THE CHARACTERISTICS OF MARINE PLANKTON AT AN INSHORE STATION IN THE GULF OF MANNAR NEAR MANDAPAM

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CONTENTS

I. Introduction

A study of the plankton of the inshore waters of the Gulf of Mannar was started in 1950 as a part of the programme of work carried out at the Central Marine Fisheries Research Station. As plankton forms directly or indirectly the food of fishes the primary object of this investigation is to get a general picture of the changes in the total plankton concentration, as indicated by fluctuations in the net-plankton volume, as well as the plankton composition and its relation to local fisheries. The present paper attempts to describe

the gross qualitative and quantitative variations in the plankton and compare them with those observed at other places along the coasts of India. Further, the occurrences of pelagic fish during the two years of this investigation in and around the area are compared.

The only detailed work on the plankton of this area is by Chacko (1950) who has described the plankton from the waters around the Krusadai Island based on data collected from various stations. He has given a list of both phyto- and zoo-planktonic elements occurring in the area and has remarked that: "The plankton of the waters around Krusadai is rich both in bulk and variety. Most of the important species appear to be cosmopolitan in distribution. The maximal period of phytoplankton is from June to November, and that of zooplankton from October to April."

Plankton studies in many places have indicated wide fluctuations both in the occurrence and distribution of plankton and hence the period over which these observations have been made is too short to permit the drawing of definite general conclusions. Therefore, those given below relate only to the conditions that existed during the period of this investigation. Prasad *et al.* (1952) have observed that there is unevenness in the distribution of plankton in the area investigated and consequently the observations included here are restricted to a single station.

The author wishes to thank Dr. N. Kesava Panikkar for his comments and criticisms.

II. Material and Methods

The study is based on 154 plankton samples collected in the period between January 1950 and December 1951 from a station approximately two miles off the coast (Fig. 1). The collections were made in fifteen-minute surface hauls by a 50 cm. diameter net made of organdie cloth (*ca.* 36 strands/cm.) towed from a catamaran between 06 00 and 07 00 hours in order to minimise the effects of any possible vertical movements of zooplankters.

After preserving the samples in 5 per cent formaldehyde, the volume of each haul was determined by the displacement method (Sheard, 1947). The method adopted in the enumeration of the various elements was the same as that described by Prasad *et al.* (*op. cit.*). A very detailed qualitative analysis was not attempted for want of facilities. Similarly on the quantitative side too, no great accuracy is claimed for the data, but it is assumed that the fluctuations observed are not entirely due either to errors of sampling or enumeration. Further, as Bigelow and Sears (1939) have remarked: "No modern student of plankton, we fancy, should claim that quantitative calculations, based on tow nettings, can be any more than approximations to the truth." The author is fully conscious of the limitations of this paper but nevertheless he felt that this report will be of value in giving a

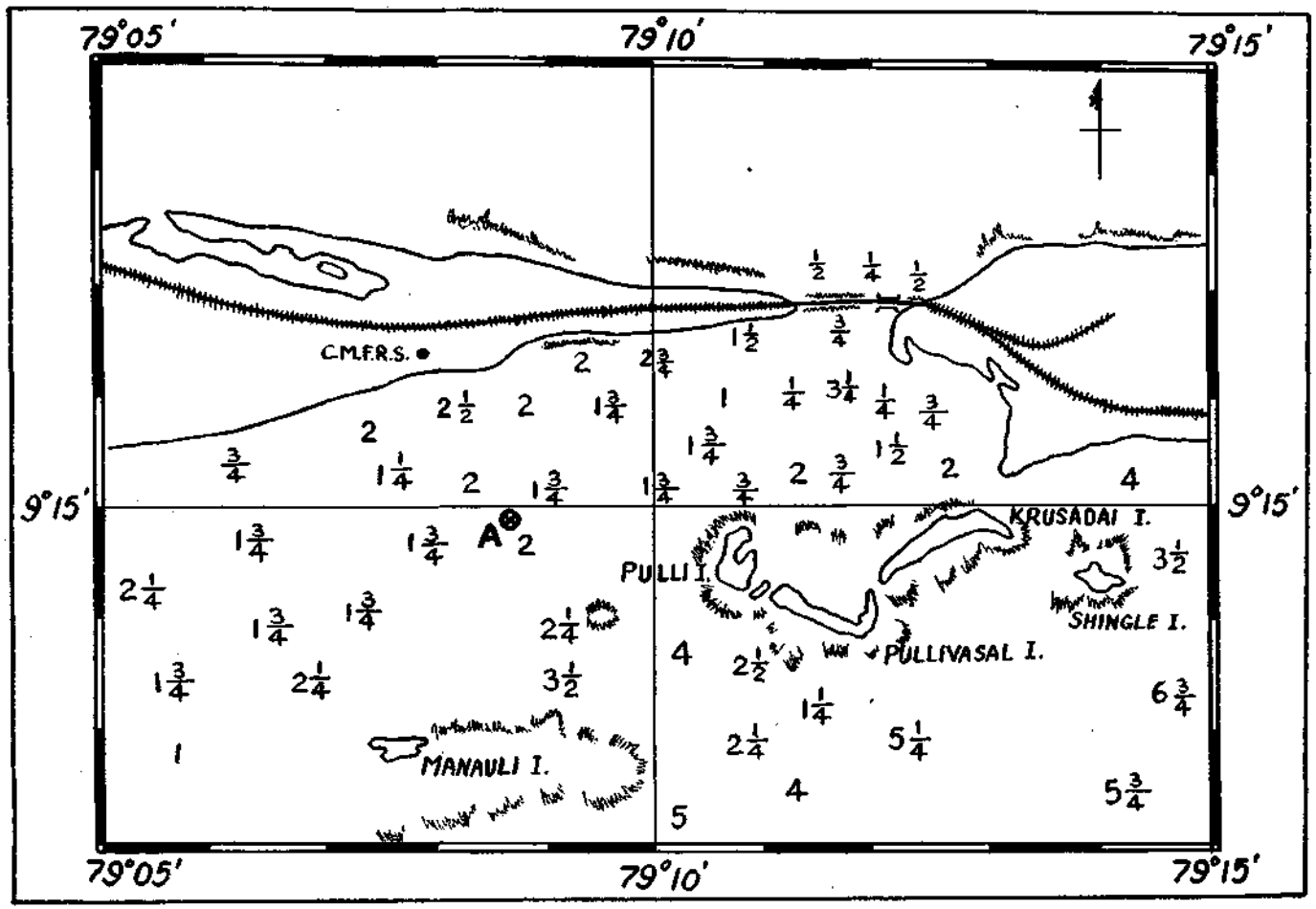

FIG. 1 showing the location of station A in the Gulf of Mannar. The numbers in the figures indicate the depth in fathoms.

general picture of the changing plankton community and the gross changes that take place from month to month.

III. Hydrological and Meteorological Features of the Area

The region from where the plankton samples were collected is an area of shallow water with extensive coral reef formation (Fig. 1), its depth not exceeding three fathoms.

The average atmospheric temperatures for the different months during 1950–51 varied from 24·50° C. to 29·94° C. (Table I). The surface temperatures at the time of collection of plankton are shown in Figs. 2 and 3. The maxima recorded in April were 31·50° C. in 1950 and 30·60° C. in 1951 and the minima 24·00° C. and 24·60° C. in 1950 January and 1951 December respectively. But it is obvious from these figures that in 1950 and 1951 there is a similarity in the trend of fluctuations, the maxima occurring during the summer months (April-May) and the minima during the winter periods (December-January). The monthly averages of surface temperatures are given in Table I.

Table I

Monthly average values of atmospheric and surface temperatures and the rainfall for 1950 *and* 1951

Month	1950			1951		
	Atmospheric temperature ° C.	Surface temperature ° C.	Rainfall (in.)	Atmospheric temperature ° C.	Surface temperature ° C.	Rainfall (in.)
January ..	24·50	24·30	2·1	25·97	25·53	3·8
February ..	25·50	25·55	1·7	26·62	26·07	1·1
March ..	26·70	26·89	2·2	28·47	27·90	0·3
April ..	29·55	29·50	1·1	29·07	29·48	8·4
May ..	29·24	29·10	0·4	29·94	29·32	0·4
June ..	27·90	27·30	0·0	29·18	27·66	0·0
July ..	27·74	27·40	0·0	28·80	27·72	0·2
August ..	27·53	27·94	1·3	28·70	28·80	0·0
September ..	27·54	27·30	0·0	28·61	28·88	2·5
October ..	27·11	27·60	5·8	28·32	28·13	1·8
November ..	27·53	27·65	8·6	26·71	27·81	15·3
December ..	26·49	25·65	3·0	25·41	25·97	6·5

Although the area is exposed to both the southwest and northeast monsoons, the rainfall during the former is negligible and the major portion

of the 36 inches of annual normal rainfall is accounted for by the northeast monsoon. The actual rainfall for the two years is given in Table I. During the southwest monsoon the waters in the Gulf of Mannar become turbulent owing to strong winds, and this condition may continue up to August. Generally speaking, it may be said that the drift of water in this area is from south to north during April to August (which coincides with the period of the southwest monsoon and of turbulence). From September onwards, *i.e.*, with the onset of the northeast monsoon the direction of the drift is reversed and during this period comparatively calm conditions prevail in the Gulf.

The salinity, phosphate and nitrate values for the surface waters collected from the station are given in Table II. (See also Shri Jayaraman's paper in this *Journal*.)[1]

TABLE II

Monthly average values of salinity, phosphate and nitrate for 1950 *and* 1951

Month	1950			1951		
	Salinity ‰	Phosphate mg./m.^{3}	Nitrate mg./m.^{3}	Salinity ‰	Phosphate mg./m.^{3}	Nitrate mg./m.^{3}
January ..	28·85	7·4	34·5	28·97	5·3	40·3
February ..	30·05	8·4	44·4	30·38	5·8	36·0
March ..	30·81	6·2	40·4	31·54	7·2	43·6
April ..	33·55	6·6	47·0	33·08	5·3	38·0
May ..	36·41	6·5	30·0	..	..	..
June ..	35·53	7·4	30·3	..	..	..
July ..	35·77	8·6	15·1	35·81	6·5	57·0
August ..	36·34	7·7	31·5	35·78	6·0	46·0
September ..	35·82	6·5	15·8	36·02	8·0	36·0
October ..	35·89	4·9	34·5	35·99	7·1	48·0
November ..	32·76	4·9	38·9	33·96	5·6	56·0
December ..	29·44	5·4	33·4	29·50	5·5	48·0

Regular observations on the transparency of the water were not attempted but occasional readings made with the Secchi disc showed that visibility may be reduced to as low as three feet when turbulent conditions prevail. This is mainly due to the large quantities of suspended debris.

