PLANKTON CALENDARS OF THE INSHORE WATERS AT MANDAPAM, WITH A NOTE ON THE PRODUCTIVITY OF THE AREA

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Introduction

Planktological investigations in various parts of the world have established that there are divergences in the pattern of annual distribution of plankton at the same station as well as between closely adjacent stations in the same general region at the same time. Despite these differences certain trends or nebulous patterns become apparent from prolonged observations. To differentiate the fortuitous from the truly repetitive changes data should necessarily cover a number of years and the observations should be spaced as closely as possible. These ideal conditions are, however, often difficult to achieve.

Based on the data collected for two years the author gave general accounts of the plankton at two inshore stations off Mandapam (Prasad, 1954 *a* and 1956). The study was continued and now after having collected the data continuously for over five years it was thought desirable to draw up general plankton calendars for this region based on these data as well as those from other stations operated at random in the area under investigation. Separate calendars were prepared for the Gulf of Mannar and Palk Bay because of the observed differences in the characteristics of plankton of the two regions. These calendars are concerned mostly with the large variations, which, after all, are the more important ones biologically and particularly in relation to fisheries.

In preparing these calendars only the common forms have been included and such megaloplanktonic forms as Scyphomedusæ, *Physalia*, *Porpita*, *Janthina*, etc., though not found in the routine collections made with a half-meter plankton net, have been included as they are seen washed ashore in large numbers during certain seasons.

The nature of the subject-matter is such that a certain amount of vagueness seems unavoidable in the terminology employed in plankton calendars

for describing the abundance of various organisms. Therefore, terms such as abundant, common, few, rare, etc., are used in a sense only to give a relative picture of the changes in the population level of particular organisms or group of organisms from month to month. It is not unusual to find in the case of several organisms striking variations from year to year in the magnitude of their population and also in the time of occurrence of maxima and minima which may be slightly earlier or later as the case may be. For details regarding the distribution and fluctuations of various groups, excluding fish eggs and larvæ, in the environs of Mandapam reference may be made to the author's earlier papers (Prasad, 1954 *a*, 1954 *b* and 1956 and Prasad *et al.*, 1952). Bapat (1955) has reported on the fish eggs and larvæ of this area.

The productivity of the inshore waters of the Gulf of Mannar and Palk Bay off Mandapam has also been briefly discussed.

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Plankton Calendars

Gulf of Mannar

January—

1. Sea calm.
2. Surface salinity and temperature of sea-water low—ranges from 27·12 to 31·31‰ and 23·5 to 27·0° C.[1] respectively.
3. The total standing crop of plankton relatively high and the mean monthly net plankton volume varies from 11·9 to 30·6 ml.[2]
4. Phytoplankton generally poor but occasional outbursts of particular species of diatoms may be noticed. The common diatoms are *Rhizosolenia, Thalassiothrix, Thalassionema, Coscinodiscus* and *Hemidiscus*. Dinophyceæ rare.
5. Zooplankton dominant. Copepods abundant. Chætognaths and cladocerans (*Evadne*) common. *Lucifer* may occur in large numbers. Nauplii and other invertebrate larvæ particularly those of molluscs and decapods common. Tintinnids, *Creseis* and *Oikopleura* few. Few hydromedusæ may be present. Occasionally few *Pleurobrachia* and *Beroë* may occur but usually rare. Fish eggs few.

[1] The values of salinity and temperature of the surface water given are the highest and lowest recorded during the course of five years.

[2] The values are based on averages for five years.

February—

1. Sea calm.
2. Salinity and temperature increase slightly—28·08 to 31·94‰ and 24·5 to 28·8° C. respectively.
3. Total standing crop shows a decrease, the mean monthly plankton volume varies from 6·5 to 19·6 ml.
4. Phytoplankton low. Species distribution of diatoms almost similar to that of January. Occasional outbursts of certain species of diatoms may take place. Dinophyceæ may show a trifling increase.
5. Zooplankton continues to be the dominant element. Copepods abundant. Several invertebrate larvæ particularly those of polychætes, decapods and molluscs and nauplii very common. Chætognaths, *Oikopleura*, *Pleurobrachia*, *Beroë* and *Evadne* common. Fish eggs common. *Noctiluca* may appear in large numbers. *Creseis* and *Lucifer* usually present. Hydromedusæ few.

March—

1. Sea remains calm.
2. Salinity ranges from 29·15 to 33·08‰ and temperature from 25·0 to 30·0° C.
3. Relatively high standing crop of plankton is characteristic. The mean monthly plankton volume varies between 15·0 and 29·3 ml.
4. Phytoplankton shows a general increase. In addition to the species of diatoms recorded before, *Bacteriastrum* also appears. Sudden blooming of certain species of diatoms may be noticed. Among the dinophyceæ, which are now generally common, species of *Ceratium* and *Peridinium* are well represented. *Trichodesmium* plenty.
5. Zooplankton still high. Copepods predominant and often reach a peak. The plankton is characterised by a large number of invertebrate larvæ of which decapod, polychæte and molluscan larvæ are the most abundant. Fish eggs abundant and are usually at a maximum. Chætognaths and *Lucifer* plenty. *Creseis* and *Oikopleura* common. Hydromedusæ few. *Evadne* become scarce and their place is taken up by *Penilia*. Few *Noctiluca*, tintinnids, siphonophores, *Pleurobrachia* and *Beroë* occur.

April—

1. Sea may become choppy.
2. Salinity and temperature show a further increase; ranges vary from 31·41 to 35·54‰ and 28·0 to 31·0° C. respectively.
3. The standing crop of plankton decreases and the mean monthly plankton volume ranges between 12·1 and 20·7 ml.

