OBSERVATIONS ON THE DISTRIBUTION AND OCCURRENCE OF DIATOMS IN THE INSHORE WATERS OF THE GULF OF MANNAR AND PALK BAY

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Introduction

From year to year qualitative and quantitative variations, as well as fluctuations of a minor nature in the regularity in appearance or disappearance of diatoms and their blooms are found in every region. As the diatoms constitute the chief components of the primary food supply of the sea, data on their occurrence, distribution pattern and fluctuations are of importance. Therefore, an attempt was made to study the nature and composition of the diatom community that occur in the plankton of Mandapam area, the abundance of species and the recurrent pattern in the annual distribution of the various species.

The results are based on regular tow-net samples collected from the inshore waters of the Gulf of Mannar during January 1950 to June 1953 and Palk Bay during May 1951 to June 1953.

The authors wish to thank Dr. S. Jones, Chief Research Officer, Central Marine Fisheries Research Station, for his comments.

General Character of the Diatom Flora

Several species of diatoms occur in the plankton of the Gulf of Mannar and Palk Bay, but out of these only about fifteen are well represented, most of which have been noticed to exhibit some kind of periodicities. The less abundant species do not show any clear seasonal fluctuations, but there are instances when some of these appear in appreciable numbers.

The principal constituents of the diatom population that occur in plankton, as can be expected, are the pelagic species of neritic and oceanic provinces. The littoral species are comparatively few.

Based on the available information regarding the bio-geographical types, species usually found in the plankton of this area may be grouped as follows:

Neritic—

Arctic	..	*Fragilaria oceanica* *Nitzschia seriata*
North Temperate	..	*Chætoceros compressus* *Leptocylindrus danicus* *Rhizosolenia stolterfothii* *R. imbricata* *Thalassionema nitzschioides*
South Temperate	..	*Asterionella japonica* *Bacteriastrum hyalinum* *Biddulphia mobiliensis* *Chætoceros affinis* *C. didymus* *C. lascinosus* *C. lorenzianus* *Ditylum brightwellii* *Eucampia zoodiacus* *Guinardia* sp. *Hemiaulus sinensis*
Tropical	..	*Bacteriastrum varians* *Bellarochea malleus* *Chætoceros diversus* *C. indicus* *Coscinodiscus gigas* *Leptocylindrus minimus* *Stephanopyxis palmeriana* *Thalassiosira coromandeliana* *Triceratium favus*

Oceanic—

Temperate	..	*Bacteriastrum delicatulum* *Chætoceros peruvianus* *Rhizosolenia alata* *R. styliformis* *Thalassiothrix frauenfeldii*

Tropical .. *Biddulphia sinensis*
Chætoceros coarctatus
Hemidiscus hardmannianus
Planktoniella sol
Rhizosolenia calcar avis
R. castracanei
R. hebetata
R. robusta

Littoral—

.. *Bacillaria paradoxa*
Biddulphia pulchella
Climacosphenia elongata
Isthmia enervis
Melosira sulcata
Nitzschia closterium
N. longissima
Pleurosigma spp.
Rhabdonema spp.

It will be seen from the classification given above, that Arctic neritic species are represented only by two species, whereas there are no Arctic oceanic species in the local flora. There are sixteen temperate neritic, nine tropical neritic, five temperate oceanic and eight tropical oceanic species. Nine species are littoral. Two other species which occur commonly, *viz.*, *Schræderella delicatula* and *Chætoceros denticulatum* are unclassified.

Most of the species occurring at both the areas and constituting the bulk in many months of the year are the so-called temperate forms. *Chætoceros* spp., *Rhizosolenia alata, R. imbricata, Thalassionema nitzschioides, Thalassiothrix frauenfeldii, Bacteriastrum hyalinum, Biddulphia sinensis* were the predominant ones occurring both in the Gulf of Mannar and Palk Bay. Besides, *Thalassiosira coromandeliana, Guinardia* sp., *R. styliformis, R. calcar avis, R. castracanei, Hemiaulus sinensis, Bacteriastrum varians, Chætoceros denticulatum, Climacosphenia elongata* and *Asterionella japonica* were found in great numbers only in Palk Bay, most of which are either south temperate or tropical neritic forms. In the Gulf of Mannar, on the other hand, species such as *Chætoceros coarctatus, Ditylum brightwellii, Biddulphia sinensis* and *Hemidiscus hardmannianus*, which are mostly tropical oceanic forms, were more common. Prasad (1954) observed blooms of single species of *Rhizosolenia, R. imbricata* in February 1951 and *R. alata* during March

1950 in the Gulf of Mannar, whereas during the summer as well as the August to September maxima more than one genus and several species were noticed flowering. He also observed that there are variations in the species composition of the diatom maxima taking place at different months of the year.

Seasonal occurrence and abundance of the more common species

Asterionella japonica Cleve (Fig. 1).—This species was often an important constituent in Palk Bay from February to April and from June to November, with the maximum abundance in August when they occurred in blooms. In the Gulf of Mannar its distribution was rather sparse except during the summer. Thus, in May 1950 it appeared in large numbers but was totally absent during the same period in the next two successive years and again reappeared, though in less number, in 1953. The largest catch was made in August 1951 from Palk Bay when a weekly average of 162,000 cells/c.c. of the standardised sample were obtained, whereas the largest