[1] The data on salinity, phosphate and nitrate were supplied by Mr. R. Jayaraman, Central Marine Fisheries Research Station, to whom the author wishes to express his thanks.

IV. Standing Crop of Plankton

The standing crop has been estimated by the displacement method, and the plankton volumes for 1950–51 are shown in Figs. 2 and 3. Although there is an agreement in the general trend in fluctuations of the volume, striking differences are observed in the actual volumes obtained for different days of the same month, the different months of the same year as well as the same months of the two years. In 1950 the maximum standing crop occurred in March and September-October while in 1951 it was in February-March and September. The minimum for 1950 was in December, whereas that for 1951 was in October. The mean plankton volumes are given in Table III. It will also be noticed from this table that there is a marked difference between the standing crops for 1950 and 1951, the crop for the latter year being much less. It may be mentioned here that the surface temperature is of a higher order for all the months in 1951, but whether this has anything to do with the lower standing crop observed, it is difficult to say at this stage.

Table III

Monthly average displacement volumes for 1950 *and* 1951

Month	Average displacement volume (ml.) 1950	1951
January ..	13·6	11·9
February ..	10·1	19·6
March ..	29·3	19·2
April ..	12·1	13·7
May ..	19·0	..
June ..	20·0	..
July ..	18·6	13·0
August ..	22·0	13·0
September ..	31·0	18·2
October ..	28·0	9·2
November ..	13·0	13·0
December ..	7·2	12·0

It has already been pointed out that during the period of the southwest monsoon turbulent conditions exist in the coastal areas where the water becomes charged with a considerable amount of silt, and that the transparency of waters is very much reduced. By about September, comparatively calm conditions are established and with the resumption of this and following the southwest monsoon period, the standing crop reaches its maximum sometime in September. From October to January the level of standing

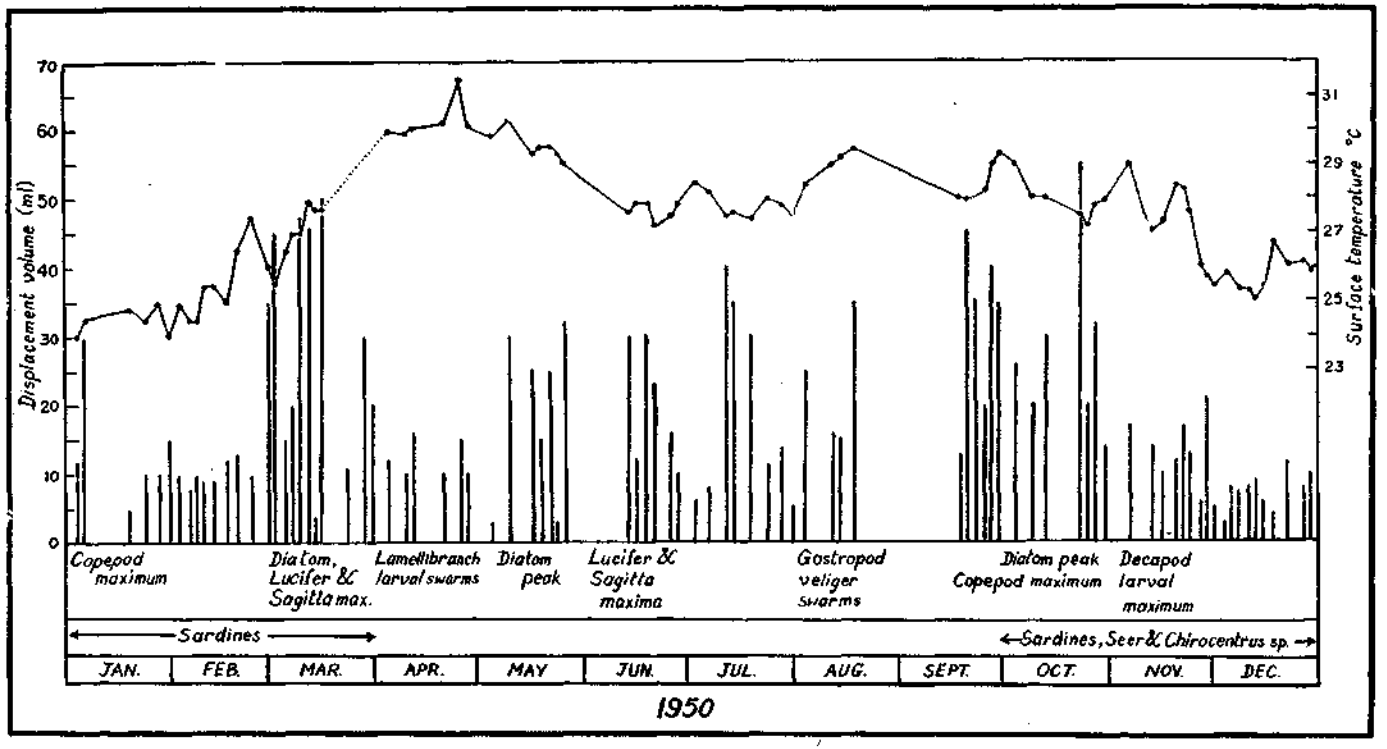

FIG. 2 showing the net-plankton volume, surface temperature, the important planktonic elements and the occurrence of pelagic fish for 1950.

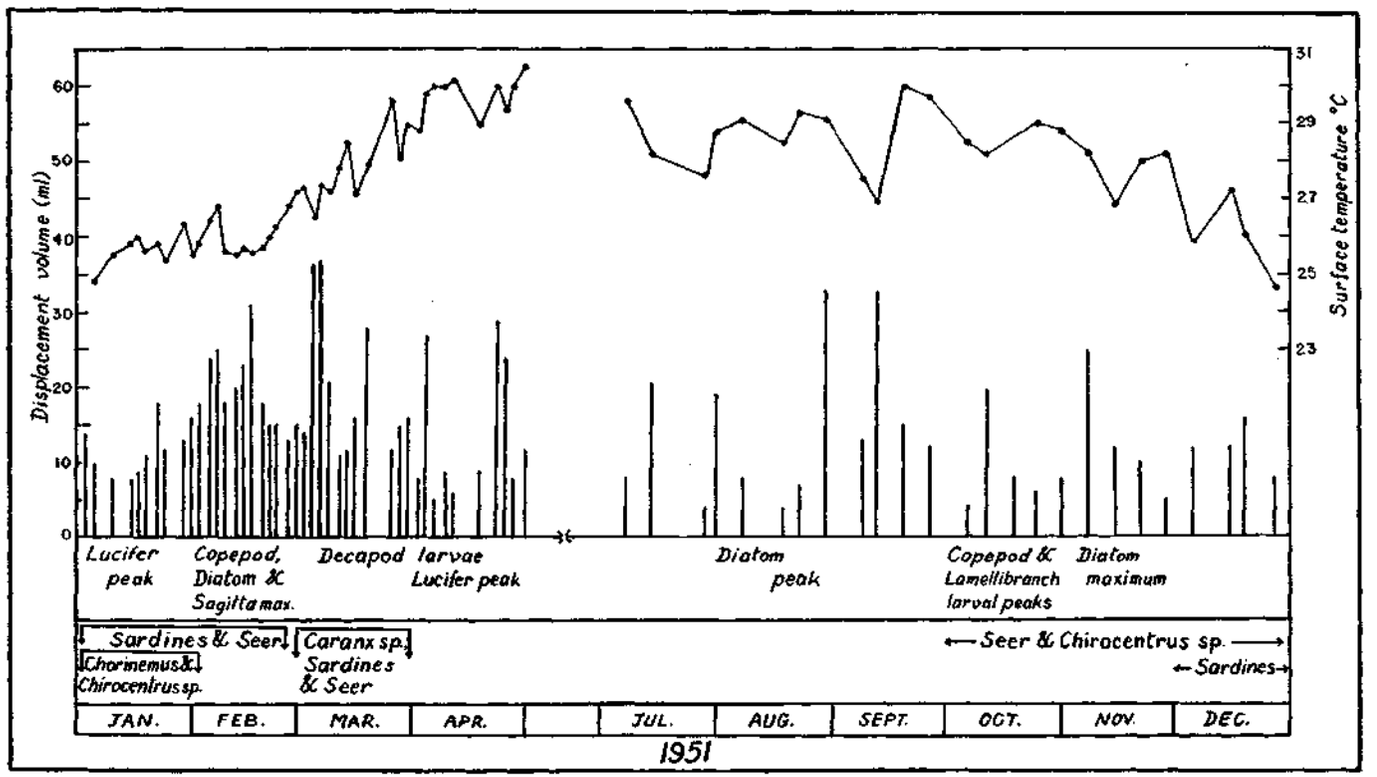

FIG. 3. The net-plankton volume, surface temperature, the important planktonic elements and the occurrence of the pelagic fish for 1951.

crop is rather low but soon after the northeast monsoon (October-December) the standing crop of plankton again increases reaching a peak in February or March. The period when the production is at its minimum is approximately from April to July and October or November to January or February, the latter period showing a lower standing crop than the former.

V. PHYTOPLANKTON

The distribution of the total phytoplankton including dinophyceæ, as cells per c.c. of the standardized sample, is shown in Fig. 4. In compiling this figure the planktonic blue-green alga *Trichodesmium erythræum* has not been considered. Tables IV to VII show the fluctuations in the quantity of the various species of diatoms and dinophyceæ. The general trend in the distribution, as can be seen from the figure, is almost the same during the years 1950 and 1951. There is apparently more than one phytoplankton maximum during a year, the summer bloom occurring in May with other maxima in February-March and also during August-November.