4. A slight decimation of phytoplankton is noticed. While the diatoms show a decrease the dinophyceæ increase. *Trichodesmium* abundant and invariably reaches a peak.
5. Zooplankton shows a decrease but still the plankton is often predominantly zooplanktonic. Hydromedusæ very common. Chætognaths plenty and are often at their peak. As in March large numbers of invertebrate larvæ are present. Copepods plenty. *Oikopleura* plenty and their maximum falls either in March or April. Siphonophores common. *Creseis* and *Lucifer* usually commom. *Noctiluca* generally present and may appear in large numbers in some years. *Penilia* and tintinnids few. Fish eggs rare.

May—

1. Sea becomes rough towards the second half of the month consequent on the commencement of the south-west monsoon during which there may be scattered showers.
2. There is a further increase in the salinity (32·36–36·69‰) but the temperature tends to fall (26·5–30·8° C.).
3. Total standing crop of plankton decreases. The mean monthly plankton volume fluctuates between 6·0 and 19·0 ml.
4. Phytoplankton increases markedly, and the plankton becomes dominated by diatoms. *Chætoceros*, *Thalassiothrix*, *Thalassionema*, *Bacteriastrum*, *Biddulphia* and *Bacillaria* are the important diatoms. Dinophyceæ common. *Trichodesmium* may continue to occur in large numbers.
5. Zooplankton population remains rather low. Copepods plenty and their population shows no appreciable difference from that of the previous month. Tintinnids and several species of hydromedusæ common. Chætognaths, *Lucifer* and *Oikopleura* fairly common. Invertebrate larvæ such as *Cyphonautes*, polychæte, echinoderm and lamellibranch larvæ are fairly common while others are relatively few. Siphonophores may continue to be present but are generally few or rare. Fish eggs may be common.

June—

1. Sea continues to be rough.
2. There is a further drop in the temperature (26·0 to 29·8° C.) and the salinity increases (34·29 to 37·43‰).
3. The standing crop of plankton is rather low; the mean monthly net plankton volume ranges from 6·3 to 20·0 ml.
4. There is a significant decrease in the quantity of phytoplankton. *Coscinodiscus*, *Biddulphia*, *Hemidiscus* and *Thalassionema* are the important diatoms. Dinophyceæ few.

5. Zooplankton population comparatively at a low level and all important zooplankters show a decrease. Copepods plenty. Numerous hydromedusæ are present and they reach a peak either in May or June. Siphonophores particularly *Physalia* and *Diphyes* may once again become common. *Janthina* common. The large Scyphomedusa—*Rhopilema* is a usual visitor. Invertebrate larvæ, *Lucifer* and chætognaths few. Fish eggs rare.

July—

1. Sea remains rough.
2. Salinity varies from 33·46 to 36·26‰ and temperature ranges from 25·3 to 30·0° C.
3. The total standing crop of plankton tends to increase. The mean monthly plankton volume ranges between 7·7 and 19·2 ml.
4. Phytoplankton tends to increase. Several species of *Chætoceros* and *Rhizosolenia* reappear. Dinophyceæ few. *Trichodesmium* occurs in fair numbers.
5. Zooplankton polpulation remains more or less at the same magnitude as that of June. Copepods common and are usually at their minimum. Siphonophores particularly *Physalia* and *Porpita* common. *Janthina* common. Chætognaths may be fairly common. Occasionally *Noctiluca* and *Lucifer* may be common. *Oikopleura*, *Evadne* and *Penilia* few. *Rhopilema* may continue to appear. Larval forms scarce and are at their minimum. Hydromedusæ and fish eggs rare.

August—

1. Sea remains somewhat rough.
2. Temperature and salinity range from 25·5 to 30·5° C. and 33·86 to 36·78‰ respectively.
3. The total volume of standing crop of plankton does not show any marked deviation from that of July, the mean monthly plankton volume ranging from 7·7 to 20·0 ml.
4. Phytoplankton in general is low but occasional blooms of *Chætoceros*, *Rhizosolenia*, *Biddulphia*, *Thalassiothrix* and *Thalassionema* may take place. Dinophyceæ common, particularly certain species of *Ceratium*. *Trichodesmium* common.
5. Zooplankton tends to increase. Copepods plenty. *Oikopleura* and chætognaths common. Several species of tintinnids may be common. Invertebrate larvæ show an increase especially some of the gastropod larvæ. Cirripede nauplii fairly common. Siphonophores particularly

Physalia continue to be present though not as common as in July. Fish eggs few. Few hydromedusæ may also occur.

September—

1. Sea becomes comparatively calm owing to the subsidence of strong wind.
2. Temperature ranges from 25·8 to 30·3° C. and salinity from 34·87 to 36·74‰.
3. The total standing crop of plankton increases. The mean monthly plankton volume varies from 7·6 to 31·0 ml.
4. Phytoplankton shows an increase. *Chætoceros, Rhizosolenia, Bacteriastrum, Biddulphia, Thalassionema, Thalassiothrix* and *Bacillaria* are the important diatoms. Dinophyceæ relatively abundant. Species of *Ceratium* and *Peridinium* are the most common. *Trichodesmium* may occur in appreciable quantity.
5. Zooplankters increase and once again become dominant. Copepods reappear in large numbers. *Oikopleura* very common. Several species of tintinnids, *Physalia* and other siphonophores, chætognaths and fish eggs common. Invertebrate larvæ not as abundant as in August but occasionally many *Cyphonautes* and nauplii are encountered. Few *Evadne* and *Lucifer* may be present.