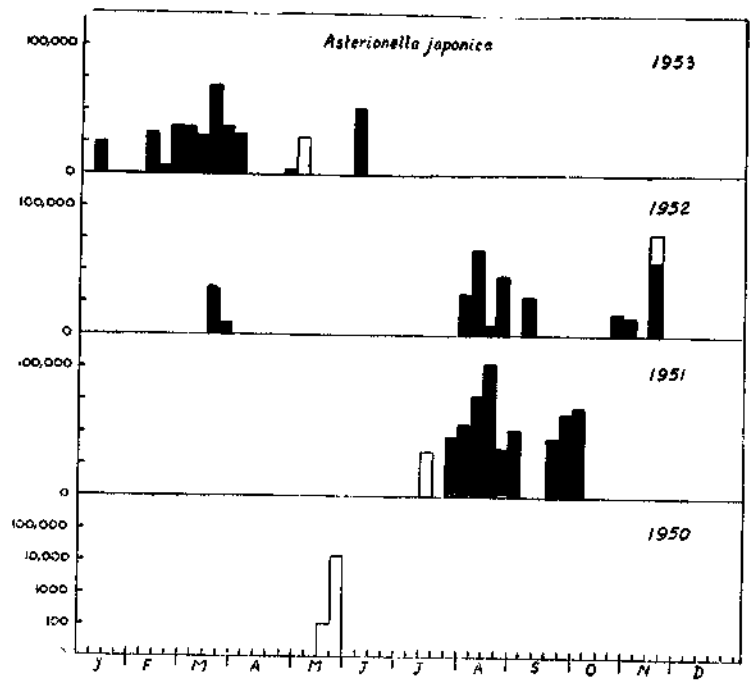

FIG. 1

FIGS. 1–15. Show the distribution and abundance of 15 common species of diatoms in the Gulf of Mannar (open bars) and Palk Bay (black bars) based on weekly tow-net samples. In all these figures the numbers on the ordinates represent the number of diatom cells per c.c. of the standardised sample.

obtained from the Gulf of Mannar was only 19,000 cells/c.c. in November 1952. There seems to be a regularity in their occurrence in Palk Bay during successive years, whereas such is not the case in the Gulf of Mannar. Allen (1945) states: "Apparently, it is one of those erratic organisms with extremes of abundance which are not seasonal (or even annual) in occurrence but are based on more or less fortuitously favourable combinations of the required conditions (external and internal)."

Bacteriastrum hyalinum Lauder (Fig. 2) occurred at both places during the summer blooms as well as the one during the latter part of the year. It was most abundant in Palk Bay from April to June and September to November and totally absent during the rest of the year. Excepting for a casual occurrence in July in one year it was found only in the major phytoplankton peaks of the Gulf with an interlude of one or two years.

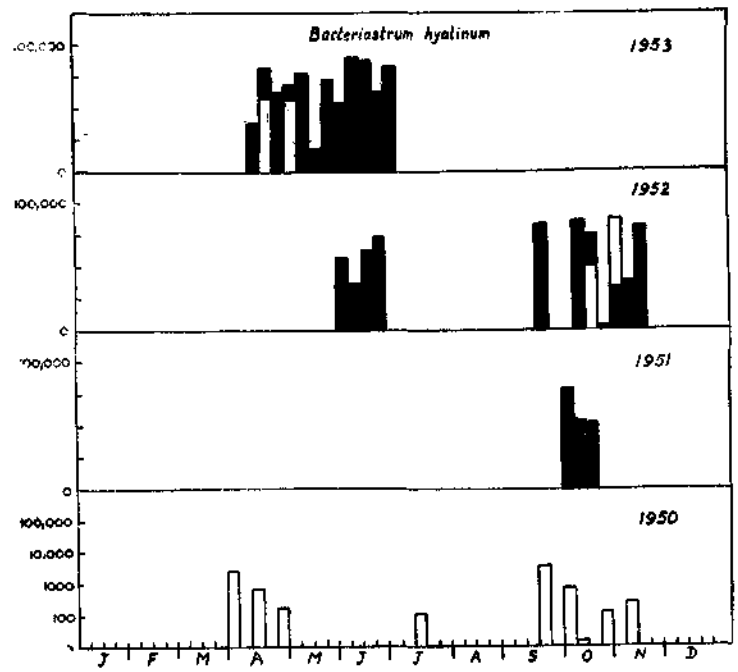

FIG. 2

Bacteriastrum varians Lauder (Fig. 3) is a more warm water species than *B. hyalinum*. In the Gulf of Mannar it was one of the constituents of the phytoplankton bulk of April to May 1950 and August 1951. In Palk Bay from May to October it occurred at intervals and was abundant,

Periods of swarms for both stations were May to June. A regular periodicit in their abundance during the summer months was observed in Palk Bay.

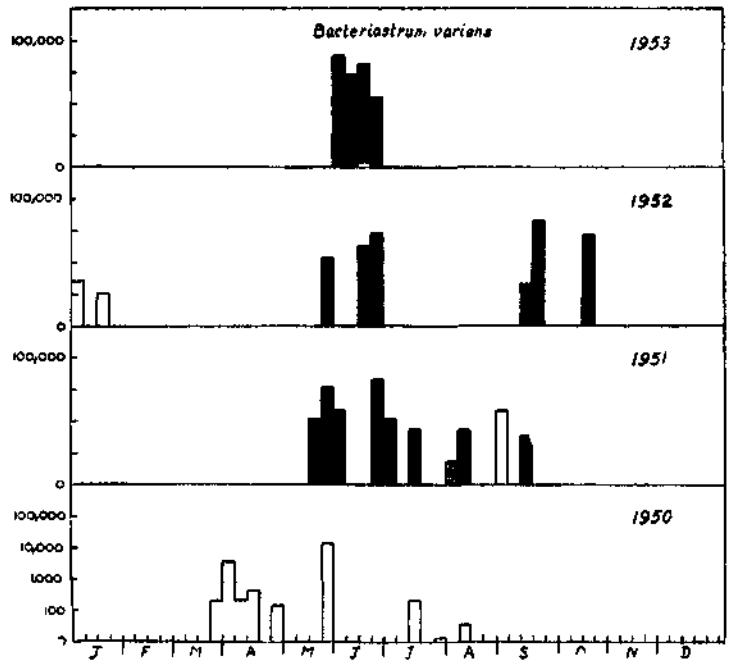

FIG. 3

The genus *Bacteriastrum* can be considered as one of the four dominant genera that makes up the diatom bulk of this area.