(*a*) *Diatoms.*—The study has revealed the interesting fact that the summer maximum as well as the one occurring during the second half of the year (August-November) is caused by the flowering of more than one genus and several species. The blooms that occur during the early part of the year (February-March) are of a single species of diatom rapidly multiplying. After reaching its peak this species falls within a few days to an insignificant rank in the flora. While in March 1950 the species concerned was *Rhizosolenia alata*, in February 1951 it was *R. imbricata*.

As already stated the summer abundance as well as the one during August-November is the cumulative effect of several species of diatoms flowering together. For example, during May 1950 the bulk of the phytoplankton was composed of several species of *Chætoceros* (mostly *C. lorenzianus*, *C. peruvianus*, *C. indicus*, *C. diversus* and *C. denticulatum*), *Thalassionema nitzschioides*, *Thalassiothrix frauenfeldii*, *Asterionella japonica*, *Biddulphia sinensis*, *B. mobiliensis*, *Bacteriastrum varians*, *Bacillaria paradoxa*, *Rhizosolenia styliformis*, *et cetera*. Similarly, the October outburst consisted chiefly of *C. lorenzianus*, *C. peruvianus*, *C. indicus*, *C. coarctatus*, *C. diversus*, *T. frauenfeldii* and several species of *Rhizosolenia* (mostly *R. alata*, *R. styliformis* and *R. imbricata*). Such forms as *Pleurosigma* spp., *Bacillaria paradoxa*, *Nitzschia* spp., *Schröderella delicatula*, *Bacteriastrum hyalinum* and *Thalassionema nitzschioides* were also present in fair numbers (Tables IV to VI and Fig. 5). The more important diatoms constituting the August 1951 bloom were two species of *Rhizosolenia*, several species of *Chætoceros*, *T. frauenfeldii*, *Thalassionema nitzschioides* and *Bacteriastrum varians* while the

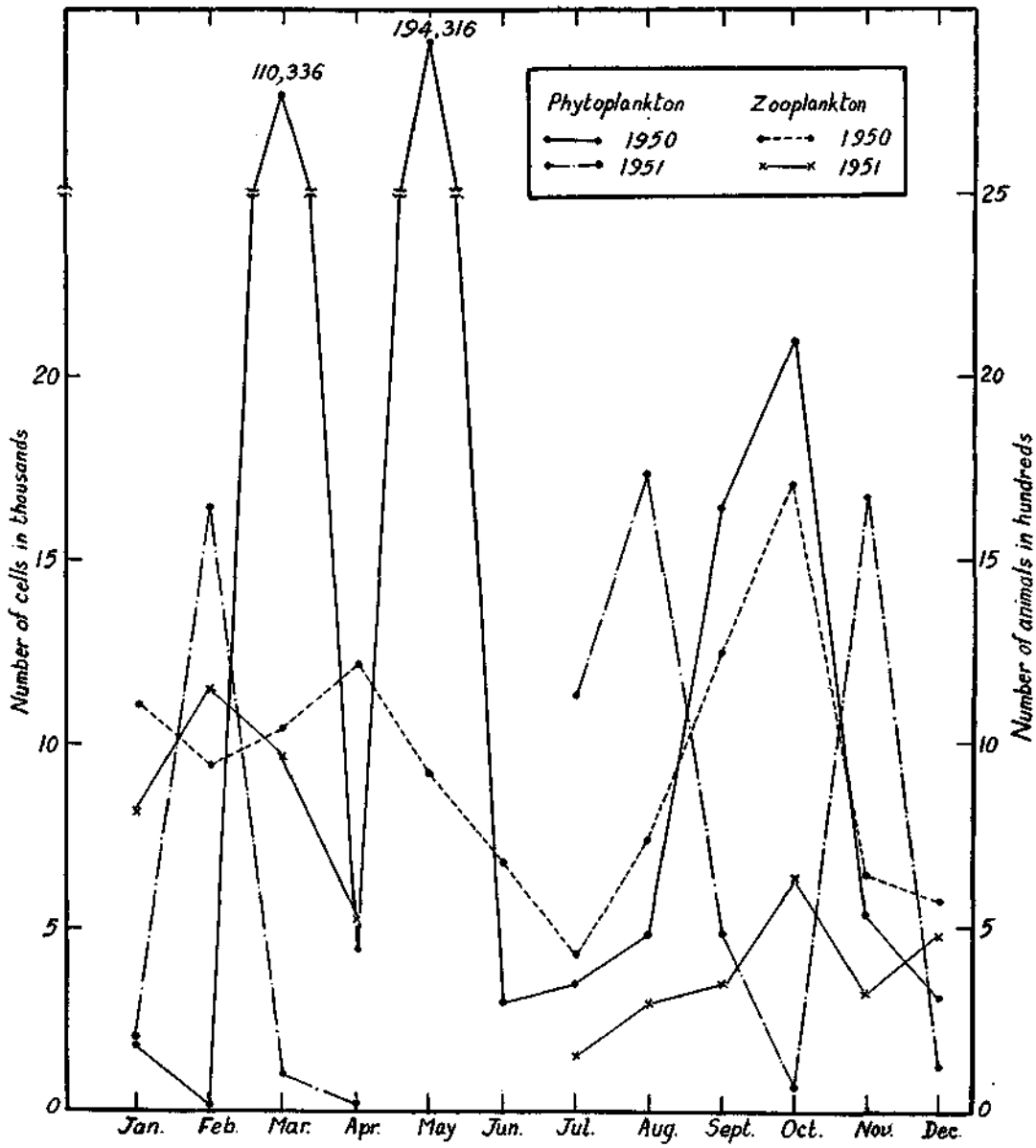

FIG. 4. Distribution of phyto- and zoo-plankton for 1950 and 1951.

November maximum was to a large extent caused by several species of *Chætoceros*, with a few *R. alata* and *T. frauenfeldii* (Tables IV to VI and Fig. 5). It is clear from what has been said above that there are variations in the species composition of the diatom maxima taking place at different months of the year. As a whole several species of *Chætoceros* and *Rhizo-*

TABLE IV

Numerical average distribution of diatoms in various months during the years 1950 *and* 1951

Month and year / Species			*Rhizosolenia alata*	*R. imbricata*	*R. styliformis*	*Rhizosolenia* spp.	*Chaetoceros lorenzianus*	*C. coarctatus*	*C. indicus*	*C. diversus*	*C. denticulatum*	*C. peruvianus*	*Chaetoceros* spp.
January	1950	..	1459·3	47·3	36·6	..	..	..	..	..	..	..	..
February	„	..	8·7	..	4·0	6·3	..	..	..	..	..	..	..
March	„	..	106105·4	135·4	..	153·3	..	3·1	..	5·4	..	5·4	..
April	„	..	13·0	30·5	..	57·3	546·6	..	76·0	20·0	..	..	..
May	„	..	5·0	..	228·5	54·1	1922·8	..	400·0	348·5	25·7	2291·4	..
June	„	..	..	35·0	..	..	..	85·3	..	..	..	..	..
July	„	..	281·0	25·0	10·0	..	539·0	278·0	180·0	..	15·0	17·5	..
August	„	..	175·0	..	..	165·0	1060·0	175·0	606·2	50·0	..	..	..
September	„	..	54·6	66·0	106·6	2·0	1420·0	..	2166·6	573·3	56·0	113·3	536·6
October	„	..	822·8	244·2	742·8	90·8	4077·1	66·8	725·7	68·5	..	1754·2	503·7
November	„	..	263·7	..	16·5	..	1412·5	4·0	750·0	80·0	5·0	345·0	..
December	„	..	212·0	..	14·5	..	32·3	..	..	21·8	..	33·4	..
January	1951	..	68·0	816·0	..	..	68·0	..	..	..	20·0	..	..
February	„	..	13·0	15930·0	..	..	..	..	..	..	..	..	..
March	„	..	..	7·2	..	..	..	..	..	..	..	..	..
April	„	..	..	52·4	..	6·4	2·0	..	..	..	..	..	..
July	„	..	60·0	4080·0	..	80·0	3510·0	..	1000·0	40·0	..	50·0	250·0
August	„	..	2506·0	43·0	5030·0	..	188·0	82·0	..	..	260·0	3110·0	3000·0
September	„	..	25·0	25·0	..	..	340·0	265·0	..	..	400·0	300·0	1400·0
October	„	..	4·6	..	..	..	160·0	248·0	..	..	..	..	..
November	„	..	1375·0	..	..	..	3000·0	..	3000·0	200·0	25·0	2400·0	4400·0
December	„	..	200·0	..	..	..	100·0	6·2	30·0	..	..	..	100·0

TABLE V

Distribution of diatoms during the years 1950 *and* 1951 (*contd.*)

Month and year / Species		*Bacteriastrum hyalinum*	*B. varians*	*Thalassiothrix frauenfeldii*	*Thalassionema nitzschioides*	*Coscinodiscus gigas*	*Coscinodiscus* spp.	*Biddulphia sinensis*	*Biddulphia mobiliensis*	*Hemidiscus hardmanianus*
January	1950	..	..	..	3·3	12·6	..	102·0	85·6	..	66·0
February	„	..	..	..	4·7	1·1	..	28·0	7·0	..	28·3
March	„	..	722·7	931·8	345·7	990·8	37·7	40·0	33·1	17·1	23·3
April	„	..	446·3	254·0	780·0	915·0	18·5	..	26·3	4·0	913·0
May	„	..	..	4657·1	31196·5	152863·4	..	5·4	8414·5	187·7	2·1
June	„	..	..	..	4·6	143·0	2187·0	10·0	148·6	..	104·6
July	„	..	25·0	67·5	517·5	225·5	199·6	..	556·0	..	33·2
August	„	..	..	..	1475·0	..	55·0	..	5·0	30·0	..
September	„	..	2885·3	2133·3	4076·6	1333·3	..	..	14·0	5·3	12·6
October	„	..	291·8	..	6905·7	185·7	86·2	..	31·4	..	20·5
November	„	..	50·0	..	989·0	215·0	..	22·0	4·0	..	7·0
December	„	..	..	..	1065·8	1440·0	..	70·9	2·1	..	..
January	1951	..	..	..	148·0	532·0	..	139·6	..	100·0	76·0
February	„	..	..	..	21·3	56·3	..	243·0	..	44·6	85·3
March	„	..	..	..	29·0	14·5	..	69·4	..	..	896·1
April	„	..	..	..	32·0	17·2	..	17·2	..	2·4	44·8
July	„	..	..	..	50·0	590·0	..	..	..	520·0	420·0
August	„	..	..	600·0	1330·0	1000·0	15·0	..	..	154·0	..
September	„	..	..	..	510·0	400·0	29·0	..	..	67·0	..
October	„	..	..	..	24·0	252·0	118·6	..	..	24·0	..
November	„	..	..	..	1400·0	120·0	..	..	..	90·0	..
December	„	..	..	..	270·0	310·0	19·0	..	..	20·0	20·0

TABLE VI

Distribution of diatoms for 1950 *and* 1951 (contd.)