October—

1. Sea calm. The north-east monsoon invariably commences during this month.
2. Salinity ranges from 33·98 to 36·94‰ and temperature from 26·0 to 29·8° C.
3. The total volume of standing crop shows no appreciable difference from that of September, the mean monthly net plankton volume varying from 9·2 to 28·0 ml.
4. Phytoplankton generally shows a remarkable increase both in quantity and number of species. In addition to the many diatoms recorded in September, others such as *Pleurosigma, Nitzschia* and *Schræderella* also become common. Dinophyceæ plenty. *Trichodesmium* may occur in appreciable numbers.
5. Zooplankton shows a definite increase. Copepods are abundant. Swarms of *Noctiluca* may appear. Numerous invertebrate larvæ are encountered and of these, nauplii, lamellibranch and *Cyphonautes* larvæ are particularly noteworthy. *Oikopleura* may be very common. Chætognaths and tintinnids often few. Fish eggs few. A few hydromedusæ and *Evadne* may be present. *Lucifer* rare.

November—

1. Sea calm. Rainfall usually at a maximum.
2. There is a drop in salinity and temperature; the latter ranges from 25·0 to 29·8° C. while the former between 28·91 and 36·76‰.

3. The total standing crop tends to decrease. The mean monthly plankton volume varies from 11·2 to 17·7 ml.
4. The phytoplankton population shows an abrupt decrease. Most of the common diatoms recorded in October still persist but in very much fewer number. Dinophyceæ few.
5. Zooplankters continue to be prominent. Copepods plenty. *Noctiluca* may appear in large numbers. Chætognaths and *Lucifer* may be common. Hydromedusæ reappear in appreciable numbers. *Oikopleura* fairly common. Invertebrate larvæ few. Few *Evadne*, *Penilia* and *Creseis* generally appear. Fish eggs few. Tintinnids rare.

December—

1. Sea calm.
2. Salinity and temperature fall still further. The ranges are 25·46 to 30·81‰ and 24·0 to 28·0° C. respectively.
3. The total standing crop of plankton generally low. The mean monthly plankton volume fluctuates between 7·2 and 18·0 ml.
4. Phytoplankton shows a further decrease in quantity but several species of diatoms recorded in November are still represented in the plankton.
5. The plankton becomes predominantly zooplanktonic. Copepods increase and are abundant. Chætognaths and *Lucifer* may be common. *Oikopleura* few. Invertebrate larvæ generally few but nauplii may be common. Hydromedusæ few. A few *Creseis* may be present. *Pleurobrachia* and *Beroë* rare. Fish eggs few.

Palk Bay

January—

1. Sea somewhat turbulent.
2. Surface salinity low and generally the lowest values are recorded. The range varies from 24·76 to 28·8‰.
3. The total standing crop of plankton is invariably at its lowest; the mean monthly net plankton volume varies from 9·0 to 14·6 ml.
4. Phytoplankton is at a low level. *Isthmia*, *Asterionella* and *Bacillaria* are the diatoms usually present. Dinophyceæ rare.
5. Zooplankton poor but in general these predominate. Copepods very common. Siphonophores such as *Physalia* and *Porpita* are common while *Diphyes* are few. *Creseis* and *Janthina* common. *Lucifer* may occur in fair numbers. Chætognaths few. Invertebrate larvæ few. Few hydromedusæ, *Pleurobrachia* and *Beroë* may be encountered. Fish eggs rare.

February—

1. Sea remains somewhat turbulent.
2. Salinity shows an upward trend and fluctuates from 26·91 to 30·16‰.
3. The total volume of standing crop of plankton increases slightly and the mean monthly net plankton volume varies from 11·0 to 17·3 ml.
4. Phytoplankton shows a slight increase but is still scarce. The diatoms recorded in January continue to be present. *Trichodesmium* rare. Dinophyceæ rare.
5. Zooplanktonic elements dominate and they tend to increase. No marked changes in the copepod population. *Physalia* and *Porpita* continue to be common, whereas other siphonophores are few. Chætognaths few. *Creseis, Janthina* and *Lucifer* may be common. Few hydromedusæ, *Pleurobrachia* and *Beroë* may be present. Fish eggs few. There is generally an increase in the invertebrate larvæ. Decapod, gastropod and *Cyphonautes* larvæ are the most common.

March—

1. Sea becomes calm.
2. Salinity ranges from 28·33 to 31·56‰.
3. There is a general increase in the total standing crop of plankton; the mean monthly plankton volume fluctuates from 11·7 to 24·6 ml.
4. Phytoplankton shows a slight increase but is still at a low level. No appreciable difference in the species composition of the diatom population from that of the previous month. Dinophyceæ, particularly species of *Ceratium*, begin to appear in moderate numbers.
5. Zooplankton shows an increase and remains the dominant component. Copepods are abundant. Numerous invertebrate larvæ are characteristic during this month and particularly those of decapods, lamellibranchs and gastropods. Polychæte larvæ are few and echinoderm larvæ rare. Fish eggs abundant. *Creseis* may appear in large numbers. Chætognaths and *Lucifer* usually few. Appendicularians (mostly *Oikopleura*) usually start appearing. Hydromedusæ few. Few siphonophores and *Noctiluca* may be present.

April—

1. Sea remains calm.
2. Salinity ranges from 29·61 to 32·45‰.
3. The total standing crop of plankton shows a further increase and the mean monthly plankton volume varies from 18·5 to 28·7 ml.