Biddulphia sinensis Greville (Fig. 4) is considered as a tropical neritic species which has invaded the temperate waters of Europe where it has become a permanent member of the plankton. According to Lebour (1930) this species has been used as an indicator of currents and for determination of the rate of flow of currents.

Being a tropical species *Biddulphia sinensis* is more common than the other member of this planktonic genus which occurs in this area, *viz.*, *B. mobiliensis*. In the Gulf of Mannar it occurred almost throughout the year in fairly good numbers with a maximum during the summer. In Palk Bay it appeared at irregular intervals almost throughout the year and had a maximum sometime during June to July. During the second diatom peak also it may occur in small numbers. The highest average number of cells

from the Gulf of Mannar was 38,000, whereas from Palk Bay it never exceeded 1,200.

Sproston (1949) noted that it is a conspicuous autumn dominant and may persist into the winter, in the Chu-San region. However, in the present instance, it was found to be dominant in summer.

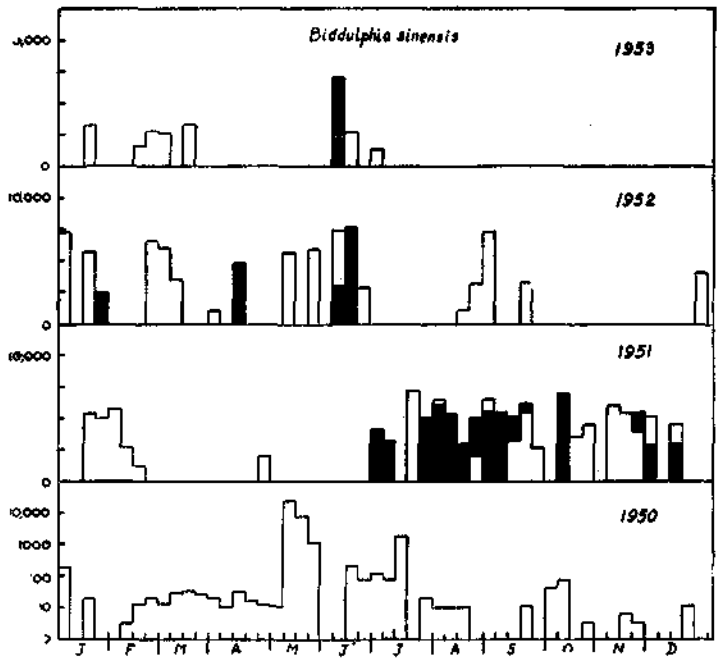

FIG. 4

Biddulphia mobiliensis also occurred in the plankton commonly. According to Gough (1907) it belongs to the winter plankton at Plymouth. But in Gulf of Mannar it was found in February, March, May and August to October. The highest number recorded was 12,000 in July and November 1951. In Palk Bay *B. mobiliensis* was almost absent excepting for a stray occurrence of few cells in June.

Chætoceros indicus Subrahmanyan (Fig. 5) was described for the first time from the plankton of the Madras coast (Subrahmanyan, 1946) and details of its abundance in any particular area or its geographical distribution beyond our waters are not available at present. In view of its abundant occurrence in the inshore plankton of both the areas it has been considered as a tropical neritic form.

This species was one of the major constituents of the diatom maxima of both the areas, but comparatively it was more abundant in Palk Bay where it occurred from May to December. In the Gulf of Mannar it occurred in small numbers intermittently from April to December. May

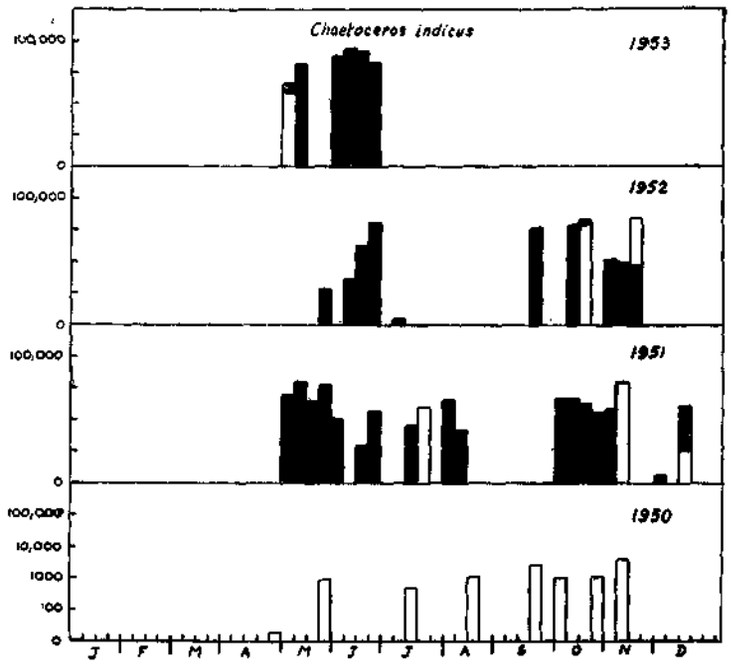

FIG. 5

and September to November were the two major peaks and during the period of observation they showed a regular periodicity in occurrence. The two major diatom blooms are well reflected in the occurrence of *C. indicus*. The largest catch from Palk Bay was 75,000 cells and from the Gulf of Mannar it was only 37,000 cells/c.c.