Month and year \ Species	*Bacillaria paradoxa*	*Asterionella japonica*	*Pleurosigma* spp.	*Nitzschia* spp.	*Schröderella delicatula*	Other species*
January 1950	..	..	..	..	..	..
February „	..	..	..	..	..	..
March „	..	..	347·5	..	..	61·8
April „	..	..	16·5	..	..	..
May „	518·5	6071·4	95·2	28·5	..	..
June „	..	..	8·0	..	..	55·3
July „	..	..	16·0	..	..	29·0
August „	225·0	..	..	100·0	..	225·0
September „	343·0	..	93·3	..	..	134·6
October „	662·8	..	858·5	597·1	537·1	37·8
November „	10·0	..	29·0	47·0	30·0	..
December „	5·4	..	..	..	14·5	..
January 1951	..	..	..	..	..	..
February „	..	..	..	..	..	..
March „	..	..	..	..	..	..
April „	..	..	..	..	..	..
May „	..	..	..	..	..	..
June „	..	..	..	..	..	..
July „	..	100·0	..	..	..	15·0
August „	..	60·0	..	..	..	5·0
September „	..	..	..	..	..	..
October „	..	..	..	..	..	..
November „	..	..	40·0	..	..	..
December „	..	..	..	..	..	..

* Includes *Ditylum brightwellii*, *Leptocylindrus minimus* and *Gyrosigma* sp.

solenia and *T. frauenfeldii* and *Thalassionema nitzschioides* play an important role in the diatom maxima of this area.

The pattern of distribution for 1950 and 1951 shows similarities in the general trends while there are certain differences in the time of occurrence and succession of various species. In both the years the phytoplankton production was at its lowest in December-January. There were sudden outbursts of single species of diatom (probably instances of local flowering) during February or March, and a summer maximum in May[2] followed by

[2] Unfortunately no data are available for May–June of 1951, but data for the same period of 1952 show that the summer bloom occurred in May followed by an abrupt fall in June.

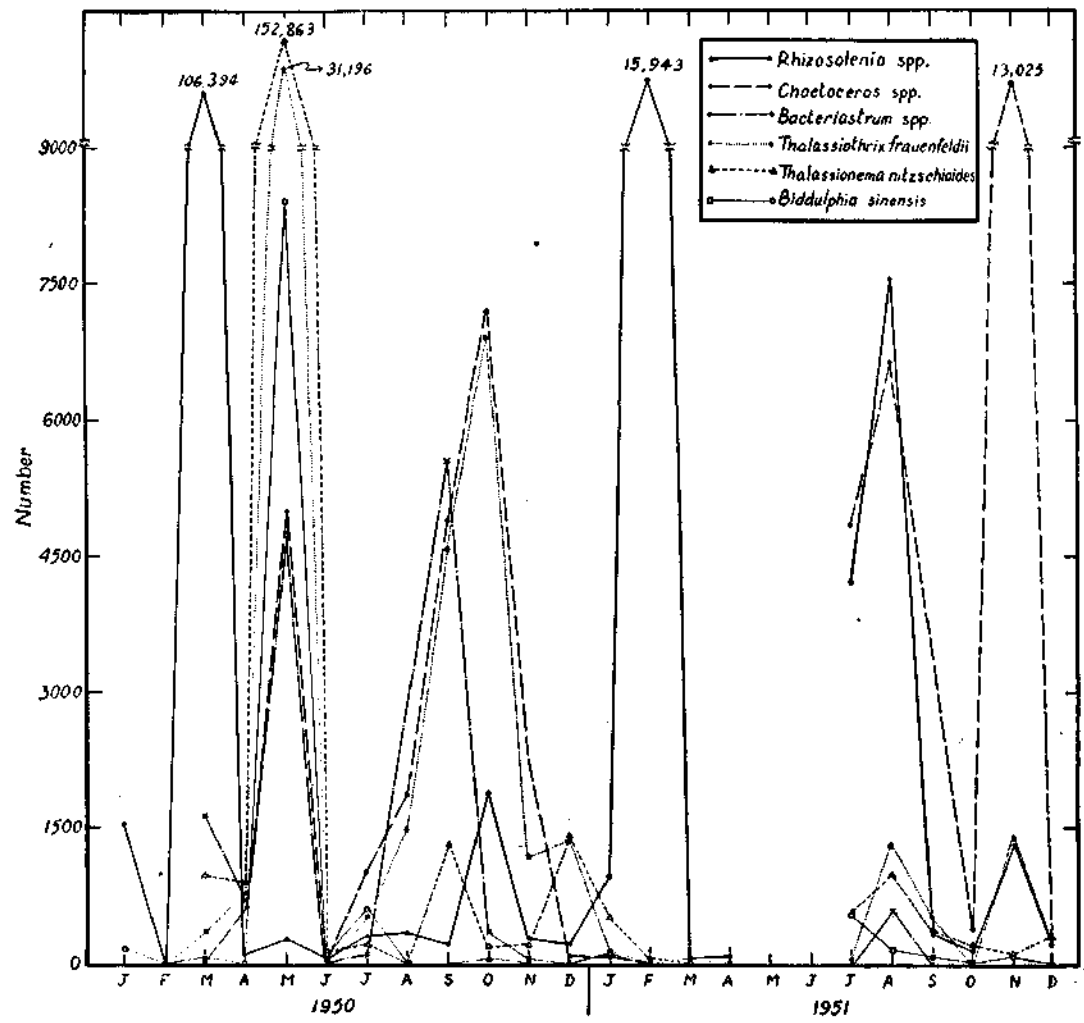

FIG. 5 showing the distribution of the important species of diatoms for 1950 and 1951.

an abrupt falling off during June and July. This is succeeded by an increase reaching a peak sometime during August-November the exact month in which the highest level is reached varying from year to year. In 1950 the peak was in October, but in 1951 though there was an increase in the phytoplankton from July, instead of a single peak as observed in the previous years there were two peaks of almost the same magnitude, in August and November respectively. The level of population during September-October was markedly low (Fig. 4). Thus it is apparent that the major diatom outbursts might vary in the exact time of their occurrence. The level of production, composition and frequency of blooms are also subject to variation from

year to year. It is not intended here to venture on any explanations regarding the factors controlling the maxima as these are not properly understood and it may take years of continuous study to have a better understanding of the problem. It is also difficult with the data at present available, to decide whether these maxima represent cycles of major outbursts, local flowering of a single species, temporary concentrations of diatoms which originate elsewhere and drift past or a combination of all these. But it looks as though the February or March outburst is an example of local flowering of a single species. The facts that during this period there was no corresponding bloom of *Rhizosolenia* near Mandapam on the Palk Bay side and that the species concerned are not those responsible for the May or August-November maxima lend additional support to this hypothesis. Such local flowerings of a single species is not an uncommon event in waters close to land. Bigelow (as quoted by Bigelow, Lillick and Sears, 1940) has observed a rich flowering of *Rhizosolenia alata* from the middle of December through January in Cape Cod Bay and of *Chætoceros* in Ipswich Bay on January 30, 1913. Bigelow, Lillick and Sears (1940) have remarked: "The fact that so short a record of observation should have revealed these flowerings is evidence that temporary enrichment of the water with planktonic vegetation is not an exceptional event in shoal water even at that season, when phytoplankton is usually scarce."

(*b*) *Dinophyceæ*.—Several species of dinophyceæ, particularly those belonging to the genus *Ceratium*, occur in this area. In quantity they never formed a significant part of the phytoplankton. As Menon (1931) has pointed out, the scarcity of Peridiniales in our collection may be attributable to the crude methods of collection. It is a well-known fact that many of the unarmoured forms of dinoflagellates are so delicate and minute that they escape through the meshes of even the finest plankton nets.

