the first record of observation of a diatom was of a planktonic form by Leeuwenhoek about 1702, and 70 years later O. F. Müller found another species from a similar habitat (Allen, 1934). Patrick (1948) stated that between 1843 and 1854 Ehrenberg brought together a great amount of information from various parts of the world on diatom floras, and this information is published in "Microgeologie". Ehrenberg also charted in table form the distribution of diatoms for various continents.

The next work to bring together information on the distribution of diatoms, according to Patrick (1948), was that of De-Toni in the mid-eighteen hundreds. Hedgpeth in Treatise on Marine Ecology (1957) stated that Victor Hensen of Germany was the founder of quantitative plankton research. In early reports of the German Commission, about 1873, Hensen inaugurated research on the distribution of organisms in relation to salinity and quantitative analysis of plankton.

P. T. Cleve in 1894 made a careful study of diatom distribution. Patrick (1948) said that Cleve recognized many species as being cosmopolitan, but that he also realized many species and genera were characteristic of certain regions.

Kofoid in 1903 gave a detailed study of the plankton of the Illinois River (Allee et al., 1949:36), and in 1919 the Scripps Oceanographic Institute of the University of California established

a series of investigations for the purpose of gathering information on the seasonal and geographical occurrence, distribution, and conditions of abundance of plankton diatoms in the Eastern Pacific (Allen, 1934).

After the early nineteen hundreds, research in the field of plankton rapidly expanded. "Plankton of the Offshore Waters of the Gulf of Maine" (Bingelow, 1925) is an extensive work on the marine plankters of that area. In conjunction with taxonomic lists Bingelow included distribution, seasonal maxima and minima, and notes on the more prominent genera and species with chemical and physical features of the environment. "A Biological Study of the Offshore Waters of the Chesapeake Bay" (Cowles, 1930) is a survey of Chesapeake Bay using collections and identifications of the various plants and animals of the area to learn more of their distribution and abundance. The completeness of the study, duration of time, large area sampled, and conclusions make this an excellent background paper for marine phytoplankton.

Wilson (1925) studied marine algal succession by collecting algae on wooden blocks suspended in the water. After the first day, numerous organisms consisting almost exclusively of colonial diatoms were found on the blocks. Wilson found Cocconeis, Licmophora, Navicula, Nitzschia, and Synedra, genera also found in my study. Further observations indicated several distinct periods in the succession on wooden blocks. Colonial diatoms were the first phase,

followed by the hydroid-colonial diatom association, the Ectocarpus-hydroid association, prekelp association, and the kelp association. Cleared rock surfaces and suspended glass slides supported the wooden block evidence, a similar diatom flora and successional pattern was produced on both. The author made the comment that the work provided unsatisfactory conclusions due to the brief sampling period, but it is my opinion that the new area of research far outweighed any criticism.

The ecological conditions governing fresh water and marine habitats vary greatly (Patrick, 1948), but studies on the littoral algal flora of fresh waters are relevent to this study because of procedure, methods, and conclusions, if not from a taxonomic viewpoint.

In 1937 Godward published a paper on the ecology and taxonomy of the littoral algal flora of two English lakes. Stones, portions of submerged vegetation, suspended glass slides and cellophane were used as collecting surfaces in an attempt to form a qualitative basis for comparison of the different habitats and substrates. One or more species of Cymbella, Navicula, Cocconeis, and Epithemia found growing on fresh water aquatics were among the genera of diatoms represented on eel grass during this study.

Butcher's (1940) study of the sessile algae of the River Hull in England also made use of the glass slide technique for algal attachment. He found no seasonal variation of genera, but noticed a

difference in total number of diatoms present between summer and winter collections. Cocconeis, a genus also found in the marine environment, was included in the dominant genera.

Aleem (1950) did an exhaustive study of marine littoral diatoms of the southern coast of England. Several diatom communities were delimited in the study. Zonal distribution was dependent on the degree of exposure to the atmosphere and amount of illumination. Work on epiphytic diatoms was also done, and the available seaweed substrate was classified into three groups, i.e., species of primary importance, secondary importance, and little importance depending on the suitability for the attachment of epiphytic diatoms. Aleem discovered that foliose seaweeds with a smooth surface did not provide as good a substratum for diatoms as did many of the forms with branched, cylindrical thalli. Among the epiphytic diatoms in evidence on the seaweed were species of Cocconeis, Fragilaria, Gomphonema, Grammatophora, and Licmophora.

Hustedt and Aleem (1951) sampled the diatoms inhabiting the mud-flats of Salcombe estuary in England. They found species of Amphiprora, Amphora, Grammatophora, Licmophora, Melosira, Navicula, and Nitzschia among the most prominent. A general study was also undertaken on the epiphytic diatoms of Vaucheria. Amphora, Cocconeis, Grammatophora, and Licmorphora were the epiphytic diatoms of interest to this study.

Hendey (1951) studied the littoral diatoms of Chicester Harbor and their ability to foul surfaces submerged in the water,

particularly ship hulls. He discovered that the littoral diatoms of Chicester Harbor did not follow the course of seasonal occurrence usually found in plankton species. This suggested to Hendey that either the littoral flora was not subject to the limiting factors which control the plankton, such as shortage of nitrate and phosphate, or that these factors were not limiting in the littoral zone. Hendey did find, however, that a few species showed definite seasonal periodicity. Among the most prominent genera found in the summer were Amphora, Licmophora, and Navicula, genera which I also found epiphytic on eel grass.

Round (1953) worked with diatoms from the benthic region of Malham Tarn and found a pronounced seasonal periodicity. He concluded that growth was not greatly affected by low temperatures, as active growth was observed during March and April. Round was not able to correlate diatom maxima with chemical conditions, but he stated that light and to a lesser degree temperature might be factors initiating spring growth. In a more recent work, Round (1957) correlated distribution in lakes of the English lake district with the pH of the water. He further stated that in many instances the combination of pH and calcium content determined both distribution and productivity.

Brook (1955) worked with the attached algae of slow sand filter beds of waterworks. He stated that this situation was similar to that of a river and compared his work to that done in rivers. Brook found periodicity present with four fairly distinct phases,

each lasting approximately three months. Although some of the common species persisted, the dominant genera differed from phase to phase. The genera found included Diatoma, Cymbella, Cocconeis, and Melosira.

Smyth's paper (1955) was of primary interest to this study because it dealt with marine bottom diatoms. The work was done in Loch Sween, a sea lock on the coast of Scotland, with salinities between 15-32 °/oo. Samples collected using the glass slide technique included Amphora, Cocconeis, Navicula, Grammatophora, Melosira, Nitzschia, Licmophora, and Tropodoneis. Cocconeis scutellum, a predominant species, was also found as an epiphyte on submerged aquatics in the vicinity of the sampling sites. Smyth found that differences in depth between 1 and 10 meters had little effect on the composition of diatoms. He observed seasonal variations in the total number of organisms presnet, but not in the number of species. Based on these results, he stated that the bottom diatom flora, in contrast ot the phytoplankton, appeared to be a remarkably stable population.

Studies of the bottom algal flora in small ponds in England (Rao, 1955) indicated that two population maxima were present, as is usually the case with planktonic diatoms. Depending on species present and environmental conditions, these maxima varied from March to May for the spring bloom and September to November for the fall bloom.

Aleem's work with the succession of marine fouling organisms near La Jolla, California showed a successional series on various

test panels. The series was similar to that observed by Wilson (1925), diatoms constituted the second phase of colonization. Among the genera found were Amphora, Cocconeis, Dimerogramma, Grammatophora, Licmophora, Navicula, and Nitzschia (Aleem, 1958).

Douglas (1958) stated in her study of attached diatoms in a small stream that it was not possible to correlate changes in the population with changes in water chemistry or temperature. A fluctuation in seasonal numbers was observed, but no regular periodicity was established.

By studying the seasonal cycle of bottom-living diatoms in Lake Windermere and Blelham Tarn, Round (1960) showed seasonal fluctuations. Based on observations of Nitzschia, Navicula, and Pinnularia Round stated that the benthic epipelic community undergoes distinct seasonal changes. He showed some correlation between silicon concentration and light, and definite fluctuations due to temperature changes. Round stated that, "the three phases of diatom growth during the year correspond with the seasonal cycle of temperature."

Later work (Round, 1961) was done in the marine habitat on the fauna and flora associated with the hydroid Sertularia operculata. Observations made while the hydroid was growing in rapids revealed that Grammatophora was the most prominent diatom genus present, but Licmophora, Striatella, Synedra, Cocconeis, and Navicula were also present. When hydroid colonies were moved to Codium Bay, an area of quieter water, there was a large increase in diatom numbers.

Cocconeis scutellum became dominant but other genera including Navicula, Diploneis, Amphiprora, and Nitzschia were also in evidence.

METHODS

A sample plot approximately 1 by 15 yards was used to include the eel grass bed from its shallowest to deepest point. The entire plot was situated in the upper region of the sublittoral zone. The shallow portion of the eel grass bed was in one foot of water at mean low water, and the deepest portion was in five feet of water at mean low water. The distance from the shallow water portion of the bed to the upper reaches of the littoral zone was about 15 feet.

The areas at 1, 3, and 5 foot depths at mean low water were chosen to study horizontal distribution. The eel grass sampled ranged from that exposed at the surface at mean low water to plants which were permanently submerged in five feet or more of water. Four blades of eel grass were collected weekly from each sample area during August 1963. The medium depth and deep water samples for the last collecting date in 1963 were not obtained because of storm conditions accompanied by unusually high tides.

In June 1964 sampling was again undertaken for approximately a month. The areas sampled were the same as those used in 1963, however, 10 blades of grass were collected at the shallow and deep water collecting sites. The medium depth site (3 feet m.l.w.) was omitted. This alteration of sampling technique was made to increase competence and to achieve more uniform samples of the population. By sampling earlier in the growing season in 1964, it was expected

that a seasonal sequence could be developed by comparing the data, on a monthly basis, for the two yearly sampling periods.

The blades of eel grass were stored in containers of sea water long enough to be transported to the laboratory for examination. In order to study vertical succession, each blade from 1963 was scraped at the base, midpoint, and tip along a 5 cm length. The samples collected in 1964, however, were scraped only at the base and tip. This alteration reduced the time needed to count the diatoms per blade, and allowed an increase in the number of blades sampled. The scope of the study was not altered by this sampling change because base and tip comparisons were still available.

The total area of each scraped portion was determined in square millimeters, and the scraping from each length of blade placed in a calibrated vial. The contents were brought up to the 2 ml mark by using 4% formalin solution.

For counting purposes, the contents of each vial were mixed thoroughly and a homogeneous sample of 1/30 ml was removed and placed on a slide for examination.

The number of organisms per slide was counted, and the total organisms per sample calculated. The population density of each genus is expressed as cells per square millimeter for each sample. The four dominant genera for each year are graphed as average density per square millimeter.

The authority for the epiphytic diatom genera in this study is C. S. Boyer, 1927.

RESULTS

A total of 18 genera were identified from the samples collected in 1963 and 1964. Data for 1963 for four of these genera, Cocconeis, Dimerogramma, Epithemia, and Navicula was presented graphically (Figures 1 - 6). These genera were present in greatest quantity throughout the sampling period.

In 1964 Cocconeis, Dimerogramma, and Navicula were again dominant forms; but Epithemia was replaced in abundance by Nitzschia.

Where the genera Pleurosigma or Gyrosigma appear in the tables they are written as a generic complex rather than as separate genera. This is due to difficulty in distinguishing between the two genera.

Collecting conditions were favorable throughout the 1963 and 1964 sampling periods with few exceptions. In 1963 the weather was mild with no major disturbances except on August 30, the last collecting date of the year. There was, however, a periodic occurrence of red tide throughout the collecting period. While not hindering collecting, the presence of these organisms has a detrimental effect on many forms of marine life. In 1964 weather conditions were generally fair and no red tide was present.

DATA FOR 1963

Vertical Distribution

Shallow water

The series of graphs illustrating the vertical distributional

Table 1. Average Density (cells/mm^2) of Epiphytic Diatoms Found on Eel Grass (Zostera marina L.) in August 1963 and June and July 1964.

	1963 Depth									1964 Depth			
	Shallow			Medium			Deep			Shallow		Deep	
Genera	Base	Mid-point	Tip	Base	Mid-point	Tip	Base	Mid-point	Tip	Base	Tip	Base	Tip
Amphiprora	0	0	T*	0	T	0	0	0	0	--	--	--	--
Amphora	T	0	T	0	0	T	0	T	0	--	--	--	--
Cocconeis	28	13	20	18	31	38	102	50	34	122	210	184	231
Coscinodiscus	0	0	T	0	0	0	0	0	0	--	--	--	--
Cymbella	T	1	1	0	1	10	2	2	0	0	0	T	T
Diatoma	0	2	2	0	0	0	0	0	0	--	--	--	--
Dimerogramma	12	40	73	6	42	138	17	28	31	1	7	1	1
Epithemia	3	12	28	T	17	42	1	5	6	T	T	T	T
Grammatophora	T	T	T	0	T	0	C	T	T	0	T	--	--
Licmophora	T	0	T	0	0	0	0	0	0	--	--	--	--
Melosira	T	1	2	T	1	2	1	1	1	0	T	T	T
Navicula	8	21	118	17	132	227	79	106	98	22	143	55	83
Nitzschia	T	T	2	T	4	7	2	4	16	T	7	1	3
Pinnularia	0	0	0	0	0	0	T	0	0	--	--	--	--
Pleurosigma-Gyrosigma	0	0	0	0	0	0	0	T	0	0	0	T	0
Striatella	0	0	0	0	0	0	0	0	0	0	0	T	0
Tropodoneis	0	T	T	0	0	0	0	T	0	0	T	T	T

*T = Trace when the density of a genus present is less than one.

pattern in shallow water showed that the four aspect dominants fluctuate with time (Figure 1). Aspect dominants are taxa which are visual dominants for short periods of time but are not true community dominants. There was considerable fluctuation in shallow water densitites between sampling periods, but at least two trends were evident. (1) There was a general increase in average density from blade base to blade tip. The peak density at blade base, exhibited by Cocconeis, only exceeded 50 cells/mm^2 on one occasion. At the blade tip, densities above 50 cells/mm^2 were reached on seven occasions by three of the four dominant genera. (2) The general pattern of fluctuation for all three sampling positions was similar. There was a general increase throughout the sampling period, but on the last sampling date in 1963 three of the four dominant genera were decreasing in value at all of the sampling positions on the blade.

Medium depth water

In medium depth water (Figure 2) fluctuation of the dominant forms was relatively uniform at the midpoint and tip of the blade, but the base samples did not conform to this pattern. There continued to be a general increase in average density from the blade base to blade tip. The increase in Navicula was particularly noticeable. The graphs for midpoint and tip also show a distinct similarity with all genera except Dimerogramma increasing between August 6 and 14, and all genera increasing between August 14 and 21.

Figure 1. Shallow water vertical distribution of dominant diatom genera in 1963.