Chætoceros lascinosus Schütt (Fig. 6), a prominent species in Palk Bay, occurred regularly during the two major peaks and almost totally absent at other times of the year. In the Gulf of Mannar it occurred intermittently during May to December without showing any regular sequence or periodicity. The largest catch of 224,000 cells was from Palk Bay in June 1953, whereas from the Gulf of Mannar it was only 22,000 cells.

Chætoceros lorenzianus Grunow (Fig. 7) occurred in the Gulf of Mannar almost throughout the year forming a major part of the diatom population.

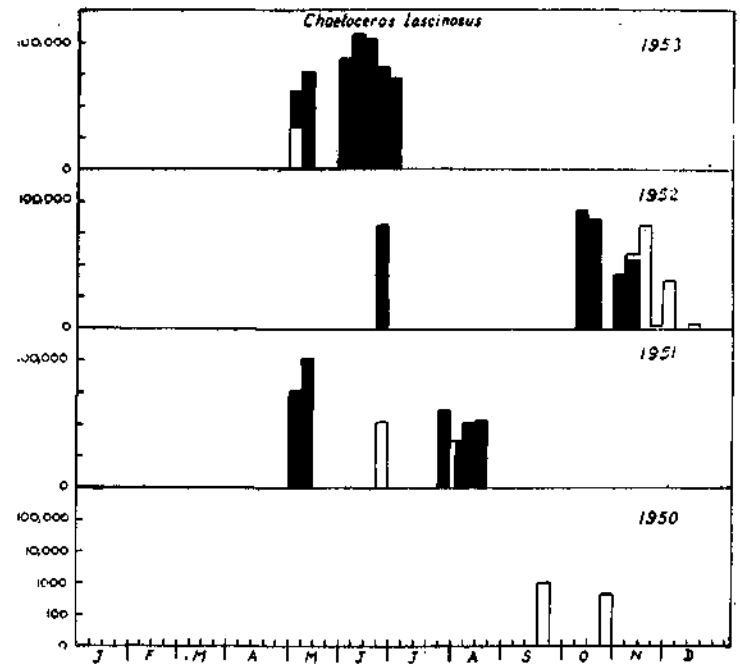
Chaetoceros lascinosus
1953
1952
1951
1950
100,000
10,000
1000
100
0
J F M A M J J A S O N D

FIG. 6

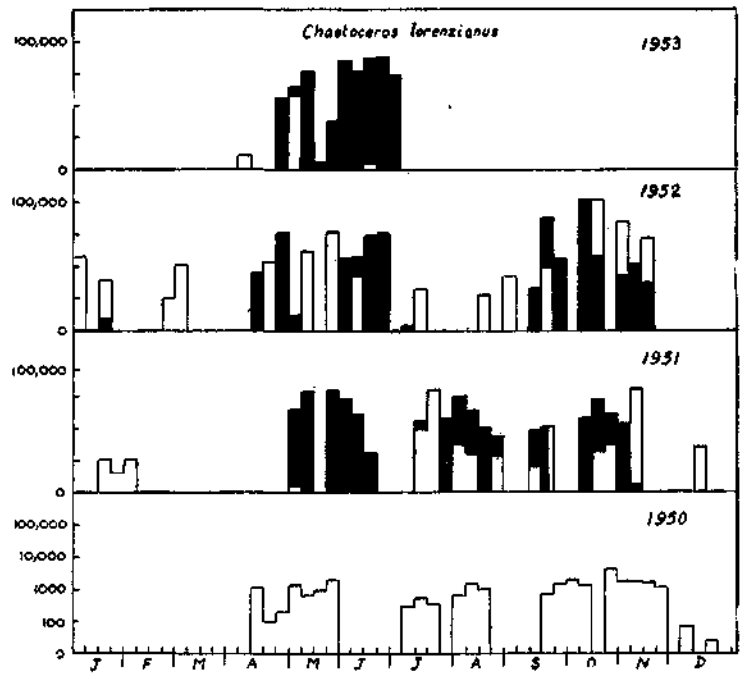
Chaetoceros lorenzianus
1953
1952
1951
1950
100,000
10,000
1000
100
0
J F M A M J J A S O N D

FIG. 7

It appeared in large numbers during the diatom blooms. *C. lorenzianus* together with *C. lascinosus* formed the bulk of *Chætoceros* abundance. The periods of peak production were more distinct in Palk Bay, one in May to June and the other in September to October. In the Gulf of Mannar as well as Palk Bay it showed a somewhat regular periodicity in occurrence, being common during the major peaks of the two areas. The largest catch of about 140,000 cells occurred in October 1952 at both stations.

Chætoceros debilis is the most abundant form of the genus in many of the temperate stations (Cupp, 1937). However, in our waters *C. lorenzianus* occupies the place when taken on a round-the-year basis though occasionally a stray catch of equally abundant or even slightly more of *C. lascinosus* may be obtained.

Chætoceros peruvianus Brightwell (Fig. 8) occurred commonly in the Gulf of Mannar from April to December at intervals. Season of persistent occurrence in successive years was November with a regular succession. In Palk Bay it was present in fairly large numbers from May to November with occasional breaks. The maximum abundance was in June with a total catch of 154,000 cells.