4. There is a noticeable increase in the phytoplankton. *Chætoceros* and *Thalassiothrix* are usually the most abundant diatoms. Dinophyceæ are common and in some years *Trichodesmium* may also be common.
5. Zooplankton increases and continues to be the dominant element. Swarms of *Noctiluca* may appear. Hydromedusæ abundant. Copepods plenty. Chætognaths, *Oikopleura*, *Creseis*, siphonophores and tintinnids are generally common. Invertebrate larvæ, in general, show a decrease. *Pleurobrachia* and *Beroë* few. Few *Evadne* and *Penilia* may occur. Fish eggs scarce.

May—

1. Sea calm.
2. Salinity increases further and varies from 30·72 to 33·78‰.
3. The standing crop of plankton shows no significant difference in quantity from that of April; the mean monthly plankton volume ranges from 18·0 to 27·3 ml.
4. Phytoplankton shows a remarkable increase and becomes the dominant element. *Chætoceros*, *Rhizosolenia*, *Bacteriastrum*, *Biddulphia*, *Thalassiothrix*, *Thalassionema* and *Coscinodiscus* are the more common diatoms. There is an increase in the number of dinophyceæ and several species of *Ceratium* and *Peridinium* are common. *Trichodesmium* few.
5. Zooplankton shows a decrease. *Noctiluca* may be present in swarms. Copepods plenty. Tintinnids, *Evadne*, siphonophores and *Oikopleura* common. Nauplii, larvæ of polychætes, echinoderms, decapods, lamellibranchs and gastropods common. Hydromedusæ, *Lucifer* and chætognaths few. Scyphomedusæ such as *Dactylometra*, *Lobonema*, *Mastigias* and *Rhopilema* appear in small numbers. Fish eggs scarce.

June—

1. Sea remains calm.
2. Salinity varies from 32·86 to 34·67‰.
3. Standing crop of plankton increases and often reaches a peak; the mean monthly plankton volume ranges from 25·8 to 35·2 ml.
4. Phytoplankton shows a further increase and the summer maximum is usually reached in June. In addition to the common diatoms which were present in May, *Leptocylindrus*, *Nitzschia* and *Pleurosigma* may also become common. Dinophyceæ common.
5. Zooplankton shows a decrease. Swarms of *Noctiluca* may appear intermittently. Copepods plenty. Tintinnids, *Oikopleura* and chætognaths common. *Dactylometra* and *Rhopilema* are common, whereas *Lobonema*

are rare. Invertebrate larvæ few, common amongst them being nauplii and larvæ of echinoderms and decapods. Few siphonophores, *Creseis*, *Evadne* and *Penilia* may occur. Fish eggs rare.

July—

1. Sea calm.
2. Salinity ranges from 32·83 to 35·91‰.
3. Total standing crop of plankton shows a decrease, the mean monthly plankton volume varies from 10·5 to 36·0 ml.
4. There is generally a sharp decrease in the phytoplankton population but all the species of diatoms recorded during the last month continue to be present. Dinophyceæ may be common.
5. Zooplankton shows a definite increase. Swarms of *Noctiluca* may continue to appear. Copepods abundant. Chætognaths and *Oikopleura* common. *Lobonema* common, whereas *Rhopilema* and *Dactylometra* are few. Invertebrate larvæ show an increase. Larvæ of decapods, gastropods, lamellibranchs and polychætes most common. *Lucifer* few. Tintinnids, hydromedusæ, *Evadne*, *Penilia* and fish eggs rare.

August—

1. Sea calm.
2. Salinity continues to increase and ranges from 33·24 to 36·42‰.
3. There is very little change in the total standing crop of plankton, the mean monthly plankton volume fluctuating between 10·2 and 37·0 ml.
4. Phytoplankton shows a further decrease but diatoms are still abundant. The species composition of the diatom population is comparable to that of June–July but with variations in the proportion of the different species. Dinophyceæ decrease. *Trichodesmium* rare.
5. Zooplankton shows generally a slight decrease. *Noctiluca* continues to occur, occasionally in abundance. Copepods abundant. *Oikopleura* and chætognaths very common and the former reach their peak either in July or in August. Invertebrate larvæ common, amongst them larvæ of decapods, gastropods, lamellibranchs and polychætes are prominent. *Cyphonautes* may also occur in fair numbers. *Evadne* and *Penilia* may be common. Tintinnids, hydromedusæ and fish eggs few. Few *Creseis* and *Lucifer* may appear.

September—

1. Sea becomes somewhat rough by the middle of the month.
2. Salinity reaches the maximum and ranges from 33·75 to 37·45‰.

3. The standing crop of plankton increases and the mean monthly plankton volume varies from 19·2 to 38·2 ml.

4. Phytoplankton tends to increase. There are no striking differences in the species composition of the diatom population from that of the last three months but in quantity the various species show differences. Dinophyceæ may increase slightly in number. *Trichodesmium* few.

5. The quantity of total zooplankton does not show a marked deviation from that of August. Large number of *Noctiluca* may continue to appear. Copepods abundant. Chætognaths very common and they usually reach their peak in August–September. *Oikopleura* and hydromedusæ common. Invertebrate larvæ plenty. Decapod and gastropod larvæ are the most common while lamellibranch and polychæte larvæ are few and echinoderm larvæ rare. Fish eggs fairly common. *Evadne* and *Penilia* may be common. *Lucifer* few. Tintinnids rare.

October—

1. Sea continues to be rough. North-east monsoon, the rain-bearing monsoon of this region, breaks out sometime during this month.

2. Salinity remains high and ranges from 33·04 to 37·45‰.

3. The volume of total standing crop of plankton shows a downward trend; the mean monthly plankton volume varies from 15·2 to 39·0 ml.