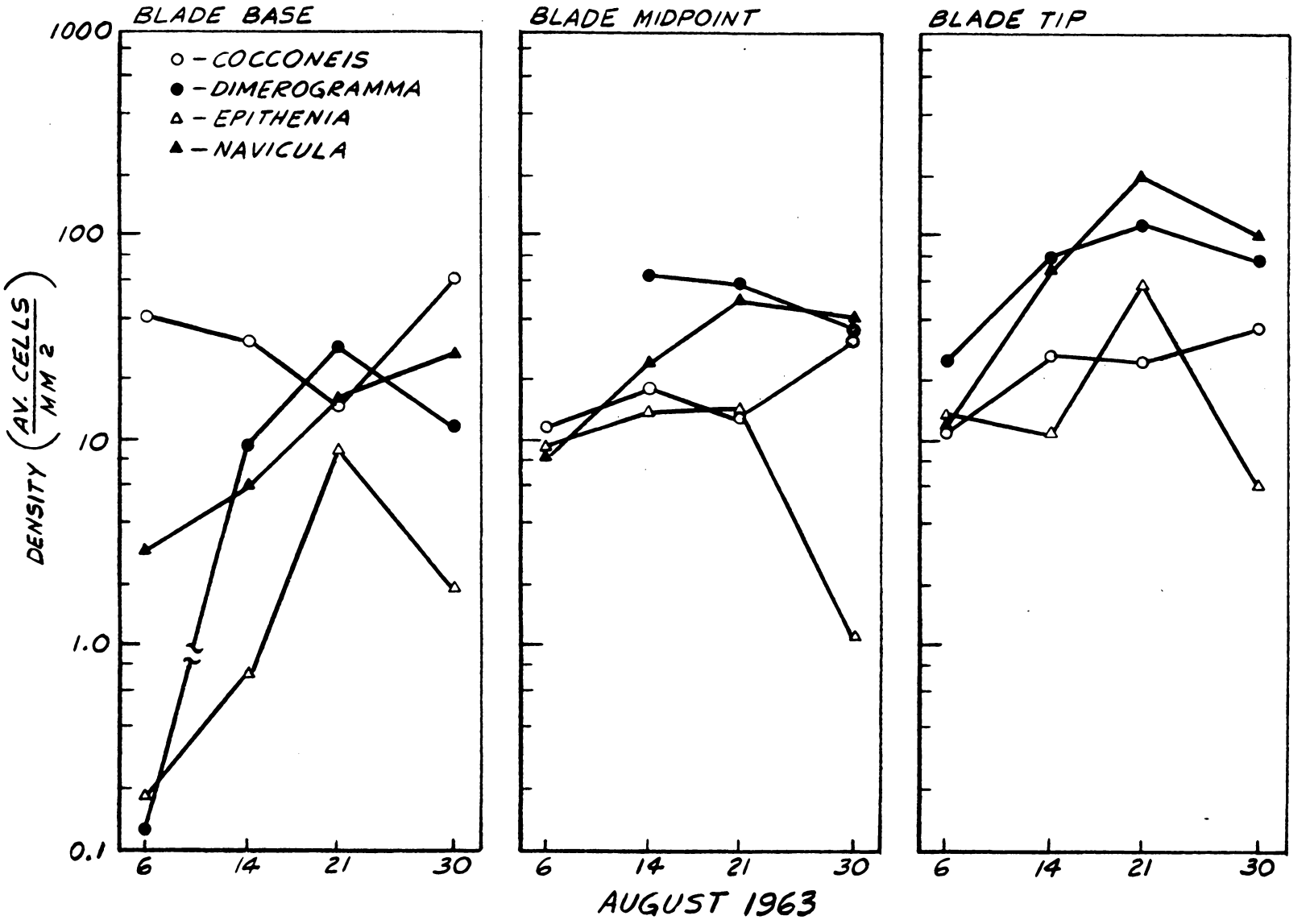
BLADE BASE
BLADE MIDPOINT
BLADE TIP
○ - COCCONEIS
● - DIMEROGRAMMA
△ - EPITHENIA
▲ - NAVICULA
1000
100
10
1.0
0.1
DENSITY (AV. CELLS / MM 2)
6
14
21
30
AUGUST 1963
SAMPLING DATES

FIGURE 1

Figure 2. Medium depth vertical distribution of dominant diatom genera in 1963.

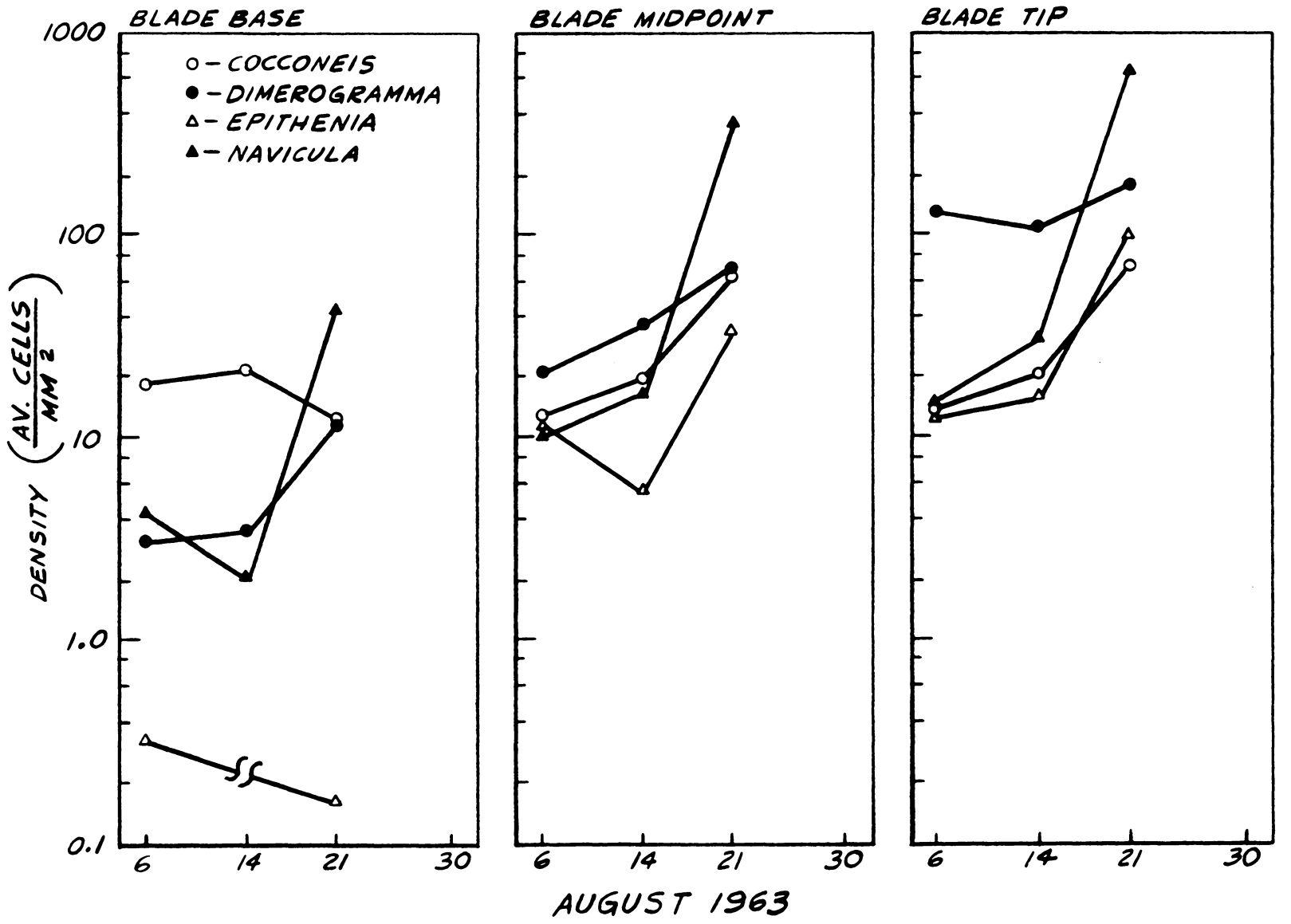
BLADE BASE
BLADE MIDPOINT
BLADE TIP
1000
100
10
1.0
0.1
DENSITY (AV. CELLS / MM²)
○ – COCCONEIS
● – DIMEROGRAMMA
△ – EPITHENIA
▲ – NAVICULA
6
14
21
30
AUGUST 1963
SAMPLING DATES

FIGURE 2

Deep water

Samples from deep water in August 1963 did not show the degree of conformity present at the other depths (Figure 3), but some correlations can be made. The peak density of a single genus was exhibited at the blade tip as shown in shallow and medium depth water, but there was not a general increase in cell number from blade base to blade tip.

Horizontal Distribution

Blade base

Distribution at the blade base in 1963 continued to show a population fluctuation with respect to time (Figure 4). There was an increase in average density between shallow and deep water, but the densities at the blade base in medium depth water did not conform to an expected pattern of increase.

Blade midpoint

Distribution at the midpoint of the blade in 1963 showed an average increase in density from shallow to medium depth water, but a slight decrease in deep water (Figure 5). The general increase in shallow and medium depth water densities supported previous observations. The population peaks shown in medium depth water were, however, difficult to correlate, particularly since the medium depth and deep water samples for the last collecting date was not obtainable.

Figure 3. Deep water vertical distribution of dominant diatom genera in 1963.

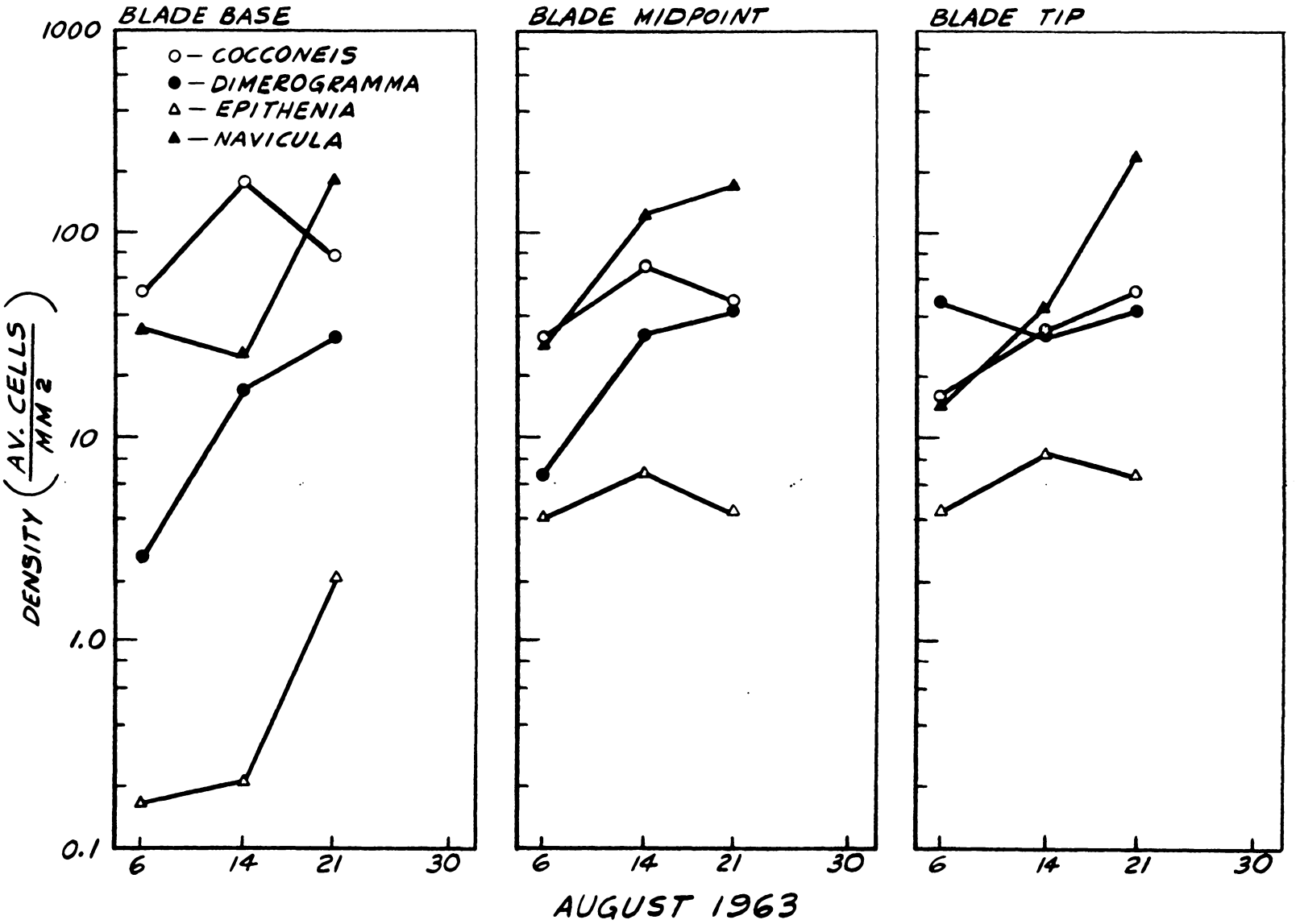
BLADE BASE
BLADE MIDPOINT
BLADE TIP
1000
100
10
1.0
0.1
○ — COCCONEIS
● — DIMEROGRAMMA
△ — EPITHENIA
▲ — NAVICULA
DENSITY (AV. CELLS / MM²)
6
14
21
30
AUGUST 1963
SAMPLING DATES

FIGURE 3

Figure 4. Horizontal distribution of dominant diatom genera at the blade base in 1963.

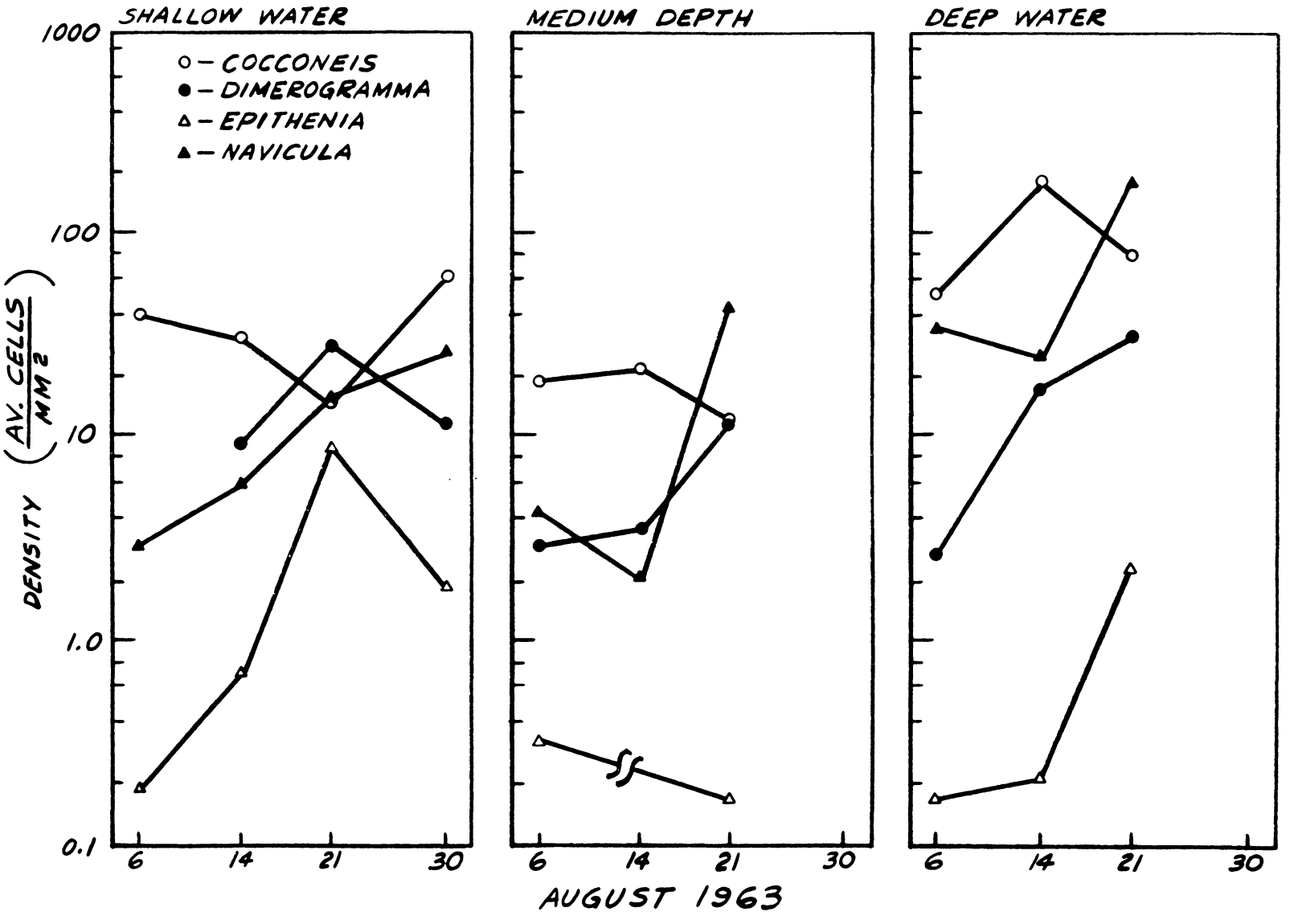
SHALLOW WATER
MEDIUM DEPTH
DEEP WATER
○ – COCCONEIS
● – DIMEROGRAMMA
△ – EPITHENIA
▲ – NAVICULA
1000
100
10
1.0
0.1
DENSITY (AV. CELLS / MM²)
6
14
21
30
AUGUST 1963
SAMPLING DATES

FIGURE 4

Figure 5. Horizontal distribution of dominant diatom genera at the blade midpoint in 1963.