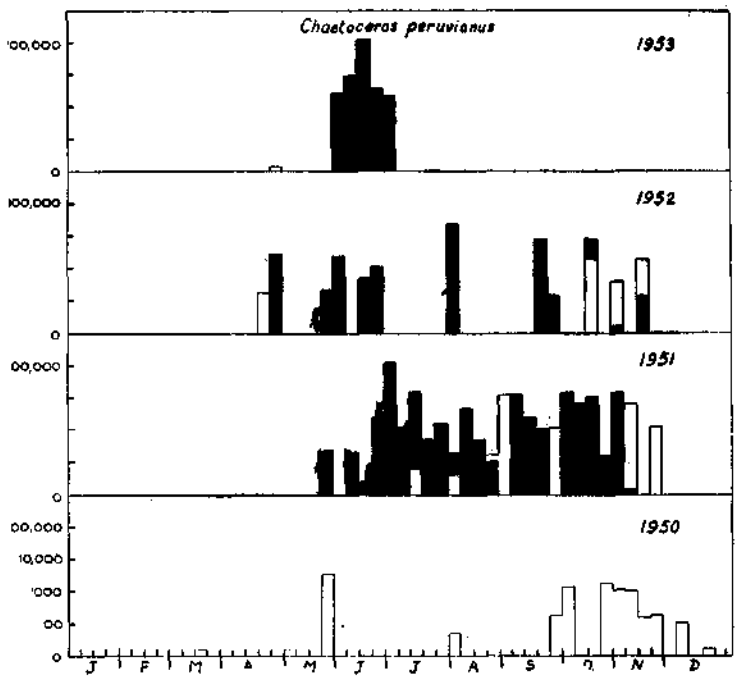

FIG. 8

Coscinodiscus gigas Ehrenberg (Fig. 9) occurred in both places almost throughout the year in small numbers. In the Gulf of Mannar there was a feeble maximum in June 1950 but it was not a regular feature. In Palk Bay their occurrence seems to be a regular feature in July.

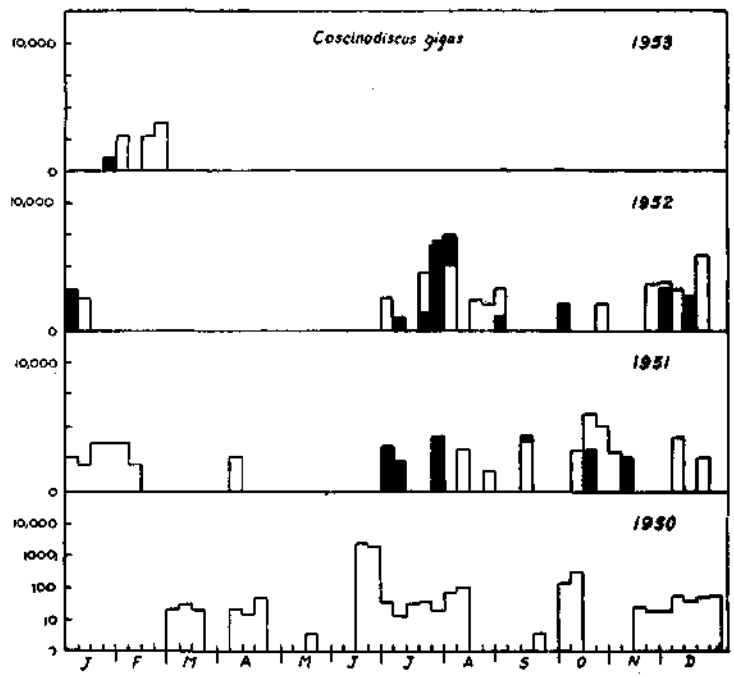

FIG. 9

Hemidiscus hardmannianus (Greville) Mann (Fig. 10) had a greater abundance in the Gulf of Mannar than in Palk Bay. It occurred throughout the year at intervals. From January to April it was very common in the plankton with maximum abundance in March to April during which period they occurred regularly indicating a distinct periodicity. In Palk Bay it was found only in small numbers along with other species during the two diatom maxima. The largest catch was 76,000 cells from the Gulf of Mannar in March 1951, while from Palk Bay it was only 800 cells during October in the same year.

Rhizosolenia alata Brightwell (Fig. 11) is a temperate oceanic species exhibiting wide fluctuation in its occurrence in both the areas. In the Gulf of Mannar during the year 1950 it was common in the plankton throughout the year excepting May and June with the maximum record of 319,000 cells

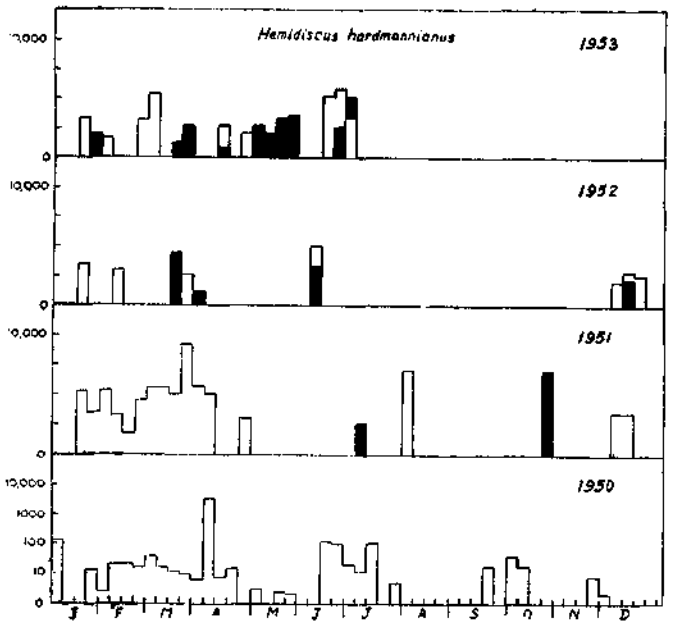
Hemidiscus hardmannianus
1953
1952
1951
1950
J F M A M J J A S O N D