4. Phytoplankton starts decreasing but most of the species of diatoms recorded during the preceding few months are still represented. Dinophyceæ generally few. *Trichodesmium* may occur in small numbers.

5. Zooplankton increases. *Noctiluca* may continue to occur occasionally in swarms but are not so common as in the previous months. Copepods abundant. Invertebrate larvæ common particularly those of decapods and gastropods. Polychæte and lamellibranch larvæ are also somewhat common at times. Tintinnids may be common. Chætognaths and fish eggs fairly common. *Creseis* and *Oikopleura* few, so also hydromedusæ. *Evadne* may be present.

November—

1. Sea very rough. The vigour of the north-east monsoon usually reaches a peak.

2. There is a perceptible fall in the surface salinity, the range varying from 27·65 to 36·58‰.

3. The total standing crop of plankton shows a further decline and the mean monthly plankton volume ranges from 15·6 to 25·7 ml.

4. There is a remarkable decrease in the phytoplankton population. Species of *Chætoceros* remain as the most common diatom while others recorded during the previous months have either completely disappeared or are rare. Dinophyceæ generally few. Few *Trichodesmium* may occur but generally rare.

5. Zooplankton shows a decrease but by now the nature of plankton becomes predominantly zooplanktonic. Copepods plenty. Invertebrate larvæ common. *Cyphonautes*, polychæte, echinoderm, decapod, lamellibranch and gastropod larvæ are all present. Hydromedusæ, chætognaths, *Oikopleura* and fish eggs few. Few *Evadne* and *Penilia* may be present. *Porpita* few.

December—

1. The north-east monsoon continues though less vigorous now. Sea remains turbulent.
2. There is a further fall in the salinity which ranges from 26·44 to 32·50‰.
3. The total standing crop of plankton decreases and the mean monthly net plankton volume fluctuates between 6·5 and 23·0 ml.
4. A further decrease in the phytoplankton is noticed and the diatoms present mostly belong to the genus *Chætoceros*. Dinophyceæ rare.
5. Zooplankton shows an increase and the plankton is characteristically zooplanktonic. Copepods abundant. The siphonophores *Physalia* and *Porpita* are common. Invertebrate larvæ common, particularly those of decapods, gastropods and polychætes. At times plenty of *Cyphonautes* larvæ may appear. *Lucifer* may be common. Hydromedusæ, chætognaths and *Oikopleura* few. Fish eggs rare.

A Note on the Productivity of the Areas

Planktological investigations in the inshore waters of the Gulf of Mannar and Palk Bay (Prasad, 1954 *a*, 1954 *b* and 1956) have revealed the interesting fact that the production and characteristics of plankton of these two regions, the water masses of which are contiguous, show remarkable differences. Undoubtedly there are many factors contributing to these differences. The topographical conditions as well as the morphometric features of the regions, wind, currents and such other dynamic factors also have an important bearing on plankton productivity.

The Gulf of Mannar is wide open at the southern end and is subject to incursions of water masses from the Indian Ocean and the Arabian Sea (see Prasad, 1954 *a*), while Palk Bay is more or less enclosed. The Palk Bay

is relatively shallow, depth not exceeding 8 fathoms in any region but in the Gulf of Mannar beyond 10–15 miles from the shore there is a sharp increase in depth, which may exceed 100 fathoms (*Admiralty Chart No.* 68 *a*, New Edition, July 21, 1950), and the regions where the present observations were conducted are comparable to two distinct types of environment, one characteristic of the open coasts* and the other that of Bays.

Jayaraman (1954) has described the seasonal variations in salinity, dissolved oxygen and nutrient salts in the inshore waters of the Gulf of Mannar and Palk Bay near Mandapam and with the additional data collected† subsequent to the publication of the above report it seems now certain that there are noticeable differences in the hydrological conditions of the water masses of these regions. The salinity, *e.g.*, of the surface waters is consistently higher from January–September and in December in the Gulf of Mannar but it is practically the same in October–November in the two regions. Similarly the dissolved oxygen in the surface waters is almost always higher in the Gulf of Mannar. This higher oxygen concentration is to be expected because of the greater coral reef formation in the Gulf of Mannar and other factors already discussed in an earlier paper by the author (Prasad, 1956). Silicates are invariably lower in the Gulf of Mannar which may indicate the possibility of greater land drainage into Palk Bay and further the more oceanic nature of the waters of the Gulf of Mannar (high salinity and low silicate). The concentration of nutrient salts also show certain interesting variations. Phosphate, which is considered at present to be an index of potential productivity, is found to be slightly higher in the Gulf of Mannar during several months, whereas nitrate is often lower. This lower concentration of nitrate in the coastal waters of the Gulf of Mannar may be due to higher population of denitrifying bacteria (Velankar, 1955).

Total plankton production.—The total plankton production, as indicated by the standing crop,‡ is considerably greater in Palk Bay during the months of April–December and the average total annual production is about one and a half times that of the Gulf of Mannar. The maximum in the Gulf of

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* Running parallel to the coast at distances ranging from 1 to 5 miles are a series of small islands, mostly of coral origin, in the Gulf of Mannar. As these islands are situated far apart they do not offer any great protection to the coastal waters.

† The author's thanks are due to Shri R. Viswanathan for making the data available.

‡ A word of caution is necessary here because the standing crop by itself cannot be considered strictly as a measure of production particularly in the tropics but for want of facilities to estimate the crops and rates of production at different tropic levels the present discussion had to be based only on the standing crop.