The common species of dinophyceæ obtained and their abundance are given in Table VII. They show a bimodal cycle, the first peak during April (just preceding the summer diatom peak) in both the years and the second one in October 1950 and November 1951 respectively, these coinciding with the diatom peaks. Almost throughout 1950 they occurred in relatively larger numbers than during the subsequent year. The dinophyceæ are at their lowest during December-January. Along the coast of Madras, Menon (1931) has observed that Peridiniales attain their maximum in May when the phytoplankton also is at its maximum. He also has remarked that *Ceratium* and *Peridinium*, the chief representatives of the Peridiniales, are present in the plankton throughout the year but the number of Peridinians rises very high in May and in the case of *Ceratium* somewhat earlier. According to Hornell and Nayudu (1923) the dinophyceæ have a maximum during

TABLE VII

Monthly distribution of the common species of Dinophyceæ

Month and year / Species			*Ceratium trichoceros*	*C. massiliense*	*C. tripos*	*C. fusus*	*C. furca*	*C. inflatum*	*C. schmidtii*	*Peridinium depressum*	*Peridinium* spp.	*Dinophysis homunculus*
January	1950	..	3·3	2·0	1·3	..	..	..	..	2·0	..	..
February	„	..	6·5	4·2	0·5	..	..	..	1·1	..	..	..
March	„	..	62·7	34·3	29·0	13·1	5·7	..	0·1	16·2	3·1	18·8
April	„	..	163·0	19·5	0·8	23·3	1·5	0·3	..	3·8	..	..
May	„	..	88·8	9·4	0·5	16·0	2·8	..	..	6·2	..	2·0
June	„	..	24·0	25·0	3·6	..	..	..	..	0·8	..	..
July	„	..	12·5	5·2	0·5	0·7	0·2	0·5	0·5	0·5	..	..
August	„	..	466·0	15·0	19·5	12·0	22·0	4·5	..	1·5	..	..
September	„	..	24·6	14·6	2·6	1·3	2·6	6·0	..	22·6	11·3	3·3
October	„	..	1362·2	21·1	5·1	4·5	19·4	9·7	..	12·5	14·2	..
November	„	..	13·5	12·0	0·5	3·5	3·0	..	..	2·0	0·5	..
December	„	..	0·7	1·8	0·3	5·0	..	..	0·7	..	..	..
January	1951	..	1·0	..	..	4·4	..	0·4	0·3	..	..	..
February	„	..	0·7	4·3	0·3	..	..	0·3	..	..	..	0·3
March	„	..	2·1	1·8	..	0·3	..	..	..	..	..	..
April	„	..	68·0	4·4	..	2·4	..	0·4	..	..	..	..
July	„	..	14·0	5·0	..	1·0	..	..	..	..	..	..
August	„	..	31·0	17·0	..	1·0	..	0·6	..	..	..	..
September	„	..	41·0	14·0	..	..	..	..	..	..	..	..
October	„	..	8·8	1·6	..	..	..	..	..	..	..	..
November	„	..	23·0	30·0	5·0	..	..	2·0	..	2·5	..	..
December	„	..	1·0	..	..	..	..	..	..	..	..	..

November–January, the peak varying according to the species. The May diatom maximum has been found to be closely followed by the dinoflagellate peak off Trivandrum (Menon, 1945).

(*c*) *Trichodesmium erythræum.*—The occurrence in large numbers of the blue-green alga *T. erythræum* during May in the tide pools on the southern side of the Krusadai Island causing mortality of marine fauna has been recorded by Chacko (1942). Chidambaram and Unny (1944) have reported a similar phenomenon during the same month on the southern coast of Pamban. Devanesan (1942) has remarked: "The alga *Trichodesmium* found in the plankton off Krusadai in great profusion during certain seasons forms a favourite item of diet of the Indian sprat (*Sardinella gibbosa*), the Gizzard Shad (*Anadontosoma chacunda*), the Milk-fish (*Chanos chanos*) and of the Mullet (*Mugil waigiensis*). The fishery of these fish depends to a certain extent on the abundant occurrence of the alga *Trichodesmium*." However, recent investigations conducted at this Station show that *Trichodesmium* does not form an item of food of *Chanos chanos* during any part of the year (Tampi, unpublished observations).

Records maintained for 1950 and 1951 show *T. erythræum* as present in this area in varying numbers during most of the months. In both the years the maximum was reached in April but the population level of 1951 was considerably lower (Table VIII). No cases of mass mortality of the local fauna caused by these have been noticed.

TABLE VIII

Distribution of Trichodesmium erythræum *during* 1950 *and* 1951. *The numbers are average number of filaments per c.c. of the standardised sample*

Month	1950	1951
January	..	..
February	..	..
March	2790·0	14·5
April	4253·0	837·0
May	551·0	..
June	..	..
July	400·0	16·0
August	..	708·5
September	..	450·0
October	1062·8	..
November	715·0	286·5
December	321·0	46·0

Along the west coast of Madras State Hornell and Nayudu (1923) have observed the dominance of *Trichodesmium* in March and April, whereas Menon (1945) has reported off Trivandrum swarms at intervals during December-May. It occurs in swarms off Madras mostly during September and February, the greatest swarms being always in September (Menon, 1931).

VI. Zooplankton

No attempt has been made in the present work to identify specifically the large number of species represented in the catches because the object of this study has been to gain a knowledge of only the more important elements of the zooplankton community. The general distribution of the total zooplankton is shown in Fig. 4. As in the case of phytoplankton, the cycle is not unimodal, but the sudden fluctuations observed in the phytoplankton cycle are not met with in the zooplankton. A bimodal cycle with one peak falling sometime during February-April and the other in October is observed (Fig. 4). The zooplankton level is at its minimum during July. It then steadily rises reaching a maximum in October, followed by a decline in November-December and a subsequent upward trend reaching a peak sometime during February-April. From January to March and, at times, even up to May, there is a fairly high and steady zooplankton population. The important elements constituting the community and their fluctuations are described below.

For the sake of comparison, observations made by other investigators at places both along the west and east coasts of India have been given wherever possible.

(*a*) *Tintinnids*[3]

The distribution of tintinnids for 1950–51 is shown in Fig. 6. Except for the appreciably lower population level in 1951 there is a striking similarity in the general trend. Generally speaking, there are two peaks, one in May and the other sometime in October-November, the latter being the main peak. The following is a list of the common species found in this area:

Tintinnopsis dadayi Kofoid
T. tocantinensis Kofoid and Campbell
T. gracilis Kofoid and Campbell
T. radix (Imhof)
T. mortensenii Schmidt

[3] In bulk these are insignificant components of the zooplankton, but a detailed study of these forms was started with a view to finding out whether any of the species occurring in this area can be used as indicators of incursions of oceanic water masses as many species of Tintinnids are known to be typically oceanic. A full account of the tintinnids occurring in this area will be published in due course.

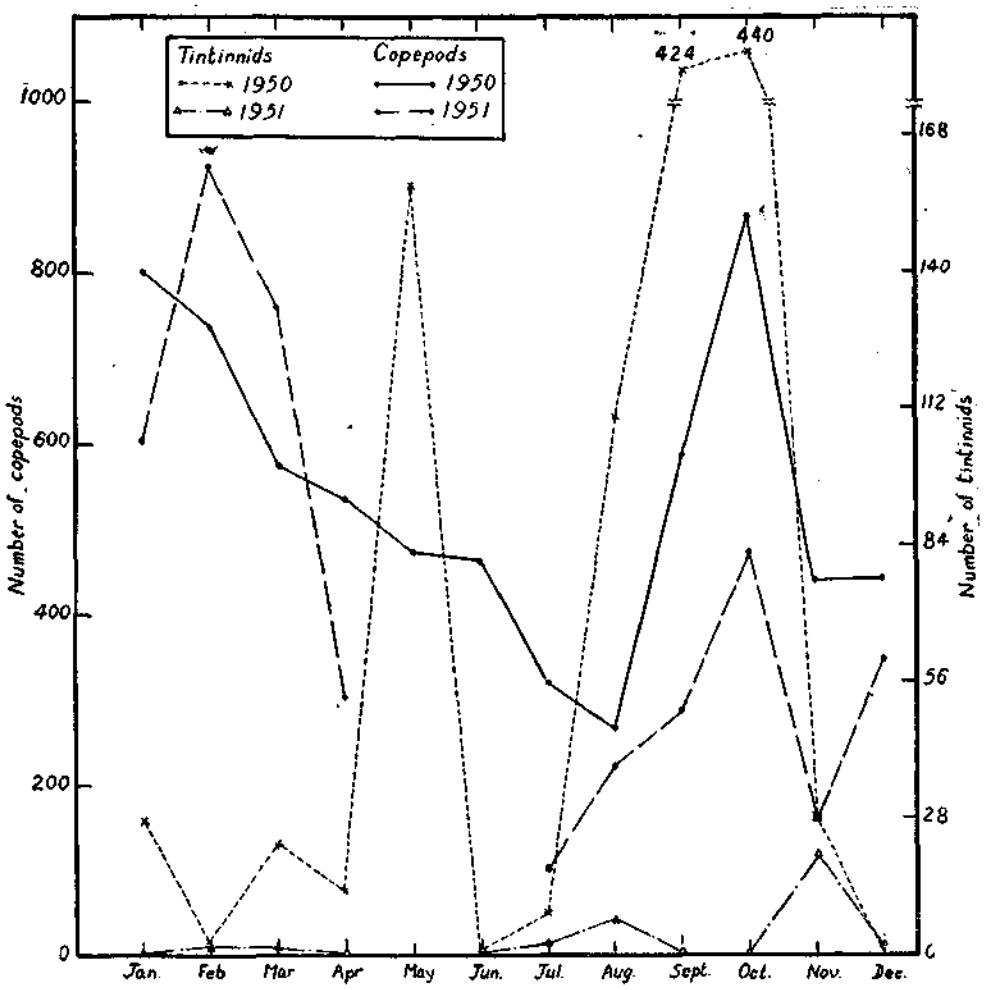

FIG. 6 sohwing the fluctuations of tintinnids and copepods.

T. nordqvisti Brandt
Tintinnus lusus-undæ Entz.
Cyttarocylis ehrenbergi (Clap. and Lachm.)
Codonella ostenfeldii Schmidt

Detailed work on the species occurring in our coastal waters is wanting, but all previous investigators have recorded *Tintinnus* sp. Menon (1931) has observed their occurrence throughout the year off Madras. Chacko (1950) has recorded *T. borealis* Hensen rarely around Krusadai during January, April-June and October and November. *Tintinnus* sp. is reported to be common from November to April off Trivandrum (Menon, 1945) while according to Hornell and Nayudu (1923) *Tintinnus* sp. begins to appear in large numbers in November in the West Hill area near Calicut.