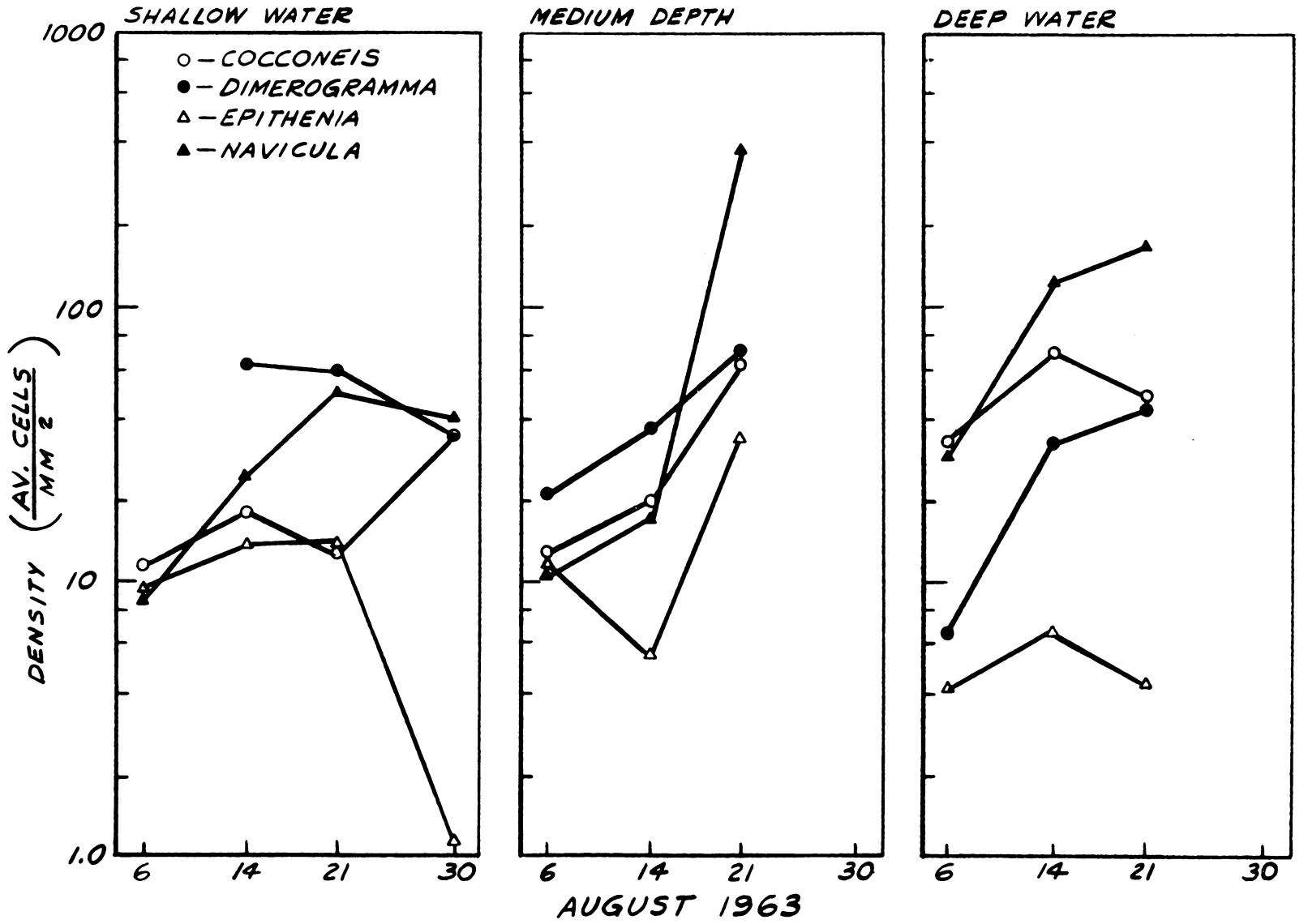
SHALLOW WATER
MEDIUM DEPTH
DEEP WATER
○ – COCCONEIS
● – DIMEROGRAMMA
△ – EPITHENIA
▲ – NAVICULA
1000
100
10
1.0
DENSITY (AV. CELLS / MM 2)
6
14
21
30
AUGUST 1963
SAMPLING DATES

FIGURE 5

Blade tip

Data on the distribution of genera at the blade tip showed fluctuations in aspect dominance which were quite similar for all depths (Figure 6). There was a general increase in population numbers through August 21, and from the decrease in shallow water between August 21 and 30 it is reasonable to assume that population densities in medium and deep water would also show a decrease in population numbers. The graphs, however, do not show a general density increase from shallow to deep water at the tip.

DATA FOR 1964

Vertical Distribution

Shallow water

Vertical comparisons of the four major shallow water genera in 1964 demonstrated a general increase from blade base to blade tip (Figure 7). Navicula and Cocconeis, the two most prominent genera, showed similar fluctuations even though they differed in magnitude. It should be noted that Dimerogramma and Nitzschia showed small population numbers for this period.

Deep water

The vertical comparisons for deep water in 1964 (Figure 8) showed a definite fluctuation with time. The curves for Navicula were similar at both the blade base and tip. Cocconeis, however, showed a similarity only between June 20 and July 14. Cocconeis was the dominant form for all sampling dates at both the blade base and

Figure 6. Horizontal distribution of dominant diatom genera at the blade tip in 1963.

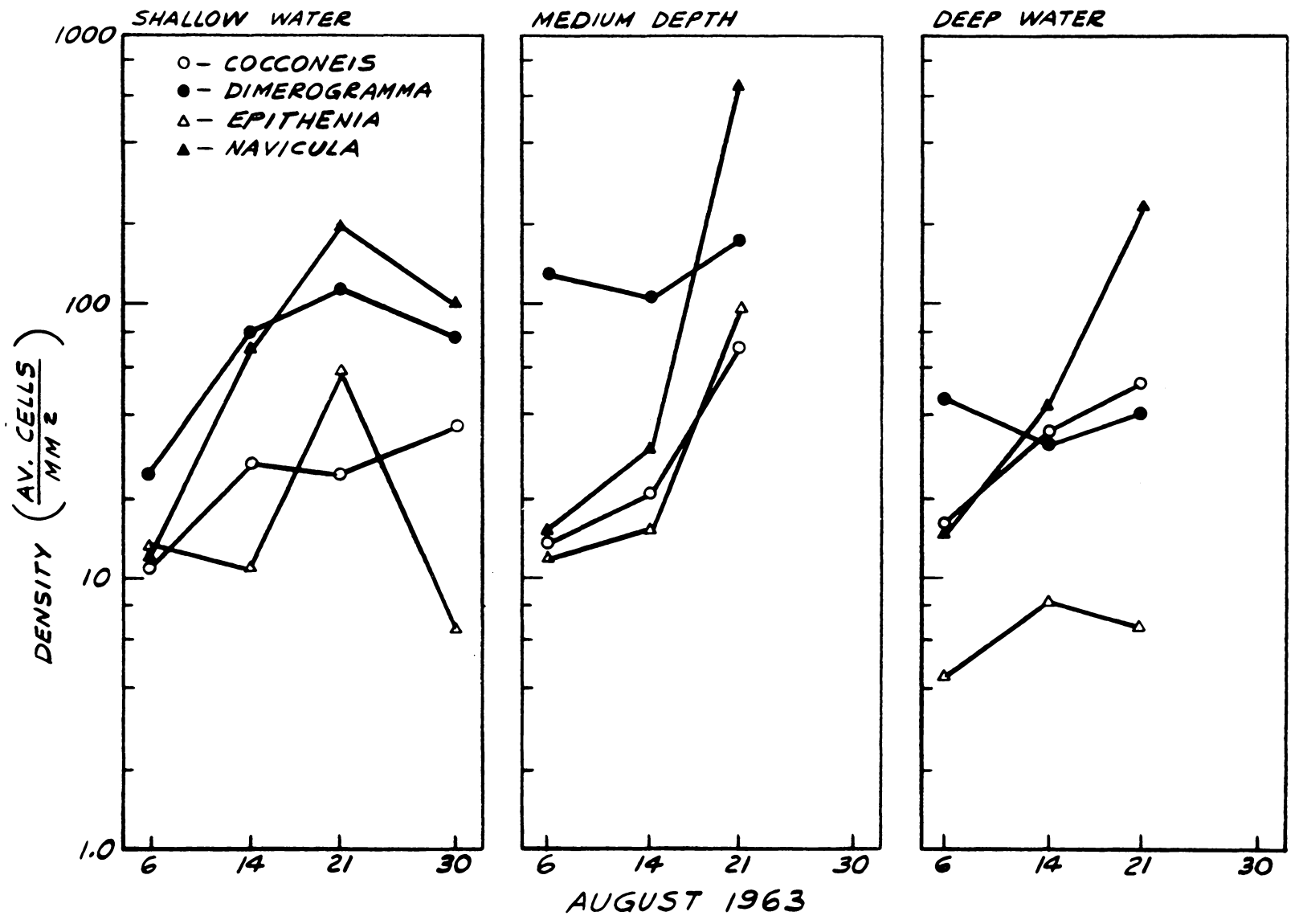
SHALLOW WATER
MEDIUM DEPTH
DEEP WATER
○ – COCCONEIS
● – DIMEROGRAMMA
△ – EPITHENIA
▲ – NAVICULA
1000
100
10
1.0
DENSITY (AV. CELLS / MM²)
6
14
21
30
AUGUST 1963
SAMPLING DATES

FIGURE 6

Figure 7. Shallow water vertical distribution of dominant diatom genera in 1964.

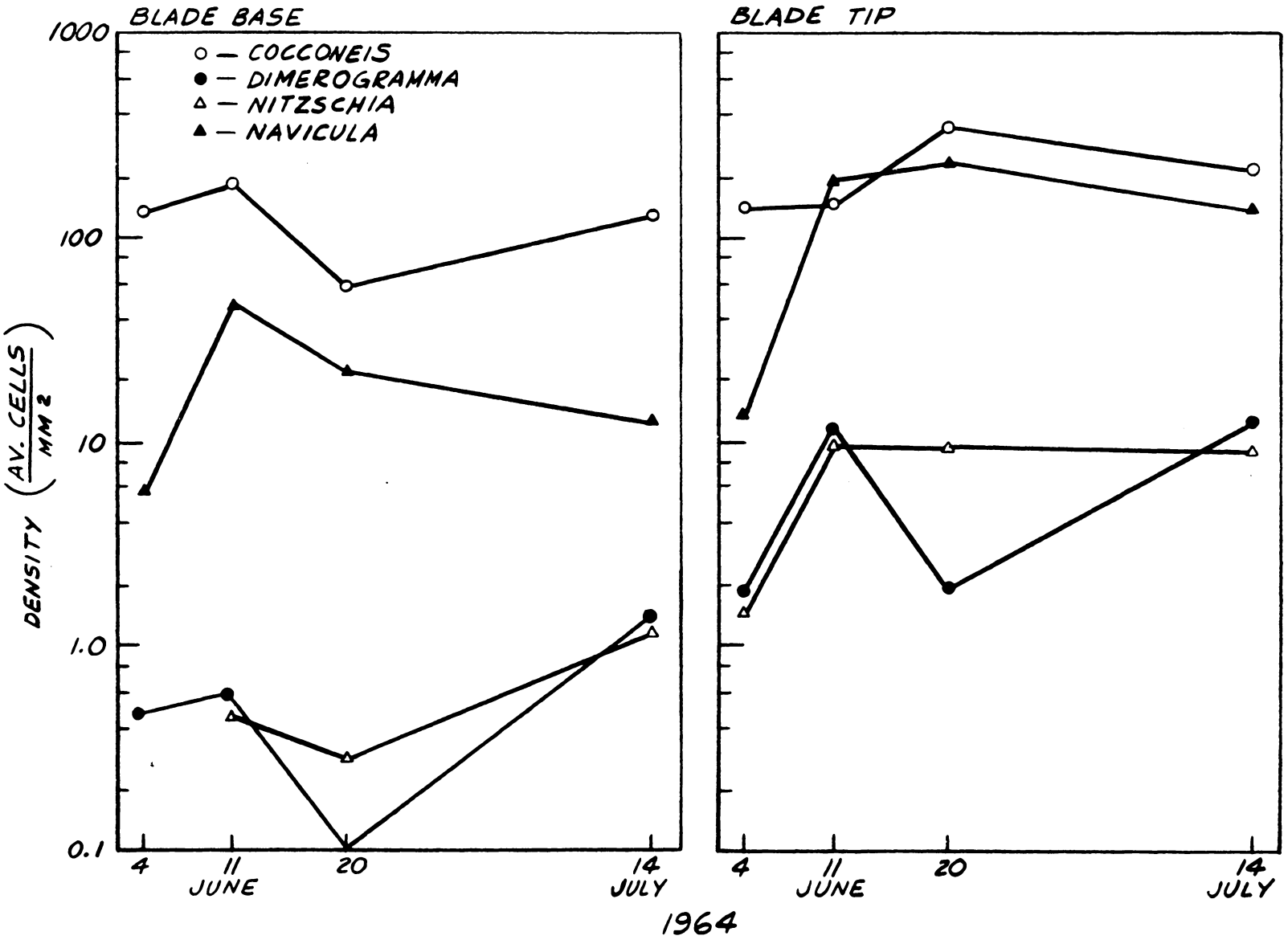
BLADE BASE
BLADE TIP
1000
100
10
1.0
0.1
○ — COCCONEIS
● — DIMEROGRAMMA
△ — NITZSCHIA
▲ — NAVICULA
DENSITY (AV. CELLS / MM²)
4
11
20
14
JUNE
JULY
1964
SAMPLING DATES

FIGURE 7

Figure 8. Deep water vertical distribution of dominant diatom genera in 1964.

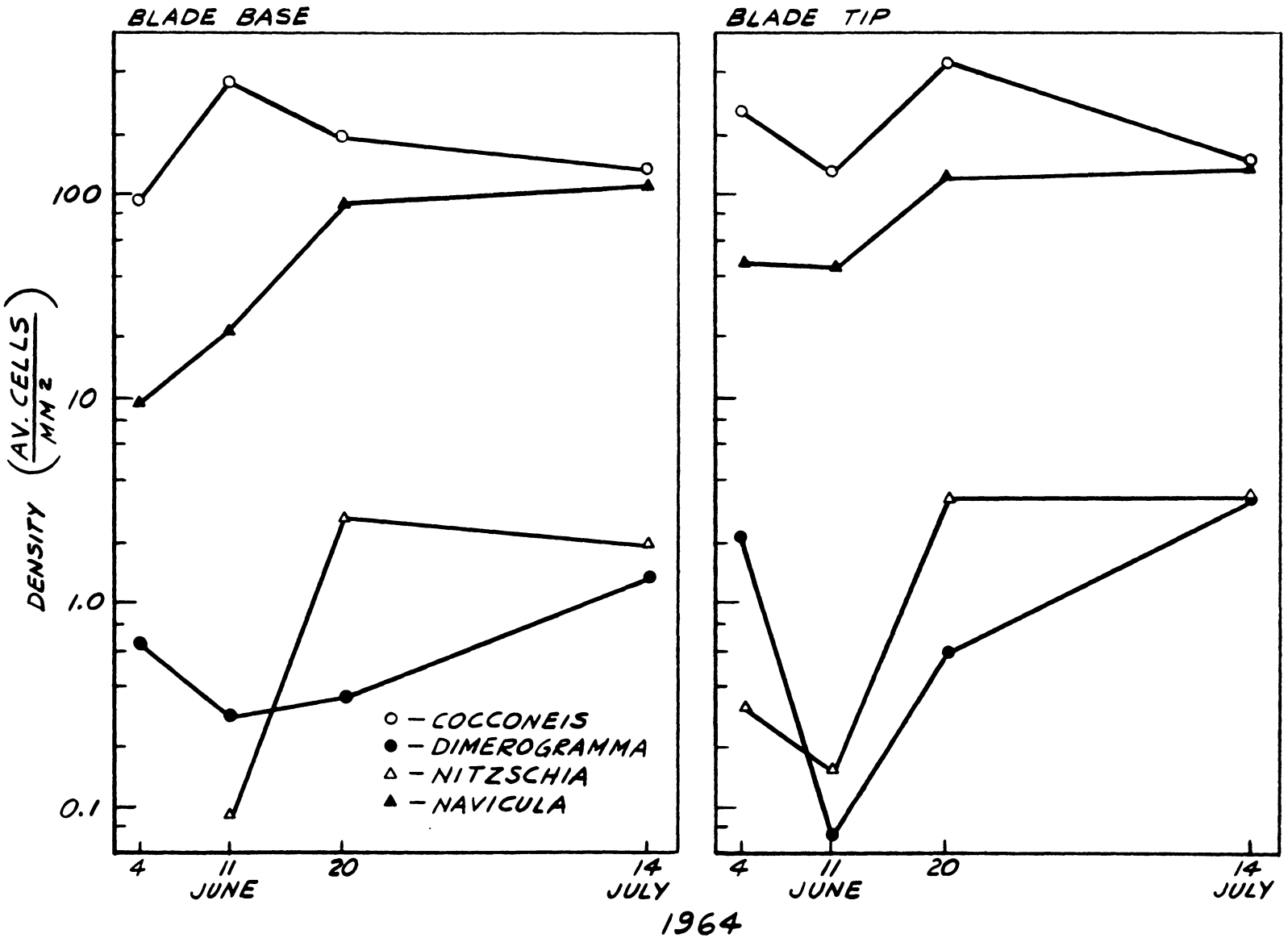
BLADE BASE
BLADE TIP
100
10
1.0
0.1
DENSITY (AV. CELLS / MM²)
○ – COCCONEIS
● – DIMEROGRAMMA
△ – NITZSCHIA
▲ – NAVICULA
4
11
20
14
JUNE
JULY
1964
SAMPLING DATES

FIGURE 8

tip, a condition which was not prevalent in 1963. Dimerogramma and Nitzschia again did not exhibit significant population numbers. There was, however, a general density increase from blade base to tip as shown in 1963.