Mannar and Palk Bay fall in different months, usually in March and June respectively. During the second half of the year the trend in fluctuations of the quantity of plankton generally shows a similarity. The annual cycle of production of plankton in the Gulf of Mannar is distinctly dicyclic, whereas this does not seem to be the case in Palk Bay (Fig. 1).

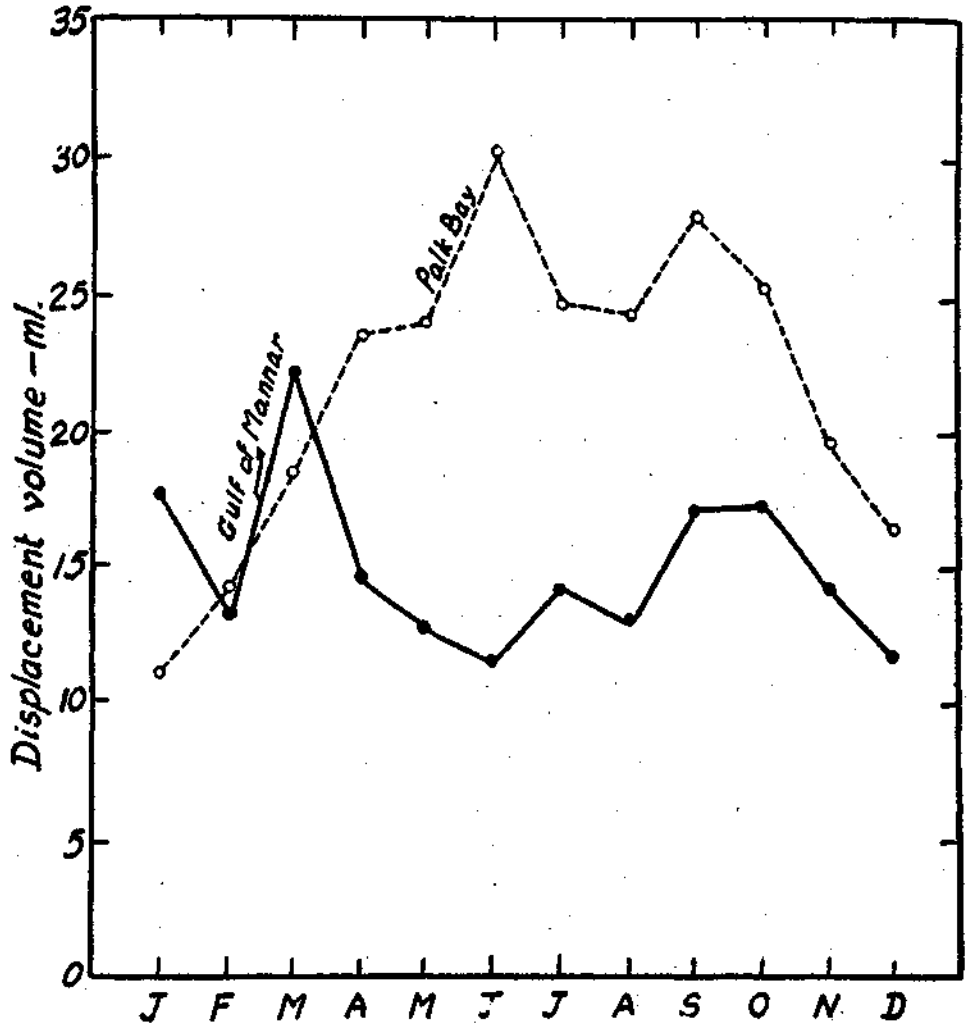

FIG. 1. The standing crop of total plankton (plankton volume) in the Gulf of Mannar and the Palk Bay. Figs. 1–3 are based on averages for 5 years.

Phytoplankton.—The total annual phytoplankton production in Palk Bay, again judged from the standing crop, is a little over one and a half times that of the Gulf of Mannar. This apparently lower phytoplankton production in the Gulf of Mannar is perhaps attributable to the presence of extensive

coral reefs there. Yonge *et al.* (1932) remarked that the great majority of reef animals (almost all cœlenterates, some foraminiferans, tunicates, etc.) possess zooxanthellæ which intercept the nutrient salts which would otherwise be excreted into the water, so that only a very limited phytoplankton can exist. Its place is taken up by the zooxanthellæ which are essentially imprisoned phytoplankton and if the coral and other reef animals did not possess these within their tissues, the great quantities of nutrient salts which they would discharge into the water would permit the growth of an abundant phytoplankton population. This, according to Yonge *et al.* (*op. cit.*), would develop so rapidly in the bright light and utilize the nutrient salts at a rate that would probably prevent the diffusion of these far from the reefs and there would be a very abundant phytoplankton in the waters actually washing the reefs. In estimating the total phytoplankton production of the two areas under discussion we have to take into account the permanent imprisoned phytoplankton too, and considering this it may be safe to assume that the total production in the Gulf of Mannar may be equal to or even slightly higher than that of Palk Bay.

The distribution pattern in the two regions is different and phytoplankton production reaches its highest level in Palk Bay in summer, May–June, and often during the second half of the year, in October, in the Gulf of Mannar. In Palk Bay the highest level of phytoplankton population is higher and the lowest lower than in the Gulf of Mannar. An increase in phytoplankton leading to the first significant peak, the summer peak, commences in the Gulf of Mannar in March, while in Palk Bay any appreciable increase is noticed only towards April. In the Gulf of Mannar the time of appearance of the first and second phytoplankton peaks precedes and follows respectively that of the corresponding peaks in Palk Bay (Fig. 2).