FIG. 10

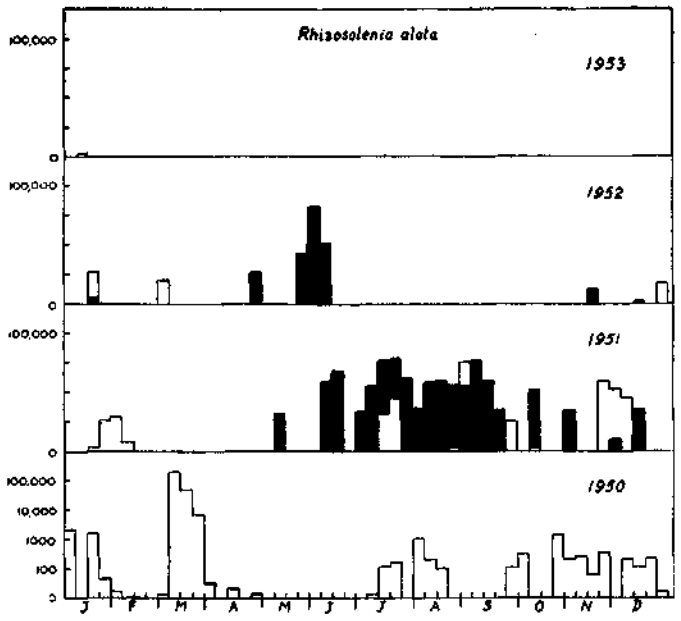
Rhizosolenia alata
1953
1952
1951
1950
J F M A M J J A S O N D

FIG. 11

in March. In the succeeding years it was comparatively less in abundance. In Palk Bay from June to September 1951 it occurred in large numbers with a regular periodicity in June. During the period covered by the present investigations, a progressive decrease in abundance was observed in both regions. Gough (1907) observed that it was always absent or, nearly always, at all the more neritic stations in the English Channel.

Rhizosolenia imbricata Brightwell (Fig. 12) occurred in the Gulf of Mannar at intervals. It was common in February or March and in November. In Palk Bay from June to September it was abundant and was the dominant member of the genus. A regular periodicity in its occurrence during January to March in Gulf of Mannar and in June and September in Palk Bay was also observed. In 1951 they were remarkably abundant at both places; the highest catch from the Gulf of Mannar was 29,000 cells in February while from Palk Bay it was 113,000 cells in July.

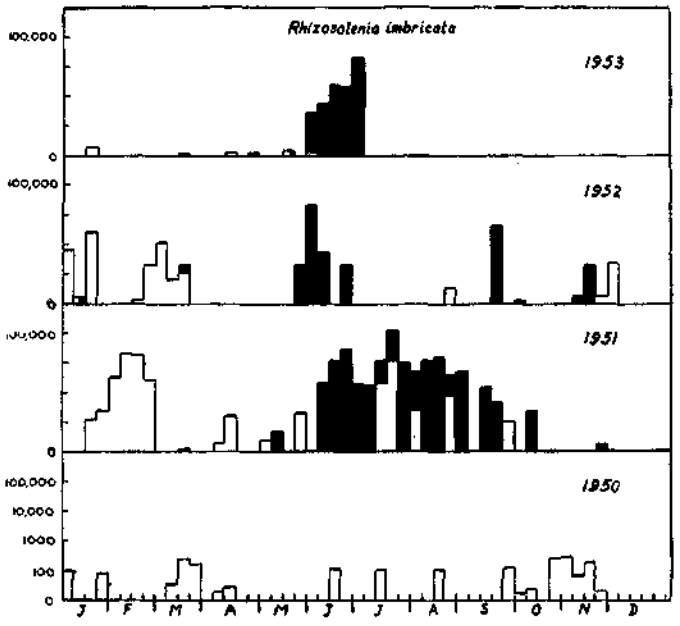

FIG. 12

Rhizosolenia styliformis Brightwell (Fig. 13).—A group of forms are met with in this species. But seasonal variations have been determined for the species as a whole. As observed by Delsman (1939), in the waters of Java, in the present instance too, this species had only a subordinate position in the plankton compared to the other species of *Rhizosolenia*.

Rhizosolenia styliformis occurred at intervals throughout the year in the Gulf of Mannar but it was more prominent during August to January. In Palk Bay the occurrence of *R. styliformis* was mainly restricted to the summer months. In both places a regular periodicity in its occurrence was observed. The highest catch from the Gulf of Mannar was 20,000 cells and from Palk Bay 8,000 cells.

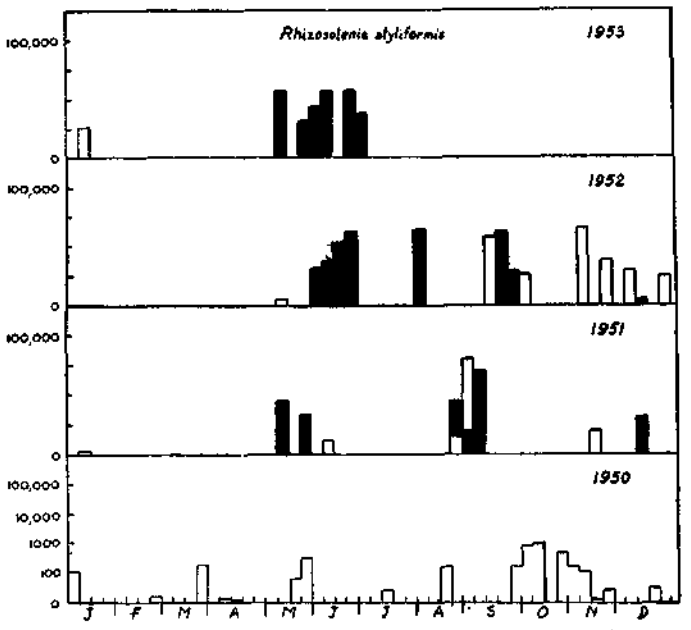

FIG. 13

According to Sproston (1949), *Rhizosolenia* spp. have a midsummer maximum wherever they occur. However, our observations are not quite in agreement with this, the maximum being between June and September.