(*b*) *Chætognaths.*—Fig. 7 shows the distribution of chætognaths. Their numbers vary throughout the year, but they are usually most abundant during the early part of the year. In 1950 they were taken in greatest numbers in March, whereas in 1951 their maximum fell in February. After this peak there is usually

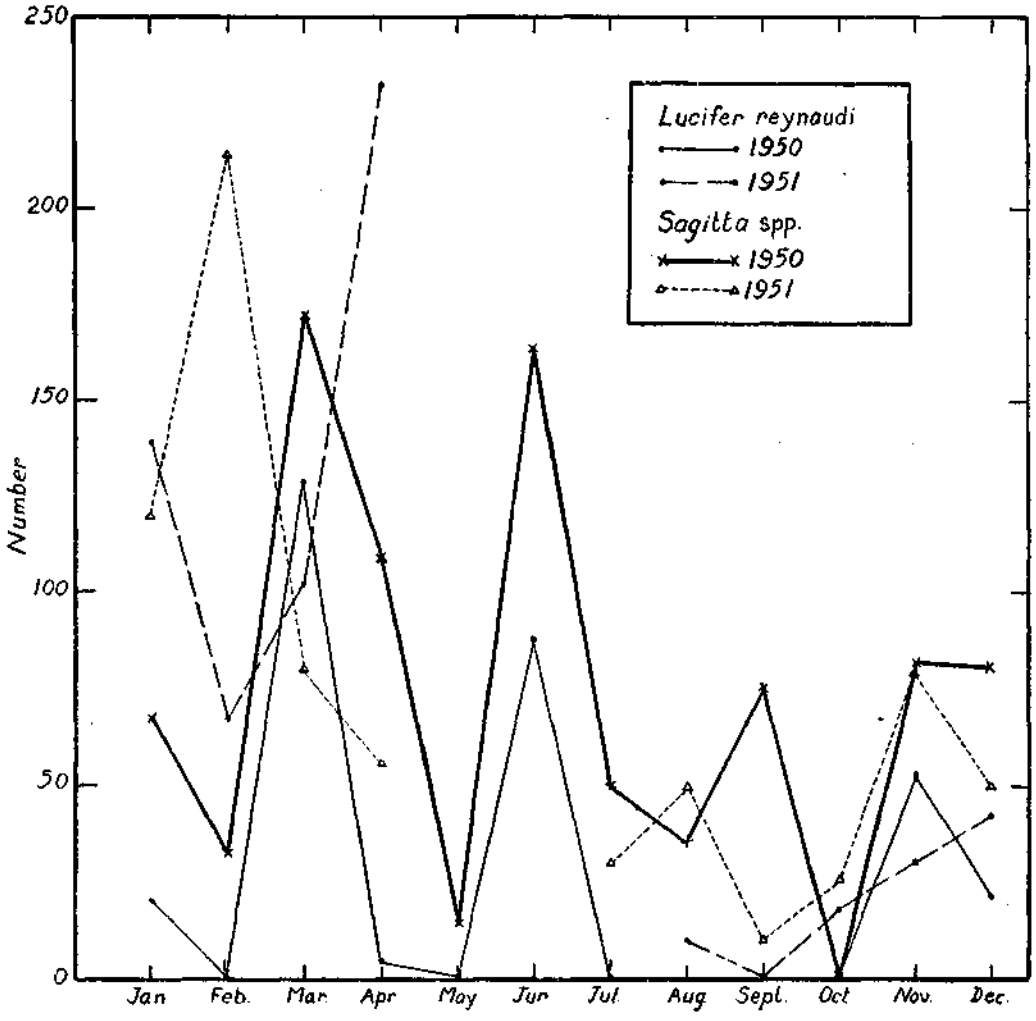

FIG. 7. The distribution and fluctuations of *Sagitta* spp. and *Lucifer reynaudi.*

a decline in their number followed by an increase. During the second half of the year the distribution is erratic and characterized by ups and downs but the population level does not reach that of February or March. The most common species occurring in this area is *Sagitta enflata.* Others such as *S. tenuis* and *S. robusta* are also noticed but in fewer numbers. According to John (1937) *S. enflata* occurs during all the months of the year while *S. tenuis* and *S. robusta*

are only found during the summer months along the Madras coast. However, as Subramaniam (1937) has pointed out, the genus *Sagitta* occurs throughout the year in these waters although only a few species may be represented at a time. According to Menon (1945) species of *Sagitta* are uniformly distributed off Trivandrum from December to April, but with the onset of the southwest monsoon their occurrence is somewhat erratic, huge swarms often appearing at intervals from May to September. George (1952) observed that chætognaths as a group occurred in the coastal waters of the west coast of India throughout the year with a few periodical inter- and intra-specific fluctuations, the individual species having their own seasons of abundance and scarcity.

(*c*) *Cladocerans.*—Two species of cladocerans have been collected from this area, *viz.*, *Evadne tergestina* Claus and *Penilia avirostris* Dana the former being more common and appearing mostly during January-April while the latter occurs in March-April and sometimes in November too (Table IX).

TABLE IX

Distribution of Evadne tergestina *and* Penilia avirostris

Month	*Evadne tergestina*		*Penilia avirostris*	
	1950	1951	1950	1951
January ..	2·2	2·5	..	..
February ..	6·0	1·6	..	..
March ..	3·0	2·4	12·9	3·2
April ..	0·6	0·8	..	8·0
May ..	..	..	..	..
June ..	..	..	..	..
July ..	..	1·0	..	..
August ..	..	..	..	..
September ..	..	..	..	..
October ..	..	..	..	..
November ..	0·5	..	2·5	..
December ..	..	..	..	..

Swarms of *Evadne* sp. are found off Madras during October and again in February-March and off Trivandrum during April-November. *Podon intermedius* recorded from Madras by Menon (1931) and *Podon* sp. from Trivandrum (Menon, 1945) have not been obtained from the present station. Chacko (1950) has listed *P. intermedius* as occurring rarely during January, February, May, June, August, October and December.

(*d*) *Copepods.*—The copepods, as is generally the case elsewhere too, formed perhaps the most important element of the zooplankton. Although in species and individuals they are numerous, only a few may be regarded as really contributing

to the bulk of the copepod population. Of these, the Calanoids are more abundant than the Harpacticoids or Cyclopoids the following being the more important species:

Acartia erythræa Giesbrecht
Paracalanus parvus Giesbrecht
Canthocalanus pauper (Giesbrecht)
Acrocalanus sp.
Calanopia sp.
Labidocera sp.
Euterpina acutifrons (Dana)
Metis jousseaumei Sewell
Macrosetella gracilis Dana
Oithona sp.
Corycæus sp.

It will be seen from Fig. 6 that there is a striking similarity between the distribution and fluctuations of copepods in the years 1950 and 1951. They show two distinct peaks; one during the early part of the year, January-February, and the second in October. The population starts declining in March and reaches its lowest ebb by about July, when it steadily increases reaching a maximum in October. Following the second maximum there is an abrupt fall in November but by December there is again a tendency to increase resulting in a maximum in January or February.

It is of interest to note that along the coast of India wherever investigations have so far been carried out on planktonic copepods a unimodal distribution has been reported. Thus, the Text-Fig. 3 of Menon (1931) shows a single mode for the distribution of copepods along the Madras coast. Menon (1945) has observed a single copepod maximum during January-February off Trivandrum, while Jacob and Menon (1947) have remarked that: "The fluctuation of Copepods shows unimodal curves indicating a Copepodan abundance for a prolonged period from September to January reaching peaks in December when they assume the 'Swarm' stage in the plankton." In the present observations there is a definite fall in the number of copepods both in 1950 and 1951 during November (from 864 copepods in October to 435 in November 1950 and from 471 in October to 162 in November 1951) indicating a reduction to half or more of the population level resulting in two definite peaks. It is possible that while in other localities the maximum occurrence of one or more species may overlap, there may be still others whose maxima fall in such a way as to fill the gaps and present an overall unimodal distribution. A similar phenomenon may not be taking place here thereby resulting in an apparent reduction in population level and a bimodal curve. Another cause of these fluctuations can be that the copepod population is being preyed upon by migratory pelagic fish in varying degrees from time to time. A detailed study of fluctuations of the different species may throw more light on this problem when it will be possible to offer a more satisfactory explanation. In a recent paper Bal and

Pradhan (1952) have mentioned that in Bombay waters copepods show two or three peaks from May to September and their number dwindle considerably from November to April.

(*e*) *Decapods.*—The only adult planktonic decapod occurring locally in appreciable numbers is the Sergestid—*Lucifer reynaudi* (Milne-Edwards) which is present during several months of the year with the maximum number in March or April (Fig. 7). Menon (1945) has reported *Lucifer* sp. to be common throughout the year and in swarms from January to May. Chacko (1950) has recorded *L. hanseni* Nobili as common during January-February and June-July, plenty during March, few during April-May and December, and rare during September-October in the waters around Krusadai.

(*f*) *Pteropods.*—The most common species of pteropod that occurs in this area is *Creseis acicula* Rang. In 1950 it was present from February to May and in November-December, large numbers appearing in March. But in the following year it was found only in small numbers in March, April and August (Table X). Off the coast of Trivandrum they occur in swarms from November to April at intervals (Menon, 1945). Chacko (1950) has observed swarms in March.

TABLE X

Distribution of Creseis acicula

Month	1950	1951
January	..	..
February	1·7	..
March	169·3	4·3
April	13·3	6·6
May	1·4	..
June	..	..
July	..	..
August	..	5·0
September	..	..
October	..	..
November	5·5	..
December	1·3	..

(*g*) *Tunicates.*—Menon (1931) has recorded *Thalia democratica* as occurring in swarms during September-October, *Appendicularia* sp. and *Fritillaria borealis* as common from October to May. According to Chacko (1950) *Oikopleura cophocerca, F. borealis, Doliolum tritonis, T. democratica* and *Salpa cylindrica* are present in the waters around Krusadai. Of these the last three are rare throughout

the year while the first two are common during September-December. The findings of Nair (1949) have shown that although there are several species of Thaliacea in the Madras plankton, *T. democratica, S. cylindrica, Jasis zonaria* and *Pegea confœderata* are the commonest. Barring a few stray specimens of *T. democratica* and *S. cylindrica,* none of the other species have been collected from the present station. On the other hand *Oikopleura* sp. was present throughout the year in varying numbers. It shows two distinct peaks in occurrence as seen in Fig. 8. *Fritillaria* sp. was never present in such large numbers as *Oikopleura* sp., which is most abundant during June-August. Off Trivandrum (Menon, 1945) it appears at indefinite intervals during the rest of the year.