Horizontal Distribution

Blade base

Fluctuations in density at the blade base in 1964 demonstrated a density increase between shallow and deep water (Figure 9). The population fluctuations with time and depth did not follow the same pattern for the majority of sampling dates.

Blade tip

A distributional comparison at the blade tip for 1964 (Figure 10) showed the highest peak density for deep water, but there was not a general increase in density from shallow to deep water. The two predominant genera showed some similarity in the direction of population fluctuation between sampling dates in both shallow and deep water. As in previous results for 1964, values for Dimerogramma and Nitzschia were considered to be of little significance due to low density values.

Figure 9. Horizontal distribution of dominant diatom genera at the blade base in 1964.

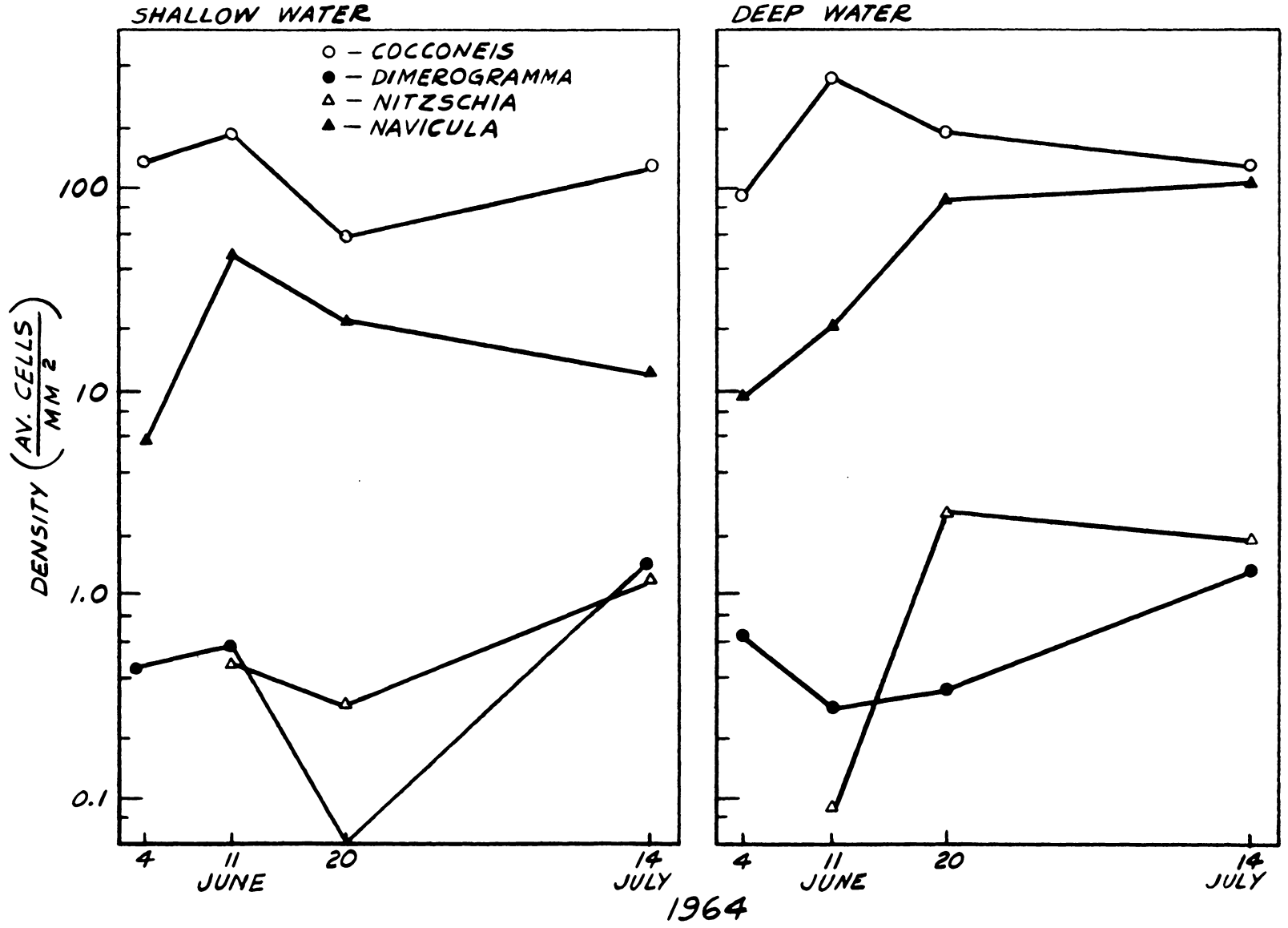
SHALLOW WATER
DEEP WATER
○ – COCCONEIS
● – DIMEROGRAMMA
△ – NITZSCHIA
▲ – NAVICULA
100
10
1.0
0.1
DENSITY (AV. CELLS / MM 2)
4
11
20
14
JUNE
JULY
1964
SAMPLING DATES

FIGURE 9

Figure 10. Horizontal distribution of dominant diatom genera at the blade tip in 1964.

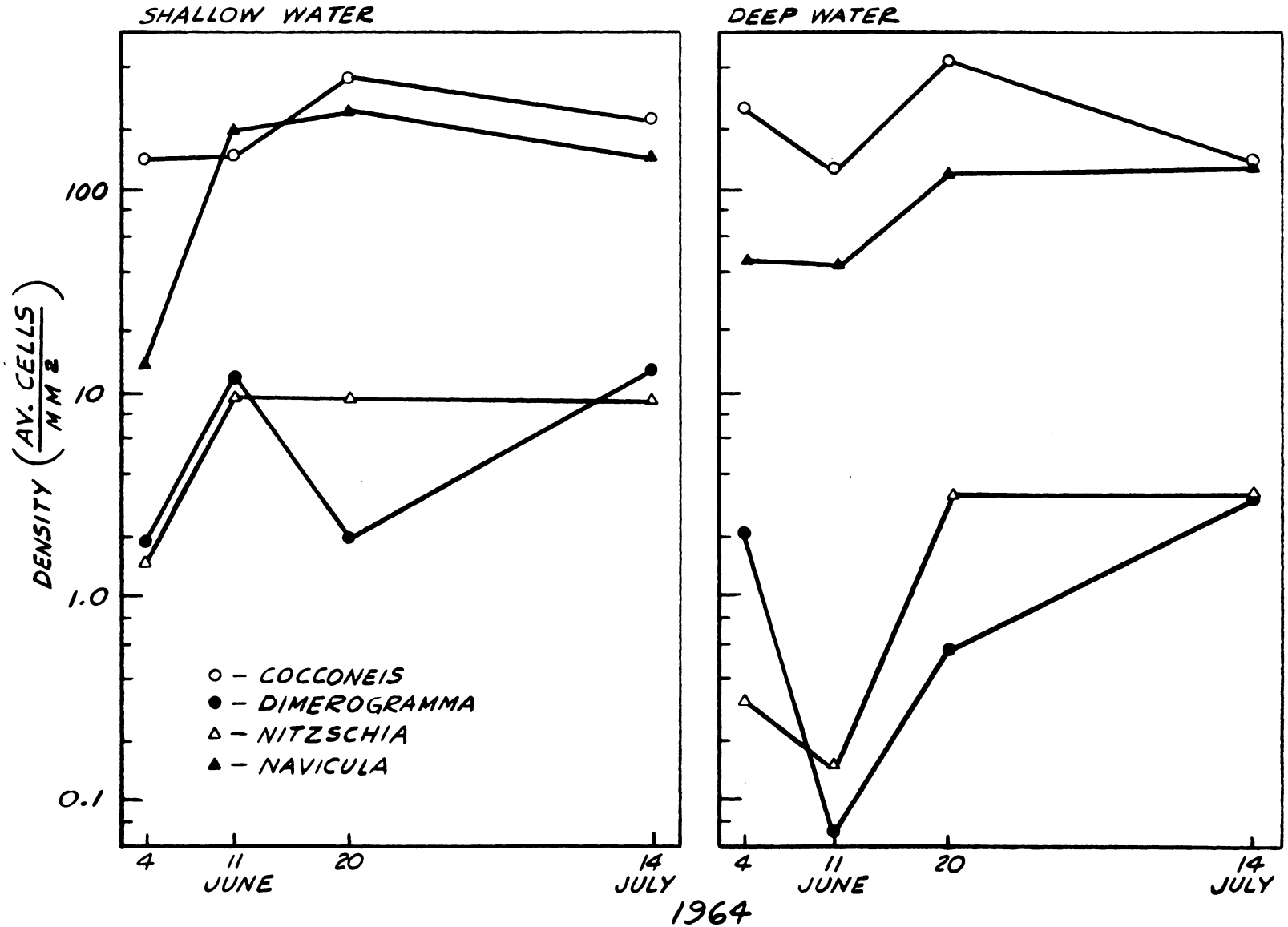
SHALLOW WATER
DEEP WATER
DENSITY (AV. CELLS / MM²)
100
10
1.0
0.1
○ – COCCONEIS
● – DIMEROGRAMMA
△ – NITZSCHIA
▲ – NAVICULA
4
11
20
14
JUNE
JULY
1964
SAMPLING DATES

FIGURE 10

DISCUSSION

Previous studies of marine diatom communities indicated that littoral forms did not follow the course of seasonal occurrence usually found in planktonic species but formed a relatively stable annual population (Hendey, 1951; Smyth, 1955).

The diatoms for this study were collected from the erect portions of eel grass. Since these erect portions are annuals, there is no possibility of a part of the diatom population existing on the plants over the winter. In the Gloucester Point area, the eel grass had completed its yearly growth by mid-April, and the erect stems were dead or dying (Setchell, 1929). Therefore, all leaf portions had been adequately exposed for diatom colonization and that source of error was not considered.

As pointed out by Patrick (1948), the factors governing occurrence of organisms in fresh water may depend on conditions which vary greatly from those in the marine environment. Certain generalizations can be made between fresh water and marine populations but all comparisons cannot be accepted as valid.

The majority of marine work has been concerned with succession and a qualitative assay of diatom genera present. This study differed from most in two major aspects: (1) the diatom population in question was epiphytic, whereas the majority of non-planktonic diatom studies have involved littoral or benthic forms. (2) this work was an attempt to show a fluctuation with respect to variations

in horizontal and vertical distribution, and to indicate seasonal periodicity.

Yearly Distribution Comparisons

Although graphs showing the yearly horizontal and vertical distributional patterns indicate possible periodicity, the graphs incorporating both the 1963 and 1964 samples (Figures 11 - 14) aid in this determination. These graphs allow the direct comparison of all sampling dates for each water depth and collecting position on the blade for the three major genera found in both years. The point should again be made that the densities for 1964 were greater than 1963. A linear scale made interpretation between 1 and 10 cells/ mm^2 difficult. Thus, in order to clearly follow the data and allow a better comparison of the two years, the data are presented on a logarithmic scale.

Nitzschia and Epithemia are omitted from the comparison graphs. Nitzschia occupied the fourth position in terms of average density in 1964, and Epithemia occupied this position in 1963. Therefore, no comparison could be made for either genus which would encompass both the 1963 and 1964 samples.

Vertical Comparisons

There was an increase in the average number of organisms present from blade base to blade tip in both 1963 and 1964. Shallow water comparisons (Figure 11) indicate an increase in total numbers

Figure 11. Shallow water vertical comparisons of dominant diatom genera for 1963 and 1964.

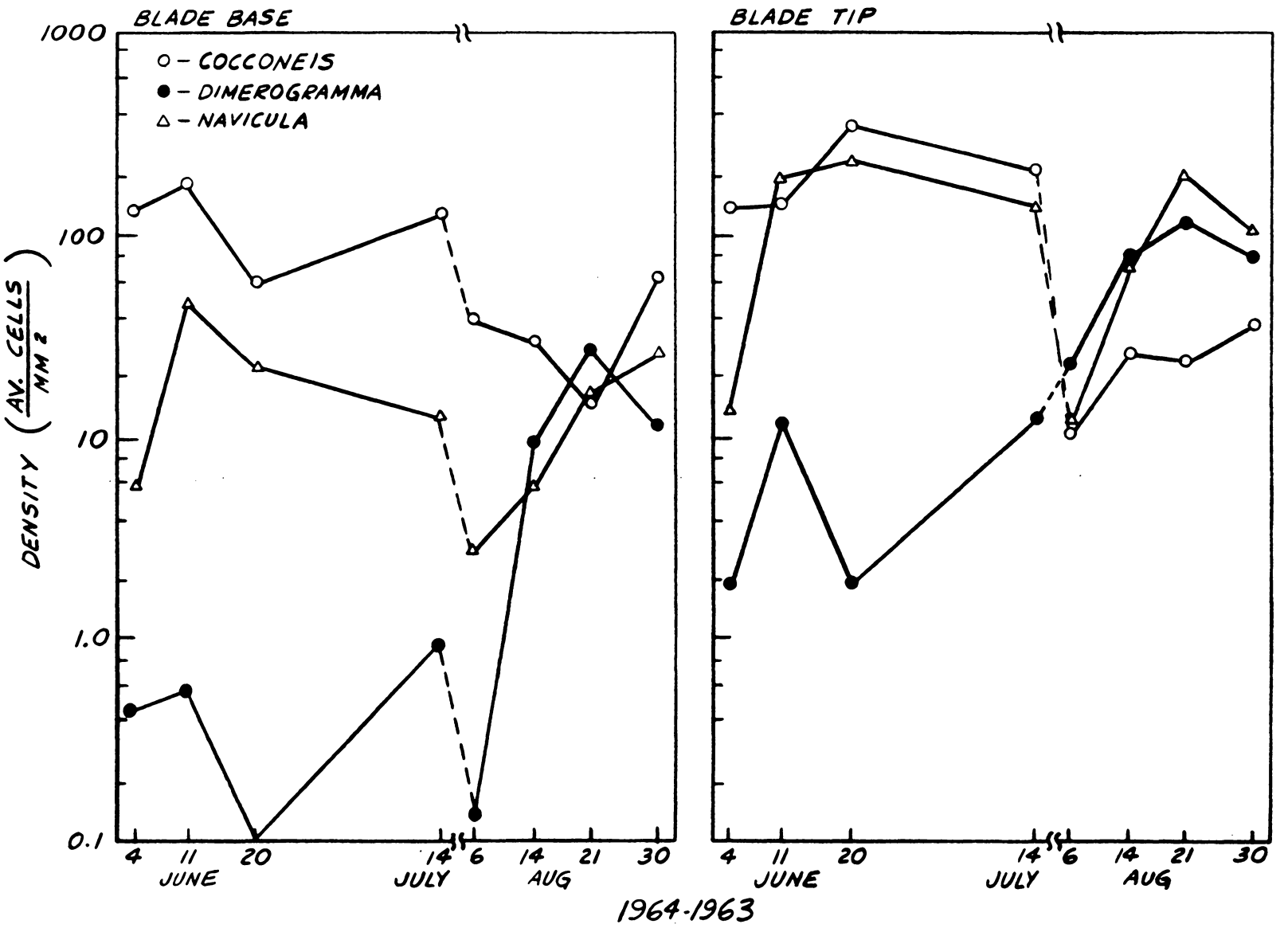
BLADE BASE
BLADE TIP
1000
100
10
1.0
0.1
○ – COCCONEIS
● – DIMEROGRAMMA
△ – NAVICULA
DENSITY (AV. CELLS / MM²)
4 11 20 14 6 14 21 30
JUNE JULY AUG
1964-1963
SAMPLING DATES

FIGURE 11

from blade base to blade tip. Cocconeis was the predominant genus at the base in both years. Navicula alone occupied the secondary position in 1964, whereas Navicula and Dimerogramma shared this position in 1963. Navicula and Dimerogramma predominated at the blade tip in 1963, a position occupied by Cocconeis and Navicula in 1964. The overall population of diatoms in 1964 was greater in shallow water at both the blade base and blade tip than in 1963. This difference was attributable to the fact that conditions in the aquatic environment often differ from one year to the next. Deep water vertical comparisons (Figure 12) add evidence in support of a distributional pattern. Cocconeis and Navicula were also dominant at the tip in 1964, but three genera occupied dominance positions at the blade tip in 1963. The greatest average density occurred at the blade tip in both 1963 and 1964.

Horizontal Comparisons

A horizontal comparison of blade bases in shallow water for 1963 and 1964 (Figure 13) indicated that Cocconeis was the predominant form, and Dimerogramma occupied the dominant position on a single date in 1963. Cocconeis and Navicula occupied the dominant positions in deep water. In both 1963 and 1964, there was little evidence of horizontal distribution in terms of genera present. Cocconeis and Navicula continued to predominate and Dimerogramma showed a significant increase in August.

Figure 12. Deep water vertical comparisons of dominant diatom genera for 1963 and 1964.