Thalassionema nitzschioides Grunow (Fig. 14) though grouped as a north temperate neritic species, according to Smayda (1958) it is circumglobal and its distribution pattern supports the contention of some investigators that neritic species can survive in oceanic environments if transported there.

It occurred almost throughout the year in the Gulf of Mannar with occasional breaks. It was an abundant species in many of the months, with a maximum record of 336,000 cells in May 1950. During the succeeding years the peak was found to shift to the earlier part of the year. From

June to December also it was a frequent member of the plankton. In the frequency of occurrence and abundance it occupied an important place in the plankton of the Gulf of Mannar, whereas in Palk Bay, it was generally present only during the two major blooms with a probable succession in the summer months.

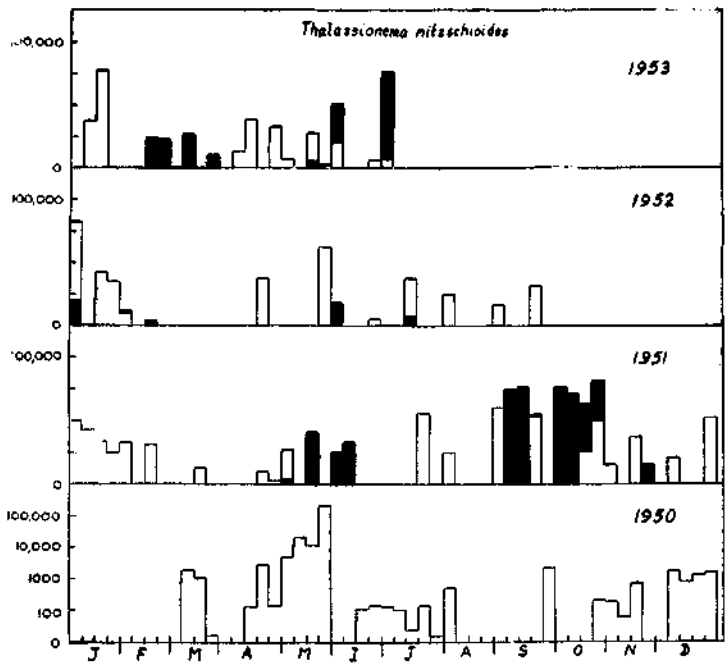

FIG. 14

Harvey *et al.* (1935) have stated that off Plymouth this species has a steady secondary importance throughout and forms the dominant member of the spring maximum. In Aomori Bay, Japan, Kokubo and Tamura (1931) found it sharing first place in the plankton, particularly near the surface, in October to November along with *Biddulphia* spp. Chacko (1950) has, however, recorded it as rare throughout the year around Krusadai Island in the Gulf of Mannar.

Thalassiothrix frauenfeldii Grunow (Fig. 15) is probably the most important species occurring in the plankton of both Palk Bay and the Gulf of Mannar. In the latter it appeared in large numbers almost throughout the year with short breaks. It was a dominant member of the summer bloom of both the stations. The peak production period in both the places appeared to be in May but in October also they were abundant.

Thalassiothrix frauenfeldii is considered as an oceanic temperate species preferring warmer waters. It is predominant in the coastal plankton of Mediterranean (Bernard and Fage, 1936) and in the Chu-San area it holds a third place in the winter, common in the spring and rare in the summer (Sproston, 1949). Fox (1929) noticed in East Pacific coast a phenomenal r'se of *T. frauenfeldii* when other diatoms failed in the spring. Chacko (1950) also has observed that *T. frauenfeldii* with *T. longissima* occupies the first place in the plankton around Krusadai Island.

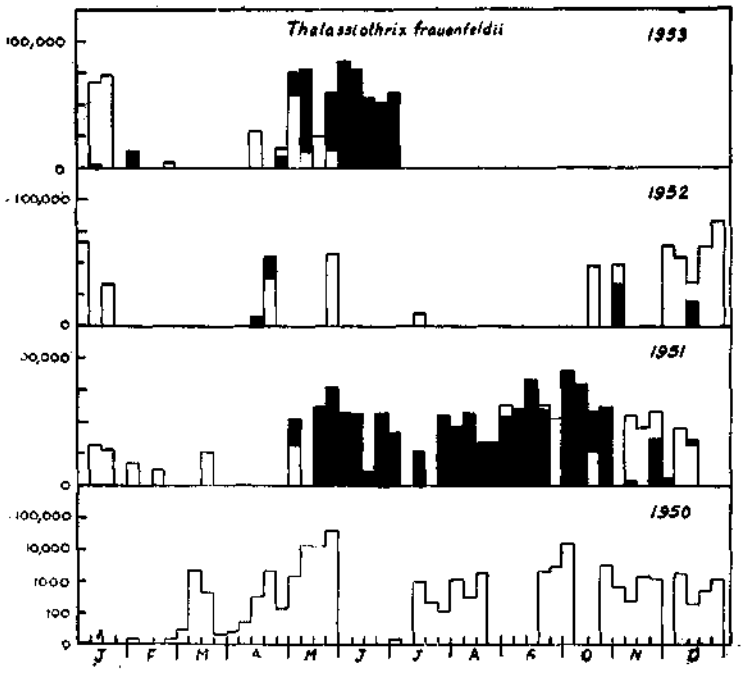

FIG. 15

DISCUSSION

Among the diatoms listed and discussed above, *Chætoceros* spp., *Rhizosolenia* spp. and *Thalassiothrix frauenfeldii* may be considered as persistent forms contributing substantially to the phytoplankton blooms and only these are found to exhibit regular periodicities in both the areas.