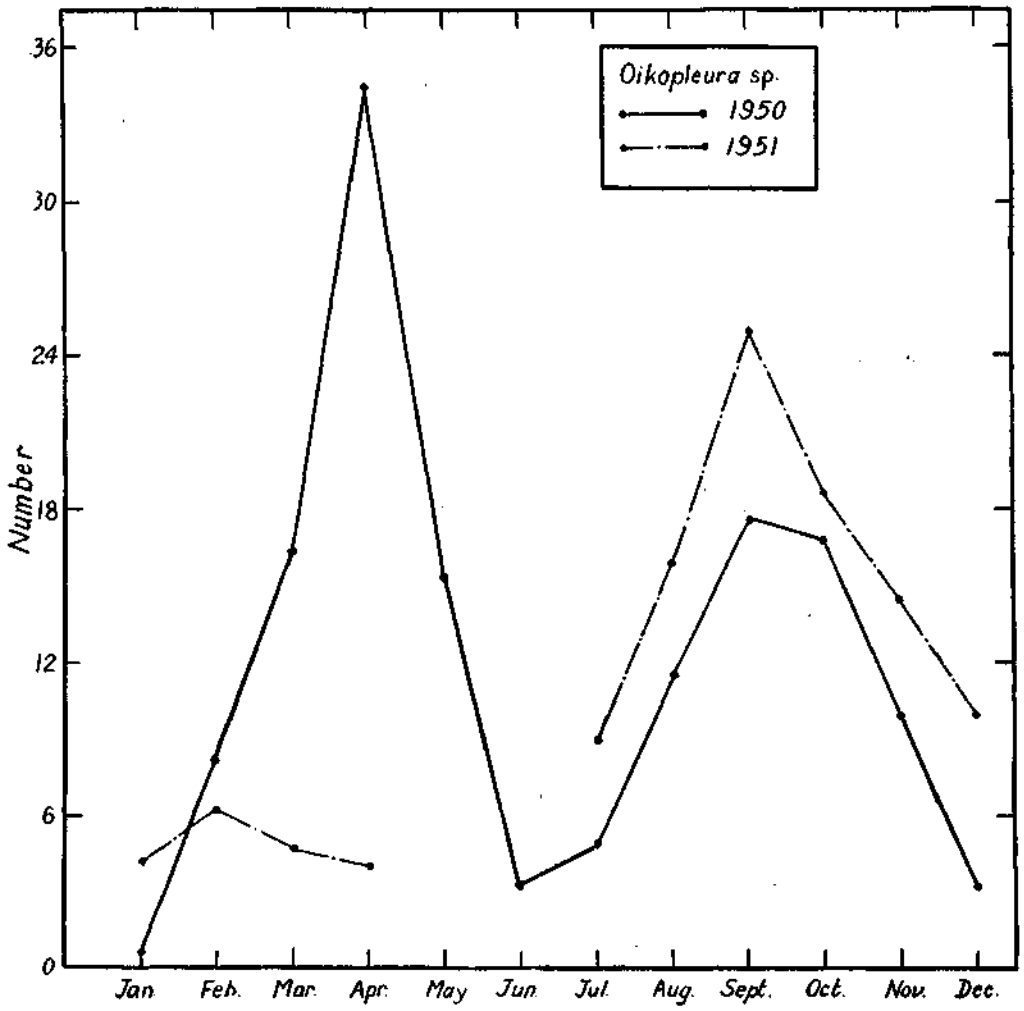

FIG. 8 showing the distribution of *Oikopleura* sp.

(*h*) *Larval forms*[4].—It is not unusual to find larval forms of marine animals in the inshore waters of tropical areas almost throughout the year. Nevertheless, there may be marked variations amongst species in the intensity of spawning resulting in definite peak seasons. Generally speaking, the maximum number of larvæ is seen between September and March or April and the bulk of the population consists of crustacean and mollucan larvæ.

Such larval forms as the Semper's larvæ (found occasionally in June), Müller's larvæ (occurring sporadically during April-September), *Pilidium* and *Actinotrocha* (in October) are rare.

Cyphonautes larvæ are often found in this area and occur in great numbers particularly in January, May, September-October and December.

Larval polychætes belonging mostly to the Polynoidæ, Nereidæ, Eunicidæ, Spionidæ, Owenidæ, Terebellidæ, Chætopteridæ and Sabellaridæ are found throughout the year but the intensity of spawning apparently reaches its maximum in January-February and again in October-November. The protracted spawning season of polychætes of this area is in agreement with the observations of Aiyar (1933). However, according to him the maximum spawning takes place during November to March off the coast of Madras.

The echinoderm larvæ collected in the course of this investigation are mainly the different types of Ophioplutei and a few Auricularia, Bipinnaria and Echinoplutei. Ophioplutei are common in February-May and again in September-October. Bipinnaria once occurred in large numbers on September 20, 1950. Menon (1945) also has noticed that Bipinnaria and Auricularia are comparatively rare along the coast of Trivandrum, whereas Echinoplutei and Ophioplutei are common during September-November and March-May (the period of occurrence of these plutei observed by Menon off Madras somewhat coincides with that observed locally). Auricularia are reported to be not so common as Bipinnaria or the plutei in the Madras plankton.

As already mentioned earlier in this section crustacean larvæ form one of the most important elements of the temporary plankton. They are present almost throughout the year and in swarms on certain days. Decapod larvæ, especially zœae of different groups, are common from September to June. Similarly, plenty of megalopæ also appear during the same period. Cirripede nauplii occur frequently during January-April and again in August-October. These are common from July to September along the Madras coast and from February-March and July-October off Trivandrum. Nauplii of copepods found in plenty locally during October-February occur in abundance from December-April off Madras and September-November and April-June in the plankton off the Trivandrum coast.

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[4] A detailed account of the occurrence and fluctuations of larval forms in the plankton of this area is under preparation and will be published in course of time.

Stray individuals of stomatopod larvæ, the *Alima* stage of *Squilla*, are seen in this area during February-March and then again from June-September.

Lamellibranch and gastropod larvæ are seen in the plankton of this area almost throughout the year and sometimes several thousands of veligers are obtained in a single sample. The lamellibranchs show two peak spawning seasons a year, one in March-April and the other late in the year by about October. While the first spawning maximum of the gastropods is at about the same time as that of the others, the second one is usually a little earlier, around August. Reports show that lamellibranch larvæ are common from October–February off Madras and during February-April and July-September off Trivandrum. Similarly, along these two coasts gastropod larvæ are common during September-November and December-April respectively. A similar phenomenon occurs in the waters around the Andaman Islands during these months (Unpublished observations of H. S. Rao).

Ascidian tadpoles are sometimes found in the plankton from November-January but their numbers have always been few.

Fish larvæ belonging to different groups are present from December to May, reaching a maximum sometime between January and March.

(*i*) *Other zooplankton forms.—Noctiluca miliaris* Suriray is very common in July and August off Madras and causes sometimes the 'red tide'. Hornell and Nayudu (1923) have remarked that *Noctiluca* is present nearly throughout the year but appears in swarms in June, August and September. Menon (1945) has recorded *N. miliaris* as most common during July-October. Swarms of this have been reported to have caused heavy mortality of fish off Madras (Aiyar, 1936). Certain abrupt set-backs in fisheries off Calicut have also been attributed to the swarming and subsequent death and decay of these (Bhimachar and George, 1950). In the area under the present investigation during two years it occurred only in small numbers during January-April. Chacko (1950) records it as present throughout the year, common during December-February and rare at other times in the waters around Krusadai.

Among the cœlenterates hydromedusæ are the most common and occur in varying numbers during several months of the year, the maximum being from March-June. From July-September they are scarce and following this there may be a minor peak during October-November. In December-January they once again become rare. Along the coast of Madras, hydromedusæ are reported to be rare between July and September, but from October onwards their number increases reaching a maximum in February or March (Menon, 1931). Greatest numbers of hydromedusæ have been observed off Trivandrum (Menon, 1945) from January-February and again in swarms in July with a minimum in May

and June. The following species have been recorded locally: *Cytæis tetrastyla* Eschscholtz, *Bougainvillia fulva* Agassiz and Mayer, *Stomotoca* (*Amphinema*) *dinema* L. Agassiz, *Obelia* sp., *Phialucium virens* Maas, *Pseudoclytia gardineri* Browne, *Eutima curva* Browne, *Eutima* (*Octorchis*) *orientalis* (Browne), *Phortis palkensis* (Browne), *Irenopsis hexanemalis* Götte, *Octocanna polynema* (Haeckel), *Aequorea conica* Browne and *Liriope tetraphylla* Gegenbaur.

Scyphomedusæ such as *Carybdea xaymacana* Conant, *Chiropsalmus* sp., *Mastigias papua* Maas, *Rhizostoma* sp., *Rhopilema hispidum* Maas are often present during June-July and sometimes also in November.

A regular appearance in June-July of *Physalia utriculus* (La Martiniere) in appreciable numbers has been noticed. Occasionally *Porpita pacifica* Lesson also appears at the same time but in fewer numbers. Stray specimens of *Vellela* sp., also have been met with during the same season. Menon (1945) has recorded the occurrence of *Physalia* sp., and *Porpita* sp., during July. But off Madras *Physalia* is reported to be not very common, whereas *Porpita pacifica* is common from September-March (Menon, 1931).

Pleurobrachia globosa Moser and *Beroe* sp., appear in this area sporadically. *P. globosa* usually occurs in large numbers during March and at other times fewer specimens may be seen. *Beroe* sp., found generally during February-April has been observed to be present in small numbers.

The adult pelagic polychætes such as *Tomopteris*, *Alciopa* and *Autolytus orientalis* Willey are rather rare in this area.

The pelagic mollusc *Janthina roseola* Reeve has been noticed during the months of June-July and sometimes several of these are seen washed ashore.