One cannot fail to notice the possible relationship between the monsoons and phytoplankton maxima. The highest peak in an area seems to follow rather closely the particular monsoon causing turbulence, which 'stir up' the water resulting in the replenishment of the plant nutrients from the bottom, and coincides somewhat with the resumption of calm conditions when the water becomes relatively free from the detritus brought up from the bottom and kept in suspension during the period of turbulence (see Prasad, 1954 *a*). In the case of Palk Bay the north-east monsoon causes the turbulence and in the case of the Gulf of Mannar the south-west is responsible. Thus, the highest peak in the Gulf of Mannar is in October and in Palk Bay in June although there is apparently a greater time lag between the establishment of the calm conditions and the time of maxima in the latter region. The

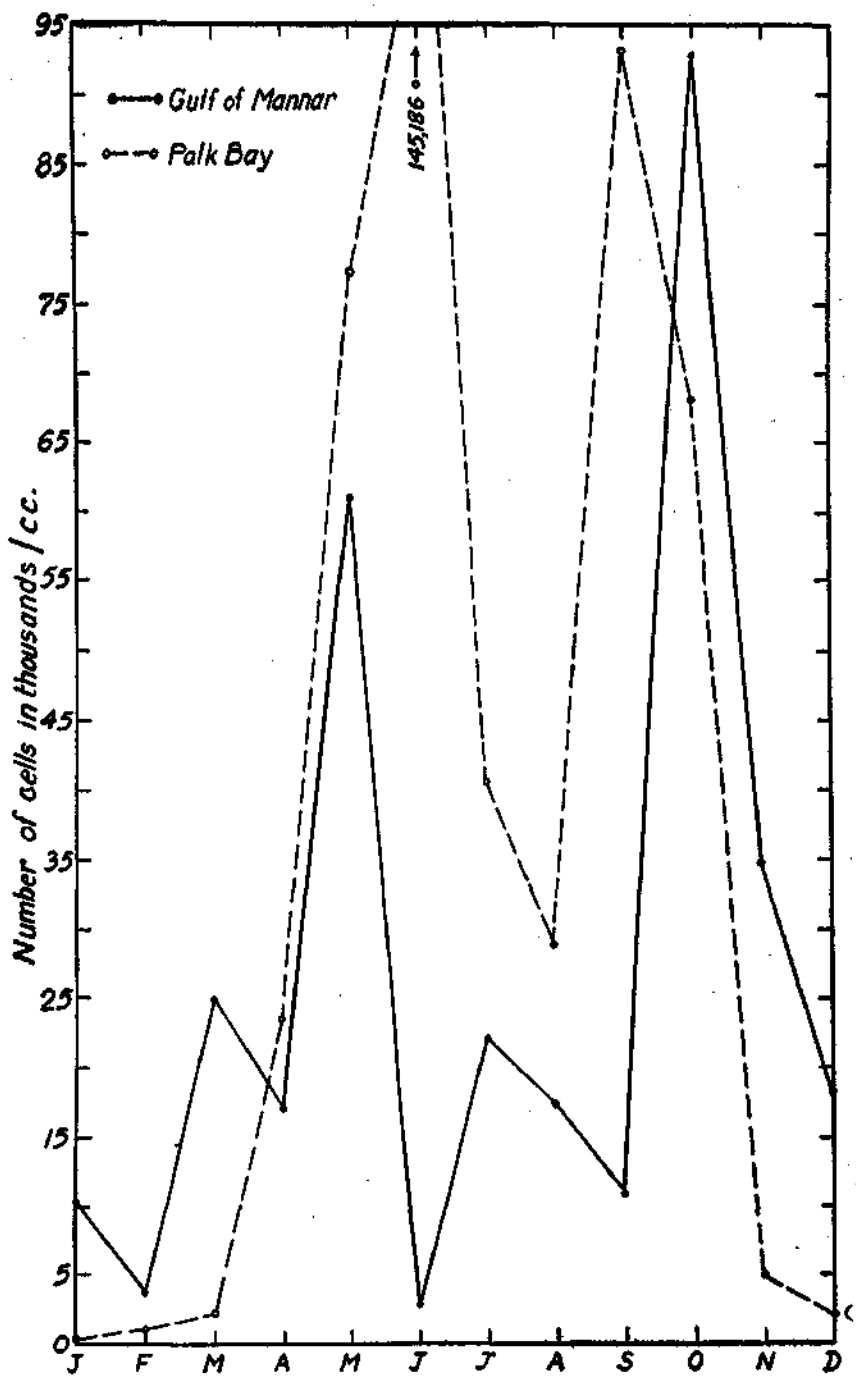

FIG. 2. Phytoplankton population of the Gulf of Mannar (continuous line) and the Palk Bay (broken line).

smaller peak of one area, on the other hand, occurs almost at the same time as that of the highest peak of the other region, *i.e.*, following the monsoon that does not directly affect the area. Tham Ah Kow (1953) noticed in the Straits of Singapore that the periods of high diatom numbers coincided more or less with periods of " changeover " from one monsoon to the other when the temperature and salinity conditions were at a maximum and the seas calm with the current drifts reversed causing a sort of circulation similar to upwelling in the whole area.

Zooplankton.—The average annual production of zooplankton in the two areas does not show the same degree of difference which the phytoplankton population of these regions exhibits and in Palk Bay it is only about 9 per cent. more than that of the Gulf of Mannar. The distribution pattern is apparently unimodal in the Gulf of Mannar, while it is not in Palk Bay where the population shows greater fluctuations (Fig. 3). It is also clear from this figure that at the time when zooplankton is at its lowest in the Gulf it is high in Palk Bay and *vice versa*. In Palk Bay zooplankton, on an average, is considerably low in January–February and in December the population in both regions is often of the same magnitude.