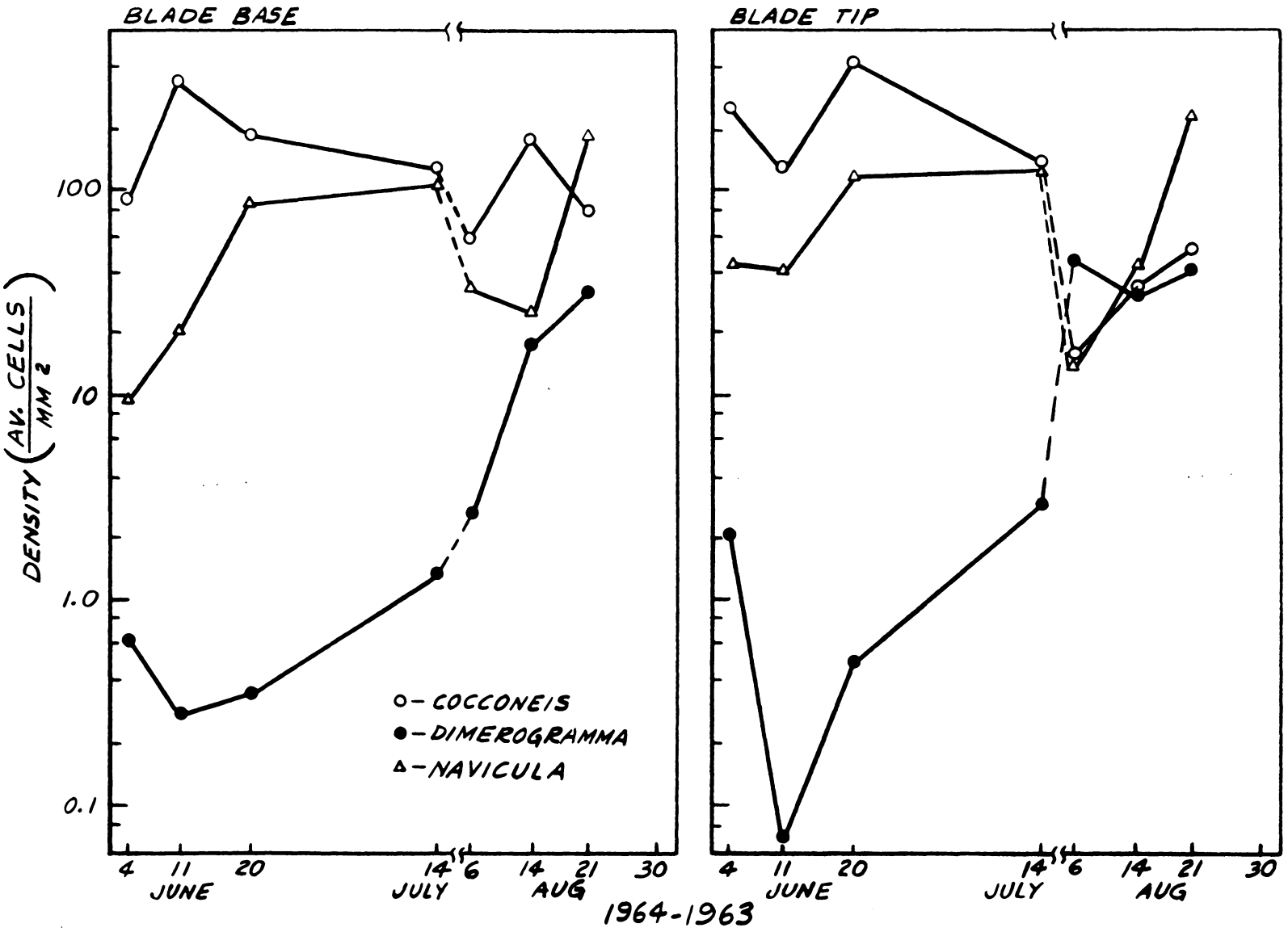
BLADE BASE
BLADE TIP
DENSITY (AV. CELLS / MM²)
100
10
1.0
0.1
○ - COCCONEIS
● - DIMEROGRAMMA
△ - NAVICULA
4 11 20 14 6 14 21 30
JUNE JULY AUG
1964-1963
SAMPLING DATES

FIGURE 12

Figure 13. Horizontal comparisons of dominant diatom genera at base of blade for 1963 and 1964.

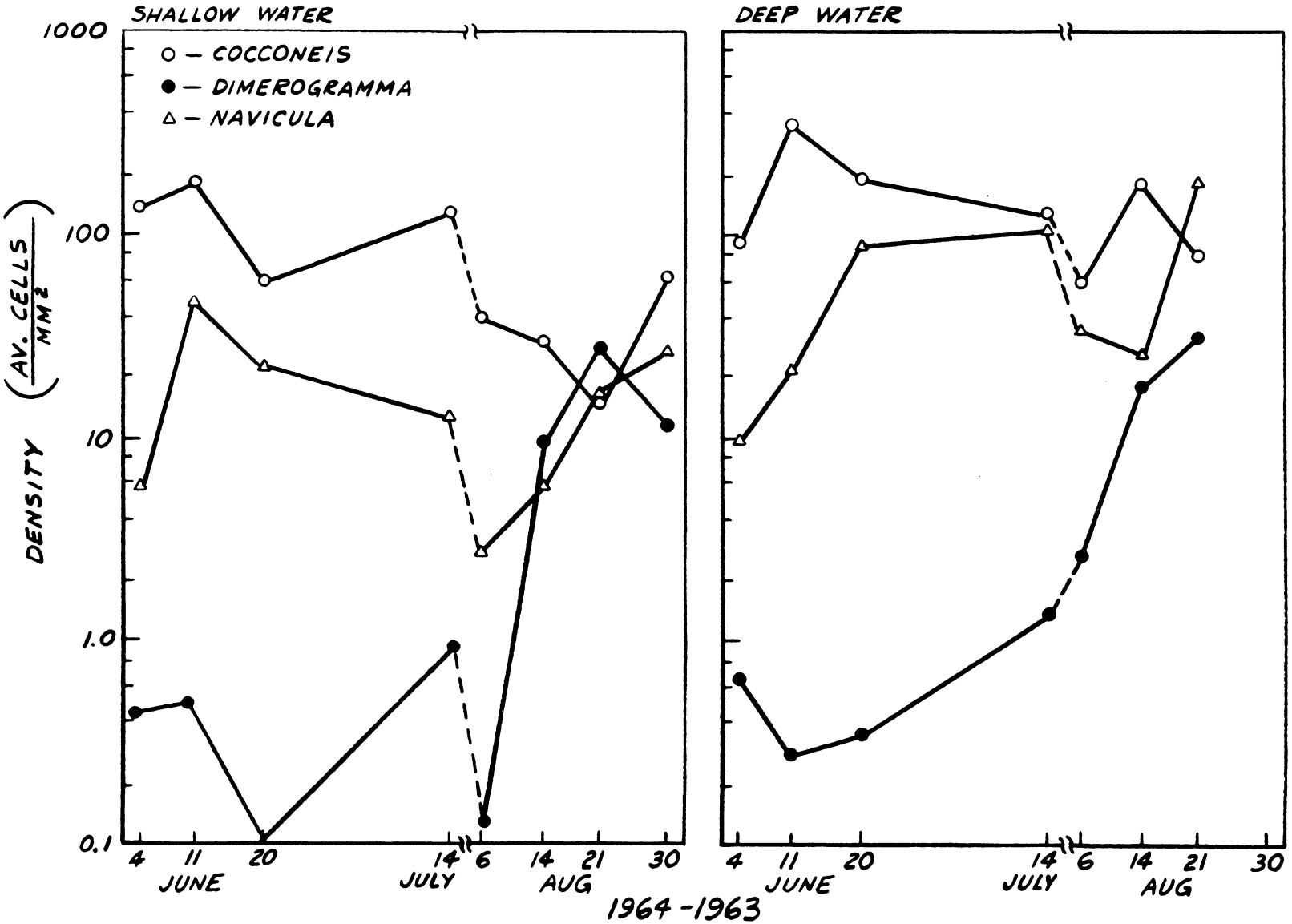
SHALLOW WATER
DEEP WATER
○ — COCCONEIS
● — DIMEROGRAMMA
△ — NAVICULA
DENSITY (AV. CELLS / MM²)
1000
100
10
1.0
0.1
4 11 20 14 6 14 21 30
JUNE JULY AUG
1964 - 1963
SAMPLING DATES

FIGURE 13

A comparison of the blade tips for 1963 and 1964 (Figure 14) did not permit a definite conclusion to be made. Dimerogramma was not a major component at the blade base in either shallow or deep water in June or July. In August, however, all three genera were comparable at relatively high average densities; and Dimerogramma was dominant at the base in shallow water on August 21. The variation in total number of organisms at the tip between shallow and deep water samples in both years showed the single peak density to be in deep water, but this was not of great enough significance to show a definite horizontal distribution.

General Discussion

Two trends were evident in both the shallow and deep water vertical and horizontal comparisons (Figures 11 - 14). The first was exhibited by Cocconeis and Navicula. These two genera maintained a relatively high average density for both the 1963 and 1964 sampling periods. A pattern similar to that observed for Cocconeis and Navicula in the present study was also observed by Smyth (1955). In working with marine benthic diatoms, he found a rise of diatom numbers in February and April, followed by a fairly steady high summer population. The diatom population showed another rise in August and finally a slow decrease to the winter level. Cannon et al (1961), in working with Tabellaria flocculosa var. flocculosa, also found that the diatoms increased from mid-April until early June and then maintained a population through the summer which never dropped below

Figure 14. Horizontal comparisons of dominant diatom genera at tip of blade for 1963 and 1964.

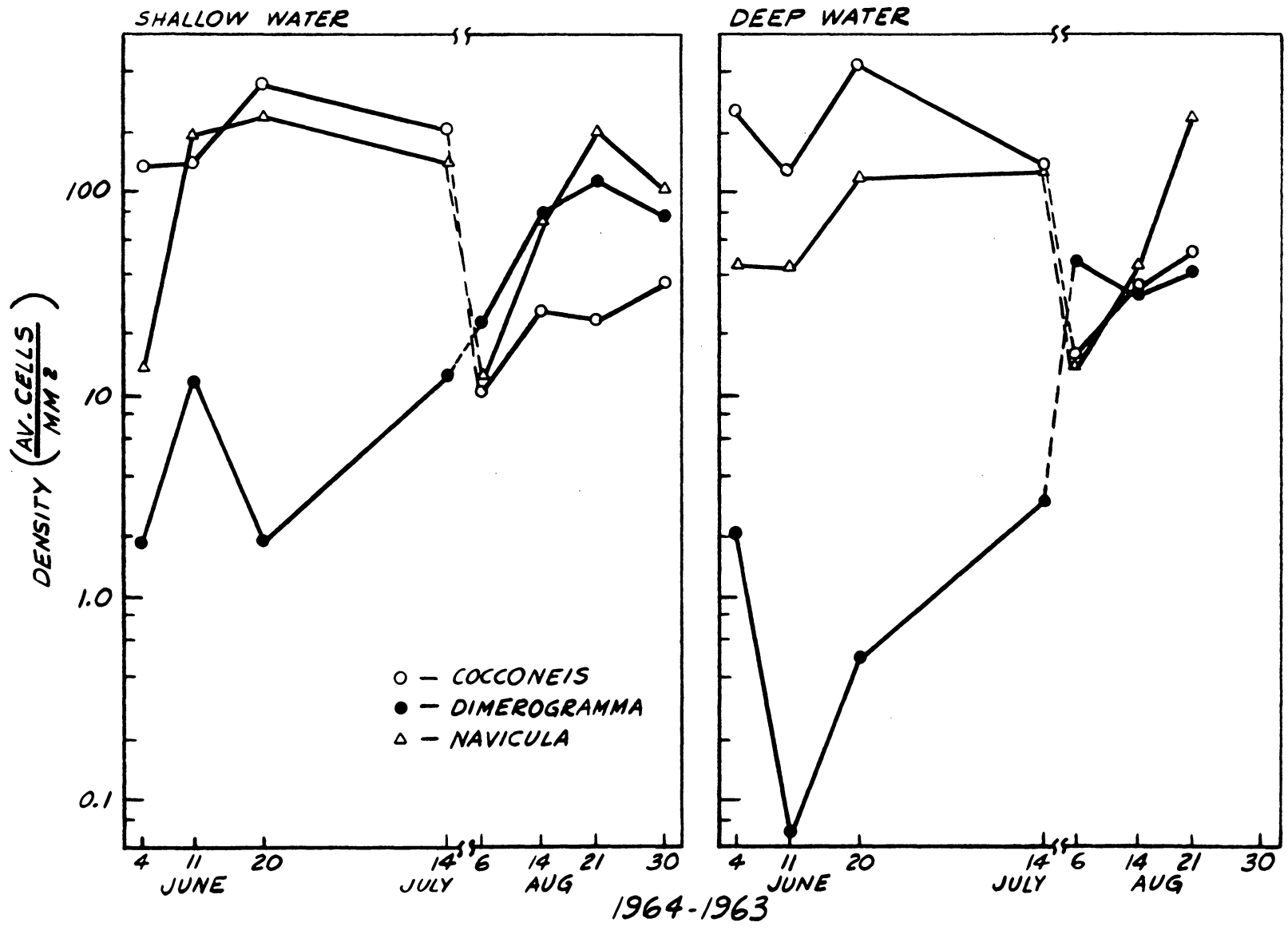
SHALLOW WATER
DEEP WATER
DENSITY (AV. CELLS / MM²)
100
10
1.0
0.1
○ — COCCONEIS
● — DIMEROGRAMMA
△ — NAVICULA
4
11
20
14
6
14
21
30
JUNE
JULY
AUG
1964-1963
SAMPLING DATES

FIGURE 14

5.9 cell divisions per week. Dimerogramma, however, showed a much lower average density in June and July and reached a more comparable average density in August. Further study of the graphs allowed at least two interpretations of the behavior of Dimerogramma. It is possible that Dimerogramma had reached a spring maximum considerably before the June sampling period and declined to a low average density. In August, Dimerogramma had begun an increase which would result in the fall maximum. Cocconeis and Navicula, on the other hand, probably reached a peak later in the spring and would reach a peak density again at a later fall date than Dimerogramma. Butcher (1940) worked with sessile algae in the River Hull and found that the spring maxima for different diatoms varied from May to early summer. Rao (1955), in work done on diatoms in small ponds, found that the spring maxima varied from March to May or June and the fall maxima from September through November, depending on both diatom species and environmental conditions. A second possibility is that Dimerogramma was not a primary component of the epiphytic diatom community at Gloucester Point and did not reach the maxima exhibited by Cocconeis and Navicula. Both Butcher (1940) and Hendey (1951) found that some members of the diatom community did not exhibit marked periods of greater occurrence.

The fact that Cocconeis and Navicula maintained a relatively high density as compared to Dimerogramma could be due to several factors, but selective use of some element in the nutrient pool is the most likely possibility. Round (1953) was able to correlate extended growth periods with silica concentrations, but he stated

that many fluctuations in growth could not be explained in terms of chemical conditions recorded. Rao (1955) found silica, nitrate, and phosphate to be among the most important factors governing periodicity; and Knudson (1961) also correlated diatom growth with nutrient availability. In the graphs for 1963 (Figures 1 - 6), Epithemia showed a pattern similar to that for Dimerogramma. This low density pattern was also exhibited by Nitzschia (Figures 7 - 10) in 1964. The slightly higher average densities at the blade tip were probably more closely related to turbidity than to any other environmental factor. The sample sites were located in shallow water where tide action and wind caused constant mixing.

It is my opinion that this study indicates a distributional pattern for the epiphytic diatoms studied in which the trend is for higher densities at the blade tip than at the blade base. A vertical distributional pattern is more pronounced than one in the horizontal direction.

CONCLUSIONS

The predominant diatoms during the study period showed sufficient fluctuations in population density to illustrate that these populations undergo periods of growth and decline during the summer. Growth fluctuations range from less than 1 cell/mm^2 to approximately 425 cells/mm^2.

A distributional pattern appeared to be present with respect to the epiphytic diatoms on eel grass, Zostera marina L. The vertical comparison showed average growth to be slightly greater at the tip of the blade in both shallow and deep water. The horizontal pattern was more obscure. Cocconeis showed slightly more growth in deep water at the blade base and tip, but Dimerogramma and Navicula did not exhibit this consistency.

Trends were present which indicate that periodicity was present within the diatom community. These trends were represented by several fluctuations during the study. Two growth patterns were evident which further support periodicity. Cocconeis and Navicula appeared to have reached peaks during or shortly before the June sampling period and continued at relatively high densities throughout the summer. These two organisms probably reached the fall peak during the last of August or first of September. Dimerogramma, on the other hand, exhibited low densities during the sampling period from June through July and appeared to have peaked considerably before the June sampling period. Values for Dimerogramma in August would lead one to suspect that Dimerogramma reached a fall peak comparable to that of

Cocconeis and Navicula but at an earlier date.