According to Bogorov (1958) seasonal variations in qualitative composition and abundance of organisms permit us to distinguish definite biological seasons. In general, the biological winter is characterised by a minimum of phytoplankton and the biological spring by a rapid multiplication of phytoplankton. In the subtropical regions the biological spring corres-

ponds to the month of May and the autumnal maximum occurs in November. As far as the regions, where the present observations were conducted are concerned, this biological spring is found to be also in May. In the Gulf of Mannar the "autumnal maximum" occurs in October or November, while in the Palk Bay the abundance due to spring outburst persists till October except for a slight decimation in July to August (Prasad, 1956).

From the classified list, it may be observed that the local flora of the two inshore stations are mostly composed of neritic species. Oceanic species of the genus *Rhizosolenia* and *Thalassiothrix frauenfeldii* only are exceptions. Littoral forms, excepting *Pleurosigma* spp., are only occasionally met with, and are often more abundant, as is to be expected, during or immediately after a period of turbulence. While reviewing the probable seasonal succession of the more important species in the South-West Atlantic, Hart (1934) has classified them into (i) spring forms; (ii) forms with a spring maximum but which remain more or less important throughout the season; (iii) forms with spring and autumn maxima, and (iv) a few comparatively unimportant forms found most frequently in late summer and autumn. Based on the above grouping it may be said that most of the species considered here come under the second category, while *Chætoceros indicus*, *C. lascinosus* and *Bacteriastrum* spp. are found to be with a distinct spring and autumn maxima, thus falling in the third category.

Palk Bay being a more or less enclosed area, several of the tropical and south temperate species which occur there exhibit regular periodicities. The relatively more regular seasonal variations and succession exhibited by these species may be an indication of a larger autochthonous breeding stock of diatoms in this area.

On the other hand Gulf of Mannar is more conspicuous in oceanic species like *Biddulphia sinensis*, *Chætoceros coarctatus*, *Hemidiscus hardmannianus*, etc., which have a round-the-year distribution. The information available in literature on the currents of this area suggests the possibility of influx of water of oceanic origin, by horizontal transport, during February to March (*see* also Prasad, 1954). This may also be in some way responsible for the instances of local flowering of single species of diatoms reported by Prasad (1954). It may be worthwhile to note in this context that Ruud (1932) commented on the fact that regions with converging currents tend to encourage a rich production of plankton and Hart (1934) remarked that the influence of the mixing of the currents may be the determining factor in the localizations observed in the Weddel Sea area. Hardy, in Hardy and Gunther (1935), has further suggested that the rich production in regions

with converging currents is due to the stimulus to growth consequent upon slight changes in the external conditions of the environment. Bigelow, Lillick and Sears (1940), who have noted local flowerings of *Rhizosolenia alata* and *Chætoceros* in shoal water close to land in the Gulf of Maine even in early mid-winter, conclude that temporary enrichment of the water with planktonic vegetation is not an exceptional event in shoal water even in seasons when phytoplankton is scarce, as these flowerings were observed in such short record of observations. Wood (1959) is of the opinion that vertical mixing of surface muds and the waters of the continental shelf is responsible, in part, for the neritic blooms of phytoplankton.

From the analyses of the intensity and occurrence of the different groups of diatoms, it can be seen that some of the most abundant, persistent and dominant varieties are those which have been grouped by Cleve and others as Temperate Species. Smayda (1958) remarked that Cleve overemphasised the role of visiting species in contributing to and moulding the seasonal phytoplankton cycle and attributed the seasonal changes in composition and dominance of the community to the periodic recruitment of species from different areas. He supports the view of Gran (1912) that when conditions of existence in the flowing water-masses gradually alter, it is the new conditions of existence that decide the character of flora, since the species best qualified to endure them will very soon get the upper hand over the others, and adds that the seasonal composition of a developing population is derived primarily from a local stock and secondarily from visitors.

In the complex of interdependent factors governing the seasonal variations and yearly fluctuations in phytoplankton production, transportation by surface currents is a significant one. Currents from the south temperate regions reach these areas only during October to January (Sewell, 1937) and the monsoon drift from June to August (Prasad, 1954). So if these temperate species have their normal distribution in temperate regions and are carried by the water-masses they would reach here only during these months. But their occurrence, in other months also, makes one feel that most of these temperate species are really ubiquitous. This is not altogether improbable since this grouping is based mainly on collections made during expeditions and very little was known of the seasonal distribution of diatoms in the tropical regions. The occurrence of these so-called temperate species in such large numbers during the greater part of the year in areas outside the temperate regions makes one doubt the validity of this grouping. As for the classification of species into neritic and oceanic, Smayda (1958) is of the opinion that such a classification places the species in an undefined

region and tells nothing of its life cycle or why it is found there and hence even these bio-geographical terms should be rejected. All these indicate that in many cases our concepts of species habits and habitats need to be broadened.

Summary

Forty-nine out of the fifty-one species of diatoms occurring commonly in the plankton of Mandapam area have been classified into bio-geographical groups and the general character of the diatom flora of the Gulf of Mannar and Palk Bay is described.

The seasonal variations and periodicities exhibited by fifteen species, which are well-represented in the plankton have been compared for both the places. It is found that the biological spring falls in May and the 'autumnal maximum' occurs in October or November. Most of these species are forms with a spring maxima but which remain more or less important throughout the season while a few are with a distinct spring and autumn maxima.

The data suggest that Palk Bay is having a larger breeding stock of autochthonous diatoms which are mostly neritic, whereas in the Gulf of Mannar there are more oceanic diatoms.

The validity of the existing bio-geographical grouping of some of the species of diatoms and the necessity of widening the concept of species habits and habitats are mentioned in the light of the available data.

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