The most important group of zooplankters—the copepods—show certain differences in their annual standing crop, distribution pattern and percentage in the total zooplankton. In the Gulf of Mannar the annual standing crop of copepods is about 15 per cent. more and their annual percentage in the total zooplankton varies from 44·1 to 73·6, while in Palk Bay it ranges from 23·4 to 68·7. It may also be added that the crustacean plankton as a whole seems to be richer in the Gulf of Mannar.

In the light of what has been said above it may not be too speculative to suggest here that the waters of the Gulf of Mannar are inherently rich in nutrient salts and may even be richer than the waters of Palk Bay with the potentiality to produce a greater biomass, particularly so since it is believed that a tongue of the Antarctic bottom water rich in nutrients strikes the south end of Ceylon and upwells in the Gulf of Mannar (Sewell, 1932).§ Although the production in terms of plankton alone is lower in the inshore waters of the Gulf of Mannar a consideration of the total biomass of the two areas tend to suggest that it may be greater in the Gulf of Mannar. It is rather a difficult task at this stage to estimate the total biomass of these areas for comparison; moreover the ultimate purpose of these investigations is not to assess the

§ The upwelling taking place along the east coast of India during the months March to May, however, does not seem to extend to this region and according to LaFond (1955) the southernmost limit of this upwelling extends only up to the south of the Godavari Delta.

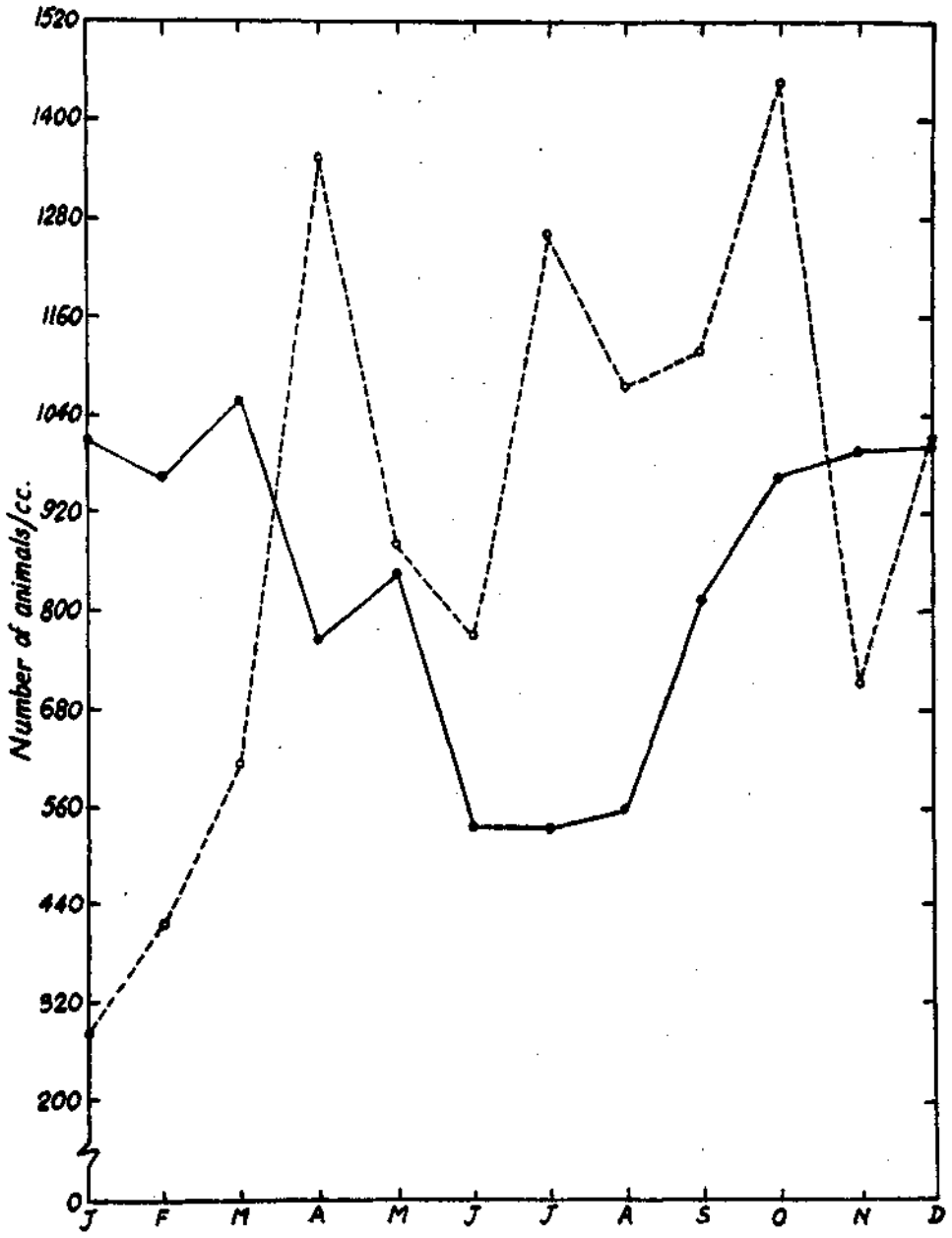

FIG. 3. Zooplankton population of the Gulf of Mannar (continuous line) and the Palk Bay (broken line).

total biomass of these regions but only to evaluate the "useful plankton production" which contributes to the food of fishes and the dependence of

fish production on plankton production and for the elucidation of this a study of the relation between plankton production and fish production in this area is in progress.

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