One might speculate that the growth patterns of the diatoms represented in this study might also be found among other epiphytic genera and species on other substrata at other times and places. Static communities as well as stable population levels are seldom, if never, found in a dynamic ecosystem.

SUMMARY

A study of diatoms epiphytic on eel grass, Zostera marina L. was conducted at the Virginia Institute of Marine Science at Gloucester Point, Virginia.

Samples were collected in August 1963 and June and July 1964. The horizontal and vertical distributional patterns, distribution on a seasonal basis, and periodicity of occurrence were studied. Diatom samples were collected at the base, midpoint, and tip of the eel grass. Sample areas were at 1, 3, and 5 foot depths at mean low water. Vertical distribution was studied by comparing fluctuations in genera and total number (density) between blade base and blade tip.

The results indicated that a distributional pattern was present with respect to total numbers of organisms. This pattern was more pronounced in the vertical than in the horizontal direction. Vertical comparisons (Figures 11 - 12) indicate higher population densities at the blade tip than at the blade base. Horizontal comparisons did not, however, indicate as distinct a pattern with respect to differences in density.

Fluctuations in the diatom population during 1963 and 1964 were of sufficient magnitude to suggest seasonal periodicity. Two trends were present in the data. The first trend was exhibited by Cocconeis and Navicula. These two organisms appeared at a relatively high average density throughout June and July and showed some decrease

in August. The second trend showed that Dimerogramma, Epithemia, and Nitzschia, however, exhibited rather low densities in June and July and increased to a density level comparable with that of Cocconeis and Navicula in August. This suggested that these two groups of organisms varied in environmental requirements, and reached peak densities or "pulses" at slightly different times during the growth period.

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Appendix I. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water* at Gloucester Point, Virginia, on August 6, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	7.5	452.4	4.5	43.4	2603.4	26.0	18.9	1131.6	9.1
Dimerogramma							26.4	1584.6	12.7
Diploneis	1.9	112.8	1.1	1.9	112.8	1.1			
Epithemia							5.7	339.6	2.7
Melosira							1.9	112.8	0.9
Navicula	1.9	112.8	1.1				11.3	679.2	5.4
Blade No. 2									
Cocconeis	109.4	6565.8	43.8	1.9	112.8	0.8	32.1	1924.2	12.8
Navicula	9.4	565.8	3.8	1.9	112.8	0.8	45.3	2716.8	18.1
Nitzschia	1.9	112.8	0.8						
Blade No. 3									
Cocconeis	69.8	4188.6	27.9	7.5	452.4	3.0	20.8	1245.0	8.3
Dimerogramma									
Diploneis	1.9	112.8	0.8						
Epithemia	1.9	112.8	0.8	1.9	112.8	0.8	103.8	6226.2	41.5
Licmophora	1.9	112.8	0.8						
Melosira							1.9	112.8	0.8
Navicula	5.7	339.6	2.3	3.8	226.2	1.5	35.8	2150.4	14.3

Appendix I. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 4									
Amphora							1.9	112.8	0.8
Cocconeis	203.8	12,226.2	81.5	41.5	2490.0	16.6	30.2	1810.8	12.1
Coscinodiscus							3.8	226.2	1.5
Diatoma				49.1	2943.0	19.6	71.7	4301.4	28.7
Dimerogramma							113.2	6792.0	45.3
Epithemia				92.5	5546.0	37.0	20.8	1245.0	8.3
Grammatophora	5.7	339.6	2.3						
Melosira				1.9	112.8	0.8	1.9	112.8	0.8
Navicula	9.4	565.8	3.8	79.2	4754.4	31.7	28.3	1698.0	11.3
Nitzschia	1.9	112.8	0.8						
Tropodoneis				1.9	112.8	0.8			

*1 foot mean low water.

Appendix II. Distribution of Epiphytic Diatoms on Eelgrass in Medium Depth Water* at Gloucester Point, Virginia, on August 6, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	56.6	3396.0	38.8	66.0	3961.8	26.4	7.5	452.4	3.0
Cymbella							1.9	112.8	0.8
Dimerogramma	15.1	905.4	5.2	18.9	1131.6	7.5	34.0	2037.6	13.3
Epithemia							20.8	1245.0	8.3
Melosira				1.9	112.8	0.8			
Navicula	15.1	905.4	5.2	17.0	1018.8	6.8	11.3	679.2	4.5
Blade No. 2									
Cocconeis	34.0	2037.6	11.6	20.8	1245.0	7.1	35.8	2150.4	12.3
Cymbella							7.5	452.4	2.6
Dimerogramma				50.9	3056.4	17.5	452.8	27,169.8	155.2
Epithemia	3.8	226.2	1.3	75.5	4528.2	25.9	34.0	2037.6	11.6
Navicula	7.5	452.4	2.6	22.6	1358.4	7.8	28.3	1698.0	9.7
Nitzschia	1.9	112.8	0.6	1.9	112.8	0.6			
Blade No. 3									
Cocconeis	58.5	3509.4	20.0	15.1	905.4	5.2	52.8	3169.8	18.1
Cymbella							3.8	226.2	1.3
Dimerogramma	11.3	679.2	3.9	20.8	1245.0	7.1	464.2	27,849.0	159.1

Appendix II. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3 concluded									
Diploneis							3.8	226.2	1.3
Epithemia				9.4	565.8	3.2	56.6	3396.0	19.4
Melosira				1.9	112.8	0.6			
Navicula	22.6	1358.4	7.8	18.9	1131.6	6.5	56.6	3396.0	19.4
Blade No. 4									
Amphiprora				9.4	565.8	3.2			
Cocconeis	5.7	339.6	1.9	34.0	2037.6	11.6	47.2	2829.6	16.2
Cymbella				11.3	679.2	3.9	3.8	226.2	1.3
Dimerogramma	7.5	452.4	2.6	158.6	9509.4	54.3	566.0	33,961.8	194.1
Epithemia				54.7	3282.6	18.8	30.2	1810.8	10.3
Grammatophora				7.5	452.4	2.6			
Melosira				7.5	452.4	2.6			
Navicula	5.7	339.6	1.9	56.6	3396.0	19.4	75.5	4528.2	25.9
Nitzschia							1.9	112.8	0.6

*3 feet mean low water.

Appendix III. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester Point, Virginia, on August 6, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	64.2	3849.0	19.2	145.3	8716.8	43.6	37.7	2263.8	12.9
Cymbella							1.9	112.8	0.6
Dimerogramma				56.6	3396.0	17.0	192.5	11,547.0	66.0
Diploneis	3.8	226.2	1.1						
Epithemia				13.2	792.0	4.0	11.3	679.2	3.9
Melosira				3.8	226.2	1.1			
Navicula	15.1	905.4	4.5	134.0	8037.6	40.2	37.7	2263.8	12.9
Blade No. 2									
Cocconeis	109.4	6565.8	37.5	20.8	1245.0	8.3	45.3	2716.8	18.1
Cymbella	7.5	452.4	2.6						
Dimerogramma							37.7	2263.8	15.1
Epithemia	1.9	112.8	0.6				9.4	565.8	3.8
Melosira	1.9	112.8	0.6						
Navicula	49.1	2943.0	16.8	39.6	2377.2	15.8	39.6	2377.2	15.8
Nitzschia							3.8	226.2	1.5

Appendix III. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3									
Cocconeis	162.3	9735.6	48.7	130.2	7810.8	39.1	52.8	3169.8	18.1
Dimerogramma	9.4	565.8	2.8	30.2	1810.8	9.1	303.8	18,226.2	104.1
Epithemia				41.5	2490.0	12.5	28.3	1698.0	9.7
Melosira	1.9	112.8	0.6						
Navicula	84.9	5094.0	25.5	156.6	9396.0	47.0	81.1	4867.8	27.8
Nitzschia	3.8	226.2	1.1	9.4	565.8	2.8	3.8	226.2	1.3
Tropodoneis				1.9	112.8	0.6			
Blade No. 4									
Cocconeis	286.8	17,207.4	98.3	98.1	5886.6	39.2	34.0	2037.6	13.6
Dimerogramma	22.6	1358.4	7.8						
Diploneis	7.5	452.4	2.6						
Melosira	18.9	1131.6	6.5						
Navicula	249.0	14,943.0	85.4	24.5	1471.2	9.8	7.5	452.4	3.0
Nitzschia	22.6	1358.4	7.8						
Pinnularia	3.8	226.2	1.3						

*5 feet mean low water.

Appendix IV. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water* at Gloucester Point, Virginia, August 14, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Amphiprora							1.9	112.8	0.6
Cocconeis	96.2	5773.2	33.0	58.5	3509.4	20.1	75.5	4528.2	25.9
Cymbella				3.8	226.2	1.3	7.5	452.4	2.6
Dimerogramma	3.8	226.2	1.3	379.2	22,754.4	130.0	388.7	23,320.2	133.3
Epithemia				130.2	7810.8	44.6	75.5	4528.2	25.9
Melosira	1.9	112.8	0.6	1.9	112.8	0.6	3.8	226.2	1.3
Navicula	17.0	1018.8	5.8	86.8	5207.4	29.8	84.9	5094.0	29.1
Nitzschia				5.7	339.6	1.9	9.4	565.8	3.2
Blade No. 2									
Cocconeis	169.8	10,188.6	58.2	60.4	3622.2	20.7	34.0	2037.6	13.6
Dimerogramma	7.5	452.4	2.6	94.3	5659.8	32.3	120.8	7245.0	48.3
Epithemia	1.9	112.8	0.6	7.5	452.4	2.6	17.0	1018.8	6.8
Grammatophora							1.9	112.8	0.8
Melosira							3.8	226.2	1.5
Navicula	11.3	679.2	3.9	18.9	1131.6	6.5	20.8	1245.0	8.3
Nitzschia				1.9	112.8	0.6			
Blade No. 3									
Cocconeis	18.9	1131.6	6.5	34.0	2037.6	11.6	64.2	3849.0	22.2
Cymbella	3.8	226.2	1.3	13.2	792.0	4.5	5.7	339.6	1.9

Appendix IV. Concluded

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3 continued									
Dimerogramma	54.7	3282.6	18.8	154.7	9282.6	53.0	252.8	15,169.8	86.7
Epithemia	3.8	226.2	1.3	18.9	1131.6	6.5	22.6	1358.4	7.8
Grammatophora				3.8	226.2	1.3	1.9	112.8	0.6
Licmophora							1.9	112.8	0.6
Melosira	1.9	112.8	0.6	7.5	452.4	2.6	5.7	339.6	1.9
Navicula	18.9	1131.6	6.5	124.5	7471.2	42.7	275.5	16,528.2	94.4
Nitzschia	5.7	339.6	1.9	3.8	226.2	1.3	5.7	339.6	1.9
Blade No. 4									
Cocconeis	50.9	3056.4	24.5	24.5	1471.2	11.8	88.7	5320.2	42.6
Cymbella				5.7	339.6	2.7	1.9	112.8	0.9
Dimerogramma	30.2	1810.8	14.5	67.9	4075.2	32.6	103.8	6226.2	49.8
Epithemia	1.9	112.8	0.9	3.8	226.2	1.8	7.5	452.4	3.6
Grammatophora	1.9	112.8	0.9				1.9	112.8	0.9
Melosira							18.9	1131.6	9.1
Navicula	15.1	905.4	7.2	34.0	2037.6	16.3	303.8	18,226.2	145.8
Nitzschia							7.5	452.4	3.6
Tropodoneis							1.9	112.8	0.9

* 1 foot mean low water

Appendix V. Distribution of Epiphytic Diatoms on Eelgrass in Medium Depth Water* at Gloucester Point, Virginia, August 14, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	37.7	2263.8	12.9	26.4	1584.6	9.1	34.0	2037.6	13.6
Cymbella				1.9	112.4	0.6			
Dimerogramma				96.2	5773.2	33.0	220.8	13,245,0	88.3
Epithemia				45.3	2716.8	15.5	26.4	1584.6	10.6
Melosira							3.8	226.2	1.5
Navicula	7.5	452.4	2.6	54.7	3282.6	18.8	67.9	4075.2	27.2
Nitzschia				1.9	112.8	0.6	1.9	112.8	0.8
Blade No. 2									
Cocconeis	79.2	4754.4	31.7	28.3	1698.0	11.3	128.3	7698.0	51.3
Cymbella							3.8	226.2	1.5
Dimerogramma	1.9	112.8	0.8	62.3	3735.6	24.9	679.2	40,754.4	271.7
Epithemia							113.2	6792.0	45.3
Melosira							7.5	452.4	3.0
Navicula	3.8	226.2	1.5	13.2	792.0	5.3	117.0	7018.8	46.8
Nitzschia							11.3	679.0	4.5

Appendix V. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3									
Cocconeis	92.5	5547.0	31.7	64.2	3849.0	25.7	35.8	2150.4	14.3
Cymbella							9.4	565.8	3.8
Dimerogramma	18.9	1131.6	6.5	139.6	8377.2	55.8	66.0	3961.8	26.4
Epithemia				7.5	452.4	3.0	11.3	679.2	4.5
Grammatophora				1.9	112.8	0.8			
Melosira	1.9	112.8	0.6				3.8	226.2	1.5
Navicula	9.4	565.8	3.2	56.6	3396.0	22.6	60.4	3622.2	24.1
Nitzschia				7.5	452.4	3.0	3.8	226.2	1.5
Blade No. 4									
Cocconeis	34.0	2037.6	13.6	84.9	5094.0	34.0	105.7	6339.6	42.3
Cymbella				3.8	226.2	1.5	3.8	226.2	1.5
Dimerogramma	17.0	1018.8	6.8	81.1	4867.8	32.5	107.5	6452.4	43.0
Epithemia				9.4	565.8	3.8	7.5	452.4	3.0
Melosira				1.9	112.8	0.8	1.9	112.8	0.8
Navicula	1.9	112.8	0.8	52.8	3169.9	21.1	58.5	3509.4	23.4
Nitzschia				9.4	565.8	3.8	1.9	112.8	0.8

* 3 feet mean low water.

Appendix VI. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester Point, Virginia, August 14, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	252.8	15,169.8	101.1	622.6	37,358.4	186.8	90.6	5433.6	27.2
Cymbella				47.2	2829.6	14.1	13.2	792.0	4.0
Dimerogramma	15.1	905.4	6.0	226.4	13,584.6	67.9	128.3	7698.0	38.5
Epithemia				1.9	112.8	0.6	22.6	1358.4	6.8
Melosira				1.9	112.8	0.6	1.9	112.8	0.6
Navicula	22.6	1358.4	9.1	1243.4	74,603.4	373.0	262.3	15,735.6	78.7
Nitzschia				64.2	3849.0	19.2	15.1	905.4	4.5
Blade No. 2									
Cocconeis	526.4	31,584.6	210.6	113.2	6792.0	38.8	103.8	6226.2	31.1
Cymbella	5.7	339.6	2.3	15.1	905.4	5.2	24.5	1471.2	7.4
Dimerogramma	79.2	4754.4	31.7	101.9	6112.8	34.9	52.8	3169.8	15.8
Epithemia				60.4	3622.2	20.7	15.1	905.4	4.5
Melosira				7.5	452.4	2.6			
Navicula	52.8	3169.8	21.1	86.8	5207.4	29.8	152.8	9169.8	45.8
Nitzschia	1.9	112.8	0.8	3.8	226.2	1.3	18.9	1131.6	5.7
Blade No. 3									
Cocconeis	556.6	33,396.0	222.6	66.0	3961.8	22.6	156.6	9396.0	53.7
Cymbella	5.7	339.6	2.3				11.3	679.2	3.9

Appendix VI. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3 continued									
Dimerogramma	60.4	3622.2	24.1	62.3	3735.6	21.3	79.2	4754.4	27.2
Epithemia				15.1	905.4	5.2	3.8	226.2	1.3
Grammatophora							1.9	112.8	0.6
Melosira	3.8	226.2	1.5	7.5	452.4	2.6			
Navicula	126.4	7584.6	50.6	132.1	7924.2	45.3	530.2	1810.8	10.3
Nitzschia				3.8	226.2	1.3	394.3	23,659.8	135.2
Blade No. 4									
Cocconeis	371.7	22,301.4	178.4	77.4	4641.0	30.9	66.0	3961.8	26.4
Cymbella	9.4	565.8	4.5	1.9	112.8	0.8	3.8	226.2	1.5
Dimerogramma	20.8	1245.0	10.0	28.3	1698.0	11.3	118.9	7131.6	47.5
Epithemia	1.9	112.8	0.9				50.9	3056.4	20.4
Grammatophora							1.9	112.8	0.8
Melosira				1.9	112.8	0.8	11.3	679.2	4.5
Navicula	45.3	2716.8	21.7	118.9	7131.6	47.5	100.0	6000.0	40.0
Nitzschia	1.9	112.8	0.9	13.2	792.0	5.3	17.0	1018.8	6.8

* 5 feet mean low water.

Appendix VII. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water* at Gloucester Point, Virginia, August 21, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	20.8	1245.0	8.3	18.9	1131.6	7.5	24.5	1471.2	9.8
Cymbella							3.8	226.2	1.5
Dimerogramma	50.9	3056.4	20.4	130.2	7810.8	52.1	132.1	7924.2	52.8
Epithemia				18.9	1131.6	7.5	54.8	3282.6	21.9
Melosira				1.9	112.8	0.8	3.8	226.2	1.5
Navicula	7.5	452.4	3.0	15.1	905.4	6.0	54.8	3282.6	21.9
Nitzschia	1.9	112.8	0.8	1.9	112.8	0.8	13.2	792.0	5.3
Blade No. 2									
Cocconeis	86.8	5207.4	34.7	60.4	3622.2	24.4	98.1	5886.6	39.2
Cymbella				5.7	339.6	2.3	5.7	339.6	2.3
Dimerogramma	145.2	8716.8	58.1	264.2	15,849.0	105.7	418.9	25,131.6	167.5
Epithemia				109.4	6565.8	43.8	109.6	11,433.6	76.2
Melosira							9.4	565.8	3.8
Navicula	34.0	2037.6	13.6	86.8	5207.4	34.7	300.0	18,000.0	120.0
Nitzschia							13.2	792.0	5.3
Blade No. 3									
Cocconeis	34.0	2037.6	13.6	43.4	2603.4	17.4	49.1	2943.0	23.5
Cymbella							1.9	112.8	0.9
Dimerogramma	79.2	4754.4	31.7	186.8	11,207.4	74.7	260.4	15,622.2	125.0

Appendix VII. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3 continued									
Epithemia	84.9	5094.0	34.0	11.3	679.2	4.5	34.0	2037.6	16.3
Melosira				1.9	112.8	0.8	11.3	679.2	5.4
Navicula	101.9	6112.8	40.8	169.8	10,188.6	67.9	607.5	36,452.4	591.6
Nitzschia							1.9	112.8	0.9
Blade No. 4									
Amphora	1.9	112.8	0.8						
Cocconeis	3.8	226.2	1.5	5.7	339.6	2.3	62.3	3735.6	24.9
Dimerogramma	1.9	112.8	0.8	13.2	792.0	5.3	290.6	17,433.6	116.2
Epithemia	3.8	226.2	1.5				301.9	18,112.8	120.8
Melosira				1.9	112.8	0.8	5.7	339.6	2.3
Navicula	5.7	339.6	2.3	26.4	1584.6	10.6	883.0	52,980.6	353.2
Nitzschia							13.2	792.0	5.3

* 1 foot mean low water.

Appendix VIII. Distribution of Epiphytic Diatoms on Eelgrass in Medium Depth Water* at Gloucester Point, Virginia, August 21, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Cocconeis	5.7	339.6	2.3	205.7	12,339.6	82.3	105.7	6339.6	42.3
Dimerogramma	1.9	112.8	0.8	160.4	9622.2	64.1	375.5	22,528.2	150.2
Epithemia				9.4	565.9	3.8	209.4	12,565.8	83.8
Melosira				3.8	226.2	1.5	9.4	565.8	3.8
Navicula				517.0	31,018.8	206.8	1441.5	86,490.0	576.6
Nitzschia				20.8	1245.0	8.3	18.9	1131.6	7.5
Blade No. 2									
Cocconeis	15.1	905.4	5.2	109.4	6565.8	37.5	352.8	21,151.8	120.9
Dimerogramma	5.7	339.6	1.9	147.2	8829.6	50.5	1094.3	65,659.8	375.2
Epithemia	1.9	112.8	0.6	13.2	792.0	4.5	383.0	22,980.6	131.3
Melosira				5.7	339.6	1.9	5.7	339.6	1.9
Navicula	56.6	3396.0	19.4	881.1	52,867.8	302.1	3452.8	207,169.8	1183.8
Nitzschia				9.4	565.8	3.2	96.2	5773.2	33.0
Blade No. 3									
Amphora							3.8	226.2	1.5
Cocconeis	32.1	1924.2	11.0	169.8	10,188.6	58.2	100.0	6000.0	40.0
Dimerogramma	96.2	5773.2	33.0	352.8	21,169.8	121.0	194.3	11,659.9	77.7
Epithemia				328.3	19,698.0	112.6	62.3	3735.6	24.9

Appendix VIII. Concluded

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3 continued									
Melosira				7.5	452.4	2.6	17.0	1018.8	6.8
Navicula	222.6	13,358.4	76.3	1673.6	100,414.8	573.8	1377.4	82,641.0	55.1
Nitzschia	3.8	226.2	1.3	79.2	4754.4	27.2	50.9	3056.4	20.4
Blade No. 4									
Cocconeis	109.4	6565.8	32.8	192.5	11,547.0	66.0	232.1	13,924.2	79.6
Dimerogramma	49.0	2943.0	14.7	100.0	6000.0	34.3	303.8	18,226.2	104.1
Epithemia				32.1	1924.2	12.0	456.6	27,396.0	156.5
Melosira							3.8	226.2	1.3
Navicula	266.0	15,961.8	79.8	1158.5	69,509.4	397.2	2118.9	127,131.6	726.5
Nitzschia				7.5	452.4	2.6	34.0	2037.6	11.6

* 3 feet mean low water

Appendix IX. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester Point, Virginia, August 21, 1963

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1									
Amphora				5.7	339.6	1.9			
Cocconeis	171.7	10,301.4	58.9	149.1	8943.0	51.1	190.6	11,433.6	65.3
Cymbella							3.8	226.2	1.3
Dimerogramma	66.0	3961.8	22.6	156.6	9396.0	53.7	135.8	8150.4	46.6
Epithemia	9.4	365.8	3.2	24.5	1471.2	8.4	17.9	1018.8	5.8
Grammatophora				9.4	565.8	3.2			
Navicula	566.0	33,961.8	194.1	760.4	45,622.2	260.7	1028.3	61,698.0	352.6
Nitzschia	5.7	339.6	1.9	28.3	1698.0	9.7	24.5	1471.2	8.4
Pleuro-Gyro.				1.9	112.8	0.6			
Blade No. 2									
Cocconeis	375.5	22,528.2	100.1	190.6	11,433.6	57.2	137.7	8263.8	36.7
Dimerogramma	154.7	9282.6	41.5	149.1	8943.0	44.7	164.2	9849.0	43.8
Epithemia	17.0	1018.8	4.5	18.9	1131.6	5.7	37.7	2263.8	10.1
Melosira				1.9	112.8	0.6	11.3	679.2	3.0
Navicula	1167.9	70,075.2	311.4	658.5	39,509.4	197.5	915.1	54,905.4	244.0
Nitzschia	17.0	1018.8	4.5	17.0	1018.8	5.1	64.1	3849.0	17.1
Blade No.3									
Cocconeis	228.3	13,698.0	68.5	126.4	7584.6	37.9	88.7	5320.2	30.4
Dimerogramma	113.2	6792.0	34.0	66.0	3961.8	19.8	71.7	4301.4	24.6
Epithemia				5.7	339.6	1.7	13.2	792.0	4.5

Appendix IX. Concluded.

Genera	Base of blade			Midpoint of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 3 continued									
Grammatophora							1.9	112.8	0.6
Melosira	1.9	112.8	0.6	3.8	226.2	1.1	9.4	565.8	3.2
Navicula	505.7	30,339.6	151.7	279.2	16,754.4	83.8	298.1	17,886.6	102.2
Nitzschia	7.5	452.4	2.3	1.9	112.8	0.6			
Blade No. 4									
Cocconeis	315.1	18,905.4	84.0	139.6	8377.2	41.9	215.1	12,905.4	73.7
Dimerogramma	96.2	5773.2	25.7	171.7	10,301.4	51.5	139.6	8377.2	47.9
Epithemia	5.7	339.6	1.5	5.7	339.6	1.7	17.0	1018.7	5.8
Melosira				9.4	565.8	2.8	9.4	565.8	3.2
Navicula	228.3	13,698.0	60.9	422.6	25,358.4	126.8	698.1	41,886.6	239.4
Nitzschia	1.9	112.8	0.5	7.5	452.4	2.3	37.7	2263.8	12.9

*5 feet mean low water.

Appendix X. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water at Gloucester Point, Virginia, June 4, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	11.3	679.2	3.4	132.1	7924.2	39.6
Dimerogramma				18.9	1131.6	5.7
Epithemia	3.8	226.2	1.1	3.8	226.2	1.1
Navicula	11.3	679.2	3.4	58.5	3509.4	17.5
Nitzschia				1.9	112.8	0.6
Blade No. 2						
Cocconeis	503.8	30,226.2	201.5	17.0	1014.0	6.8
Dimerogramma	9.4	565.8	3.8			
Epithemia	1.9	112.8	0.8			
Navicula	43.4	2603.4	17.4	20.8	1245.0	8.3
Nitzschia				3.8	226.2	1.5
Blade No. 3						
Cocconeis	705.7	42,339.6	211.7	137.7	8263.8	55.1
Dimerogramma				9.4	565.8	3.8
Epithemia				3.8	226.2	1.5
Navicula	58.5	3509.4	17.5	73.6	4414.8	29.4
Nitzschia				24.5	1471.2	9.8

Appendix X. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 4						
Cocconeis	543.4	32,603.4	217.3	264.2	15,849.0	105.7
Dimerogramma	3.8	226.2	1.5	17.0	1018.8	6.8
Navicula	18.9	1131.6	7.5	47.2	2829.6	18.9
Nitzschia				3.8	226.2	1.5
Blade No. 5						
Cocconeis	5.7	339.6	1.7	275.5	16,528.2	82.6
Navicula	3.8	226.2	1.1	20.8	1245.0	6.2
Blade No. 6						
Cocconeis	18.9	1131.6	7.5	803.8	48,226.2	385.8
Dimerogramma				5.7	339.6	2.7
Navicula	3.8	226.2	1.5	26.4	1584.6	12.7
Nitzschia				1.9	112.8	0.9
Blade No. 7						
Cocconeis	769.8	46,188.6	230.9	1250.9	75,056.4	428.9
Dimerogramma	5.7	339.6	1.7			
Navicula	9.4	565.8	2.8	34.0	2037.6	11.6

Appendix X. Concluded.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 8						
Cocconeis	611.3	36,679.2	146.7	134.0	8037.6	53.6
Navicula	9.4	565.8	2.3	11.3	679.2	4.5
Blade No. 9						
Cocconeis	462.3	27,735.6	138.7	156.6	9396.0	62.6
Navicula				3.8	226.2	1.5
Blade No. 10						
Cocconeis	469.8	28,188.6	140.9	356.6	21,396.0	142.6
Navicula	9.4	565.8	2.8	58.5	3509.4	23.4

* 1 foot mean low water.

Appendix XI. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester Point, Virginia, June 4, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	249.0	14,943.0	74.7	339.6	20,377.2	101.9
Dimerogramma	9.4	565.8	2.8	11.3	679.2	3.4
Navicula	28.3	1698.0	8.5	124.5	7471.2	37.4
Blade No. 2						
Cocconeis	92.4	5547.0	27.7	2501.9	150,112.8	750.6
Dimerogramma	7.5	452.4	2.3	26.4	1584.6	7.9
Navicula	26.4	1584.6	7.9	224.5	13,471.2	67.4
Blade No. 3						
Cocconeis	428.3	25,698.0	102.8	579.2	34,754.4	198.6
Dimerogramma				15.1	905.4	5.2
Navicula	56.6	3396.0	13.6	196.2	11,773.2	67.3
Blade No. 4						
Cocconeis	1188.7	71,320.2	285.3	88.7	5320.2	26.6
Dimerogramma	5.7	339.6	1.4			
Navicula	147.1	8829.6	35.3	203.8	12,226.2	61.1
Nitzschia				3.8	226.2	1.1

Appendix XI. Continued.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 5						
Cocconeis	235.8	14,150.4	70.8	930.2	55,810.8	318.9
Dimerogramma				13.2	792.0	4.5
Navicula	17.0	1018.8	5.1	101.9	6112.8	34.9
Blade No. 6						
Cocconeis	128.3	7698.0	38.5	243.4	14,603.4	83.4
Navicula	5.7	339.6	1.7	32.1	1924.2	11.0
Blade No. 7						
Cocconeis	39.6	2377.2	11.9	1396.2	83,773.2	418.9
Dimerogramma				3.8	226.2	1.1
Navicula	3.8	226.2	1.1	47.2	2829.6	14.1
Blade No. 8						
Cocconeis	34.0	2037.6	10.2	1441.5	86,490.0	494.2
Navicula	9.4	565.8	2.8	239.6	14,377.2	82.2

Appendix XI. Concluded.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 9						
Cocconeis	181.1	10,867.8	54.3	815.1	48,905.4	279.4
Navicula	11.3	679.2	3.4	100.0	6000.0	34.3
Blade No. 10						
Cocconeis	762.3	45,735.6	238.7	228.3	13,698.0	78.3
Navicula	50.9	3056.4	15.3	5.7	339.6	1.9
Nitzschia				115.1	6905.4	39.4

* 5 feet mean low water.

Appendix XII. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water* at Gloucester Point, Virginia, June 11, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	581.1	34,867.8	174.3	94.3	5659.8	37.7
Dimerogramma				28.3	1698.0	11.3
Navicula	50.9	3056.4	15.3	281.1	16,867.8	112.4
Nitzschia				11.3	679.2	4.5
Blade No. 2						
Cocconeis	549.0	32,943.0	164.7	192.4	11,547.0	77.0
Dimerogramma				45.3	2716.8	18.1
Navicula	67.9	4075.2	20.4	294.3	17,659.8	117.7
Nitzschia				24.5	1471.2	9.8
Blade No. 3						
Cocconeis	541.5	32,490.0	162.4	352.8	21,169.8	141.1
Dimerogramma	11.3	679.2	3.4	184.9	11,094.0	74.0
Navicula	103.8	6226.2	31.1	1188.7	71,320.2	475.5
Nitzschia				141.5	8490.0	56.6
Blade No. 4						
Cocconeis	192.4	11,547.0	57.7	417.0	25,018.8	166.8
Dimerogramma				20.8	1245.0	8.3

Appendix XII. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 4 continued						
Navicula	39.6	2377.2	11.9	377.4	22,641.0	150.9
Nitzschia				11.3	679.2	4.5
Blade No. 5						
Cocconeis	1913.2	114,792.0	574.0	294.3	17,659.8	117.7
Dimerogramma	3.8	226.2	1.1			
Navicula	341.5	20,490.0	102.4	167.9	10,075.2	67.2
Nitzschia				24.5	1471.2	9.8
Blade No. 6						
Cocconeis	896.2	53,773.2	358.5	496.2	29,773.2	198.5
Dimerogramma				3.8	226.2	1.5
Navicula	207.5	12,452.4	83.0	875.5	52,528.2	350.2
Nitzschia				11.3	679.2	4.2
Blade No. 7						
Cocconeis	13.2	792.0	5.3	241.5	14,490.0	115.9
Dimerogramma				5.7	339.6	2.7
Navicula	3.8	226.2	1.5	707.5	42,452.4	339.6
Nitzschia				11.3	679.2	5.4

Appendix XII. Concluded.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 8						
Cocconeis	50.9	3056.4	15.3	1234.0	74,037.6	493.6
Dimerogramma	3.8	226.2	1.1	5.7	339.6	2.3
Navicula	34.0	2037.6	10.2	588.7	35,320.2	235.5
Nitzschia				3.8	226.2	1.5
Blade No. 9						
Cocconeis	477.3	28,641.0	143.2	156.6	9396.0	62.6
Dimerogramma	5.7	339.6	1.7			
Navicula	469.8	28,188.6	140.8	92.4	5547.0	37.0
Nitzschia	15.1	905.4	4.5			
Blade No. 10						
Cocconeis	296.2	17,773.2	118.5	15.1	905.4	6.0
Dimerogramma	3.8	226.2	1.5			
Navicula	124.5	7471.2	49.8	37.7	2263.8	15.1

* 1 foot mean low water.

Appendix XIII. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester Point, Virginia, June 11, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	405.7	24,339.6	121.7	686.8	41,207.4	274.7
Dimerogramma				1.9	112.8	0.8
Navicula	77.4	4641.0	23.2	281.1	16,867.8	112.4
Blade No. 2						
Cocconeis	194.3	11.659.8	58.3	79.2	4754.4	31.7
Navicula	45.3	2716.8	13.6	145.3	8716.8	58.1
Blade No. 3						
Cocconeis	1822.6	109,358.4	437.4	109.4	6565.8	43.8
Navicula	417.0	25,018.8	100.1	279.2	16,754.4	111.7
Nitzschia	3.8	226.2	0.9			
Blade No. 4						
Cocconeis	186.8	11,207.4	74.7	364.2	21,849.0	145.7
Navicula	18.9	1131.6	7.5	90.6	5433.6	36.2

Appendix XIII. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 5						
Cocconeis	3018.9	181,131.6	905.6	294.3	17,659.8	117.7
Dimerogramma	9.4	565.8	2.8			
Navicula	88.7	5320.2	26.6	84.9	5094.0	34.0
Blade No. 6						
Cocconeis	2584.9	155,094.0	1034.0	398.1	23,886.6	159.2
Navicula	39.6	2377.2	15.8	45.3	2716.8	18.1
Blade No. 7						
Cocconeis	550.9	33,056.4	188.9	379.2	22,754.4	151.7
Navicula	11.3	679.2	3.9	34.0	2037.6	13.6
Blade No. 8						
Cocconeis	684.9	41,094.0	205.5	400.0	24,000.0	120.0
Navicula	37.7	2263.8	11.3	75.5	4528.2	22.6

Appendix XIII. Concluded.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 9						
Cocconeis	852.8	51,169.8	255.8	405.7	24,339.6	139.1
Navicula	15.1	905.4	4.5	20.8	1245.0	7.1
Blade No. 10						
Cocconeis	566.0	33,961.8	194.0	184.9	11,094.0	74.0
Navicula	11.3	679.2	3.9	39.6	2377.2	15.8

* 5 feet mean low water.

Appendix XIV. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water* at Gloucester Point, Virginia, June 20, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	805.7	48,339.6	322.3	398.1	23,886.6	159.2
Navicula	377.4	22,641.0	150.9	315.1	18,905.4	126.0
Blade No. 2						
Cocconeis	13.2	792.0	4.5	1320	79,245.0	528.3
Navicula	3.8	226.2	1.3	509.4	30,565.8	203.8
Blade No. 3						
Cocconeis	296.2	17,773.2	118.5	796.2	47,773.2	318.5
Melosira				5.7	339.6	2.3
Navicula	24.5	1471.2	9.8	383.0	22,980.6	153.2
Nitzschia				17.0	1018.8	6.8
Blade No. 4						
Cocconeis	56.6	3396.0	17.0	790.6	47,433.6	316.2
Dimerogramma				11.3	679.2	4.5
Grammatophora				3.8	226.2	1.5
Navicula	15.1	905.4	4.5	886.8	53,207.4	354.7
Nitzschia				66.0	3961.8	26.4

Appendix XIV. Continued.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 5						
Cocconeis	22.6	1358.4	6.8	1203.8	72,226.2	481.5
Navicula	7.5	452.4	2.3	371.7	22,301.4	148.7
Nitzschia				13.2	792.0	5.3
Blade No. 6						
Cocconeis	22.6	1358.4	7.8	379.2	22,754.4	151.7
Dimerogramma	1.9	112.8	0.6			
Navicula	5.7	339.6	1.9	434.0	26,037.6	173.6
Nitzschia				28.3	1698.0	11.3
Tropodoneis				7.5	452.4	3.0
Blade No. 7						
Cocconeis	298.1	17,886.6	89.4	715.1	42,905.4	286.0
Dimerogramma				17.0	1018.8	6.8
Navicula	145.3	8716.8	43.6	1056.7	63,396.0	422.6
Nitzschia	7.4	452.4	2.3	34.0	2037.6	13.6

Appendix XIV. Concluded.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 8						
Cocconeis	22.6	1358.4	6.8	1490.6	89,433.6	596.2
Epithemia				3.8	226.2	1.5
Navicula	13.2	792.0	4.0	618.9	37,131.6	247.5
Nitzschia				20.8	1245.0	8.3
Blade No. 9						
Cocconeis	26.4	1584.6	7.9	888.7	53,320.2	266.6
Dimerogramma				13.2	792.0	4.0
Navicula	5.7	339.6	1.7	756.6	45,396.0	227.0
Nitzschia	1.9	112.8	0.6	37.7	2263.8	11.3
Blade No. 10						
Cocconeis	17.0	1018.8	5.1	964.2	57,849.0	385.7
Dimerogramma				9.4	565.8	3.8
Epithemia				1.9	112.8	0.8
Navicula				641.5	38,490.0	256.6
Nitzschia				32.1	1924.2	12.8

* 1 foot mean low water.

Appendix XV. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester Point, Virginia, June 20, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	296.2	17,773.2	88.9	1358.5	81,509.4	407.5
Cymbella	5.7	339.6	1.7			
Dimerogramma				7.5	452.4	2.3
Navicula	243.4	14,603.4	73.0	345.3	20,716.8	103.6
Nitzschia				11.3	679.2	3.4
Tropodoneis	3.8	226.2	1.1			
Blade No. 2						
Cocconeis	305.7	18,339.6	91.7	1656.6	99,396.0	497.0
Cymbella				3.8	226.2	1.1
Navicula	164.2	9849.0	49.2	371.7	22,301.4	111.5
Tropodoneis				1.9	112.8	0.6
Blade No. 3						
Cocconeis	1679.2	100,754.4	503.8	609.4	36,565.8	208.9
Cymbella	11.3	679.2	3.4	5.7	339.6	1.9
Dimerogramma	5.7	339.6	1.7			
Navicula	541.5	32,490.0	162.4	618.9	37,131.6	212.2
Nitzschia	30.2	1810.8	9.1	39.6	2377.2	13.6

Appendix XV. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 4						
Cocconeis	296.2	17,773.2	88.9	1705.7	102,339.6	506.7
Cymbella				1.9	112.8	0.6
Dimerogramma				3.8	226.2	1.1
Melosira	1.9	112.8	0.6			
Navicula	201.9	12,112.8	60.6	369.8	22,188.6	110.9
Nitzschia	17.0	1018.8	5.1	7.5	452.4	2.3
Pleuro.-Gyro.	1.9	112.8	0.6			
Blade No. 5						
Cocconeis	437.7	26,263.8	150.0	1213.2	72,792.0	582.3
Cymbella				3.8	226.2	1.8
Navicula	373.6	22,414.8	128.0	434.0	26,037.6	208.3
Nitzschia	5.7	339.6	1.9	7.5	452.4	3.6
Tropodoneis				5.7	339.6	2.7
Blade No. 6						
Cocconeis	1337.7	80,263.8	401.3	1303.8	78,226.2	391.1
Dimerogramma				1.9	112.8	0.6
Melosira				1.9	112.8	0.6
Navicula	379.2	22,754.4	182.0	294.3	17,659.8	88.3
Nitzschia	3.8	226.2	1.1	3.8	226.2	1.1
Tropodoneis	3.8	226.2	1.1			

Appendix XV. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 7						
Cocconeis	234.0	14,037.6	56.2	866.0	51,961.8	259.8
Cymbella	1.9	112.8	0.5			
Dimerogramma	3.8	226.2	0.9			
Melosira	1.9	112.8	0.4			
Navicula	137.7	8263.8	33.1	169.8	10,188.6	50.9
Nitzschia	11.3	679.2	2.7	3.8	226.2	1.1
Blade No. 8						
Cocconeis	367.9	22,075.2	98.1	966.0	57,961.8	386.4
Dimerogramma	3.8	226.2	1.0			
Navicula	237.7	14,263.8	63.4	262.3	15,735.6	104.9
Nitzschia	9.4	565.8	2.5	5.7	339.6	2.3
Pleuro.-Gyro.	1.9	112.8	0.5			
Blade No. 9						
Cocconeis	315.1	18,905.4	84.0	1222.6	73,358.4	366.8
Cymbella				3.8	226.2	1.1
Navicula	147.2	8829.6	39.2	226.4	13,584.6	67.9
Nitzschia	3.8	226.2	1.0	11.3	679.2	3.4

Appendix XV. Concluded.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 10						
Cocconeis	924.5	55,471.2	317.0	1341.5	80,490.0	536.6
Dimerogramma				3.8	226.2	1.5
Melosira	3.8	226.2	1.3			
Navicula	247.2	14,829.6	84.7	283.0	16,980.6	113.2
Nitzschia	5.7	339.6	1.9	3.8	226.2	1.5

* 5 feet mean low water.

Appendix XVI. Distribution of Epiphytic Diatoms on Eelgrass in Shallow Water* at Gloucester Point, Virginia, July 14, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	377.4	22,641.0	129.4	679.2	40,754.4	271.7
Dimerogramma				17.0	1018.8	6.8
Navicula	3.8	226.2	1.3	356.6	21,396.0	142.6
Nitzschia	1.9	112.8	0.6	5.7	339.6	2.3
Blade No. 2						
Cocconeis	322.6	19,358.4	129.1	288.7	17,320.2	138.6
Navicula	15.1	905.4	6.0	247.2	14,829.6	118.6
Blade No. 3						
Cocconeis	498.1	29,886.6	170.8	498.1	29,886.6	239.1
Dimerogramma	3.8	226.2	1.3	34.0	2037.6	16.3
Epithemia				1.9	112.8	0.9
Grammatophora				1.9	112.8	0.9
Navicula	69.8	4188.6	23.9	383.0	22,980.6	183.8
Nitzschia				17.0	1018.8	8.2

Appendix XVI. Continued.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 4						
Cocconeis	209.4	12,565.8	62.8	515.1	30,905.4	206.0
Dimerogramma				32.1	1924.2	12.8
Navicula	41.5	2490.0	12.4	396.2	23,773.2	158.5
Nitzschia				30.2	1810.8	12.1
Blade No. 5						
Cocconeis	294.3	17,659.8	100.9	490.6	29,433.6	235.5
Dimerogramma				26.4	1584.6	12.7
Navicula	81.1	4867.8	27.8	345.3	20,716.8	165.7
Nitzschia	5.7	339.6	1.9	20.8	1245.0	10.0
Blade No. 6						
Cocconeis	334.0	20,037.6	133.6	579.2	34,754.4	278.0
Dimerogramma				41.5	2490.0	19.9
Navicula	50.9	3056.4	20.4	290.6	17,433.6	139.5
Nitzschia	3.8	226.2	1.5	35.8	2150.4	17.3

Appendix XVI. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 7						
Cocconeis	377.4	22,641.0	129.4	552.8	33,169.8	221.1
Dimerogramma	11.3	679.2	3.9	15.1	905.4	6.0
Epithemia				3.8	226.2	1.5
Navicula	26.4	1584.6	9.1	215.1	12,905.4	86.0
Nitzschia	9.4	565.8	3.2	41.5	2490.0	16.6
Blade No. 8						
Cocconeis	222.6	13,358.4	106.9	341.5	20,490.0	204.9
Dimerogramma				20.8	1245.0	12.4
Epithemia				1.9	112.8	1.1
Navicula	24.5	1471.2	11.8	201.9	12,112.8	121.1
Nitzschia				11.3	679.2	6.8
Blade No. 9						
Cocconeis	390.6	23,433.6	133.9	345.3	20,716.8	165.7
Dimerogramma				35.8	2150.4	17.2
Navicula	15.1	905.4	5.2	303.8	18,226.2	145.8
Nitzschia	5.7	339.6	1.9	18.9	1131.6	9.0

Appendix XVI. Concluded.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 10						
Cocconeis	452.8	27,169.8	135.8	418.9	25,131.6	167.5
Dimerogramma				50.9	3056.4	20.3
Navicula	20.7	1245.0	6.2	307.5	18,452.4	123.0
Nitzschia	7.5	452.4	2.3	24.5	1471.2	9.8

* 1 foot mean low water.

Appendix XVII. Distribution of Epiphytic Diatoms on Eelgrass in Deep Water* at Gloucester, Point, Virginia, July 14, 1964

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 1						
Cocconeis	435.8	26,150.4	130.7	200.0	12,000.0	80.0
Dimerogramma				11.3	679.2	4.5
Navicula	139.6	8377.2	41.9	307.5	18,452.4	123.0
Nitzschia	11.3	679.2	3.4	11.3	679.2	4.5
Pleuro.-Gyro.	3.8	226.2	1.1			
Blade No. 2						
Cocconeis	741.5	44,490.0	222.4	594.3	35,659.8	203.8
Dimerogramma	11.3	679.2	3.4			
Epithemia				15.1	905.4	5.2
Navicula	403.8	24,226.2	121.1	441.5	26,490.0	151.4
Nitzschia	7.5	452.4	2.3			
Blade No. 3						
Cocconeis	305.7	18,339.6	104.8	143.4	8603.4	57.4
Navicula	266.0	15,961.8	91.2	301.9	18,112.8	120.8
Nitzschia				7.5	452.4	3.0

Appendix XVII. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 4						
Cocconeis	290.6	17,433.6	99.6	350.9	21,056.4	140.4
Cymbella	3.8	226.2	1.3			
Dimerogramma				5.7	339.6	2.3
Epithemia	1.9	112.8	0.6	3.8	226.2	1.5
Navicula	245.3	14,716.8	84.1	435.8	26,150.4	174.3
Nitzschia	17.0	1018.8	5.8	15.1	905.4	6.0
Striatella	1.9	112.8	0.6			
Blade No. 5						
Cocconeis	307.5	18,452.4	105.4	435.8	26,150.4	174.3
Dimerogramma	11.3	679.2	3.9	17.0	1018.8	6.8
Epithemia	13.2	792.0	4.5			
Navicula	530.2	31,810.8	181.8	339.7	20,377.2	135.8
Nitzschia				5.7	339.6	2.3
Blade No. 6						
Cocconeis	415.1	24,905.4	166.0	222.6	13,358.4	106.9
Dimerogramma				11.3	679.2	5.4
Epithemia	7.5	452.4	3.0	5.7	339.6	2.7
Navicula	275.5	16,528.2	110.2	218.9	13,131.6	105.1
Nitzschia	3.8	226.2	1.5	3.8	226.2	1.8

Appendix XVII. Continued.

Genera	Base of blade: Cells per slide	Base of blade: Total cells per sample	Base of blade: Density (cells per mm^2)	Tip of blade: Cells per slide	Tip of blade: Total cells per sample	Tip of blade: Density (cells per mm^2)
Blade No. 7						
Cocconeis	322.6	19,358.4	110.6	573.6	34,414.8	229.4
Dimerogramma	13.2	792.0	4.5			
Epithemia				1.9	112.8	0.8
Navicula	247.2	14,829.6	84.7	403.8	24,226.2	161.5
Nitzschia				13.2	792.0	5.3
Blade No. 8						
Cocconeis	347.2	20,829.6	104.4	417.0	25,018.8	166.8
Dimerogramma	5.7	339.6	1.7	9.4	565.8	3.8
Navicula	418.9	25,131.6	125.7	245.3	14,716.8	98.1
Nitzschia	11.3	679.2	3.4	13.2	792.0	5.3
Blade No. 9						
Cocconeis	434.0	26,037.6	130.2	390.6	23,433.6	133.9
Cymbella				11.3	679.2	3.9
Dimerogramma				7.5	452.4	2.6
Navicula	264.2	15,849.0	79.2	347.2	20,829.6	119.0

Appendix XVII. Concluded.

Genera	Base of blade			Tip of blade		
	Cells per slide	Total cells per sample	Density (cells per mm^2)	Cells per slide	Total cells per sample	Density (cells per mm^2)
Blade No. 10						
Cocconeis	303.8	18,226.2	104.1	186.8	11,207.4	64.0
Dimerogramma				15.1	905.4	5.2
Navicula	330.2	19,810.8	113.2	394.3	23,659.8	135.2
Nitzschia	7.5	452.4	2.6	7.5	452.4	2.6

* 5 feet mean low water.

ABSTRACT OF
STUDIES OF THE HORIZONTAL AND VERTICAL DISTRIBUTIONAL PATTERNS OF DIATOMS EPIPHYTIC ON EEL GRASS, ZOSTERA MARINA L.

by

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in candidacy for the degree of

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in

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ABSTRACT

The study was concerned with the horizontal and vertical distributional patterns and the possible summer periodicity of diatoms epiphytic on eel grass, Zostera marina L., in the vicinity of Gloucester Point, Virginia.

Samples were collected in August 1963 and June and July 1964. Horizontal and vertical distributional patterns were demonstrated with respect to the change of total numbers of organisms present. The distributional pattern was, however, more pronounced in the vertical direction. The vertical comparisons generally indicated more pronounced growth of epiphytic diatoms at the blade tip than blade base. Horizontal comparisons generally show more growth in deep than shallow water, but there are exceptions.

Two trends were present which suggested periodicity and a shift in generic dominance. Cocconeis and Navicula appeared to reach peak densities on or shortly before June, whereas, Dimerogramma, Epithemia, and Nitzschia appeared to have reached a peak considerably before the June sampling date. The former two organisms maintained relatively high densities throughout the sampling period, whereas, the latter three did not reach a comparable average density until August.

Of the eighteen genera identified, four were chosen for detailed graphical illustration in 1963 and 1964 because of their predominance throughout the sampling period. Cocconeis, Dimerogramma,

Epithemia, and Navicula were predominant genera in 1963; Epithemia was replaced in abundance by Nitzschia in 1964.