VII. Discussion

The first impression derived from the results of this work, carried out in 1950 and 1951, is one of variability of the plankton characteristics, *i.e.*, each year would show considerable variations in pattern. However, the sequence of events shows similarities in general trends. The great irregularity in distribution of certain species of both phyto- and zoo-plankton shows the need for a more extensive series of observations before definite general conclusions can be drawn.

It may not be out of place here to refer to certain observations made at other places for a comparison with those made locally. The comparisons cannot be made on a strictly quantitative basis as the methods of collection and enumeration employed by different workers are not uniform. But comparisons of trends such as the time of occurrence of maxima and minima of phyto- and zoo-planktonic elements are, however, possible.

Locally, as already seen, the diatoms show more than one maximum in a year; the summer peak in May with others in February-March and August-November. Menon (1931) mentions: "Though our diatom flora resembles that of European Seas in having a general maximum in April and May, one essential difference must be mentioned. It is, that excepting for a false secondary maximum from November to January inclusive, made up entirely of *Coscinodiscus* spp., this general maximum is, as has already been stated, the culmination of a regular and constant diatom increase beginning in September, while in European waters it is the culmination of a sudden rise beginning in March." A diatom maximum occurs in May off Trivandrum and Menon (1945) has remarked that a secondary phytoplankton maximum during January-February followed by a distinct fall in March was not a regular feature of that coast. His Text-Fig. 1 *a*, however, shows such a phenomenon for 1940 when there was a secondary peak in March followed by an abrupt fall in April. Such a secondary maximum has been observed off the Malabar coast by Hornell and Nayudu (1923). According to them there is a sudden increase in diatoms in May with the onset of the rains and river floods which falls off in June. In July the preponderance is restored reaching a maximum and then decreasing gradually through September to a minimum in December. A second pulse of considerable abundance occurred in January and February with a distinct fall in March before a small rise in April. The explanation offered by these authors for the irregularity indicated is that several of the chief constituents of the diatom flora appear to respond differently to physical conditions. Off Bombay the period of phytoplankton scarcity is from May to August. Then there is an increase until January or February when the maximum is reached (Gonzalves, 1947). From these it appears that off Madras there is a steady growth of diatoms starting from October and ending in a maximum in April or May followed by an abrupt fall in August-September culminating in a minimum. Similarly along the coast of Trivandrum and also off Bombay the diatom population shows gradual increase from a particular period leading to a maximum and then falling off to a minimal level. It is of interest to point out here that both Hornell and Nayudu (1923) and the present author have, on the contrary, observed definite pulses in the diatom production off Malabar and Mandapam respectively.

The dinophyceæ show features somewhat similar to the diatoms. Locally there are two peaks, one in April and the other in October-November. While in Madras the peak of *Ceratium* is in March and that of *Peridinium* in May, their maxima are in August-November and November-January along the coast of Trivandrum and Malabar respectively. The time of occurrence

of *Noctiluca* in this area differs from those of Madras, Calicut and Trivandrum. Table XI gives the maxima and minima of diatoms and dinophyceæ for four different areas along the coast of India.

The fluctuations of diatoms and dinophyceæ observed in this area thus show certain similarities to and differences from those of the two coasts of India. The condition of the phytoplankton cycle seems to be more like the one observed along the west coast rather than the east (Table XI).

TABLE XI

Period of occurrence of maxima and minima of diatoms and dinophyceæ at four places along the coast of India

		Madras	Mandapam (Gulf of Mannar)	Trivandrum	Calicut
Diatoms	Max.	May, false secondary maximum during November-January	May and other maxima in February or March and again in August-November	May, No secondary maximum (?)	May, secondary maximum in January-February and then again during July-August
	Min.	August to September	December–January	December	December
Dinophyceæ	Max.	*Ceratium* in March and *Peridinium* in May	April and October-November	August-November	November-January
	Min.	..	December-January	January-March (?)	..

Considering the more important zooplanktonic elements such as copepods, chætognaths, cladocerans and pteropods, it has already been pointed out that the copepod fluctuation in this area is peculiar in having a bimodal cycle. Chætognaths have been reported to be present throughout the year in varying numbers, with their maximum off Malabar in November and off Trivandrum during December-April. In Mandapam their peak seems to be during February-March and in the second half of the year their distribution is rather erratic. Among the cladocerans *Evadne* sp., which is common to all these places, occurs in large numbers during October and February-March along the coast of Madras. Locally they are abundant during

January-April and off Trivandrum during April-November. Similarly *Creseis acicula* is reported to be abundant off Malabar during November, off Trivandrum during November-April and off Mandapam in March-April.

There are presumably several factors which govern the fluctuations of both phyto- and zoo-plankters. A possible explanation for the marked variations in the diatom population levels has been suggested by Hornell and Nayudu (1923). It is true that different species of diatoms react differently to the environment which might account for the irregularity noticed. So also the reaction of the different species of animals to both the organic and inorganic environment may be different. Riley (1946) has correlated the variations in the phytoplankton population of the Georges Bank with various environmental factors. According to him the variations that occurred in the distribution of phytoplankton from one place to another and also from one month to the next could be correlated with such factors as the depth of water, temperature, dissolved phosphates and nitrates and also the quantity of zooplankton, because it has been shown that grazing by zooplankters is an important controlling factor of the size of the phytoplankton population. In addition to these there are certain other causes deserving mention such as vertical and lateral current transport and, in the case of phytoplankton, large-scale sinking of cells below the compensation level, due to turbulence set up by rough weather, thus depleting the growing stock. The fluctuations may be from year to year, month to month or from day to day. Owing to lateral movements of water masses there may result in a particular area renewal of water from time to time, the period of renewal varying from place to place. Such renewals may bring about considerable fluctuations in the population because waters passing through an area may have different biological histories (*Ref.* Harvey, 1950). Thus the maintenance of a population in a given region under these conditions depends upon a balance of dynamic factors; the drift of the water and its interaction with its environment, as well as upon the rate of reproduction and mortality of the population under the environmental conditions determined by these circumstances.

The Gulf of Mannar being wide open its waters are subject to considerable influences from adjacent seas. The available data on the surface currents of waters around the peninsula of India have been given by Sewell (1929). According to him during September-November a current commencing from the head of the Bay of Bengal flows towards the southwest, sweeps along the east coast of India until it finally reaches the east coast of Ceylon then bends westwards, keeping close along the coast, and enters the Gulf of Mannar. At the same time a current from the west coast also enters

the Gulf. During the next three months, December–February, there is a significant change in the direction of the surface currents. The current from the west coast no longer enters the Gulf while a current which sweeps across the Bay of Bengal strikes the Coramandal coast, gets deflected and moves down south along the east coast of Ceylon and enters the Gulf of Mannar before it moves further west. Great changes take place during March–May when waters from the Arabian Sea and, probably also from the Indian Ocean, enter the Gulf and, as already pointed out earlier, the turbulent conditions in the Gulf, associated with the southwest monsoon, begin to prevail during this period. Lastly, the period June–August includes the greater part of the southwest monsoon. Although the chart given by Sewell, *op. cit.*, does not indicate any surface current entering the Gulf of Mannar during June-August, it has been observed that there is a drift from south to north and it is not unlikely that water masses from the Indian Ocean and Arabian Sea enter the Gulf. The possible incursion of oceanic surface waters into the coastal regions of the area under investigation during June-August is further evidenced by the presence of high salinity low silicate surface waters and the appearance of such open ocean forms as *Janthina roseola*, *Velella* sp., *Porpita pacifica* and *Physalia utriculus*.

The fact that currents are important agents in the transportation of organisms and that such movements of water masses may profoundly affect both the distribution and numbers of organisms is well established. These currents are generally more rapid in shallow waters and in the proximity of land boundaries (Fleming, 1948). Therefore, the possibility of surface currents bringing into or carrying away from the area investigated, which is particularly influenced by adjacent water masses, planktonic organisms, resulting in abrupt changes in the plankton population cannot be excluded. Similarly, the fact that the plankton of this region shows the characteristics of those of the east and west coasts of India may, at least, in part, be due to the surface currents and consequent mixing of water masses from the two different sources. However, this will have to remain as a speculation pending the collection of more data. Unless there is a continued and integrated programme to investigate the different aspects involved it will not be possible to determine the factors that control the fluctuations and cycles of the local plankton populations.

With this general picture of the plankton community it is of interest to examine the occurrences of pelagic fish larvæ and fish in the neighbourhood of the area investigated during the two years. The source of information on the pelagic fish is chiefly from the records maintained by the State Fisheries Department on the landings of their departmental boats. These

data are available only for six months.[5] During April-September when the weather conditions are unfavourable fishing is restricted to shore seine operations.

Although a large number of a variety of fish eggs are collected from this area from February-March and again, in fewer numbers, from September-November the relative scarcity of fish larvæ is striking. Delsman (1929) remarked: "The larvæ seem to strive for deeper waters than the eggs floating quite near the surface, and therefore are no longer caught in the surface hauls with the egg net." With this in mind collections were made from near the bottom but these showed no significant difference in the number of larvæ from samples taken near the surface. As the area is comparatively shallow it is likely that the larvæ preferring deeper waters may move to such regions. This may be one of the reasons for the apparent paucity of fish larvæ in this area. The few larvæ that are present are found from December to May and their maximum is reached sometime in March.

Figs. 2 and 3 show the important species of fish landed and the predominant elements of the plankton. Data on the relative abundance of the various species, based on the landings of the State Fisheries Department boats are shown in Table XII.

TABLE XII

Relative abundance of pelagic fish during 1950 *and* 1951

Fish	Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Sardines ..	1950	××××	××××	××××	××××	××××	××××
	1951	..	..	××	××××	××××	×××
Seer	1950	×××	×××	×××	..	..	..
	1951	××××	××××	××××	××	×××	××
Chirocentrus dorab	1950	××	××	××	..	..	..
	1951	×××	×××	×××	×	..	..
Chorinemus sp.	1950	..	..	..	..	..	..
	1951	..	..	..	×××	..	..
Caranx sp.	1950	..	..	..	..	..	..
	1951	..	..	..	..	..	×××

Note.—Sardines include mostly *Sardinella gibbosa* and *S. fimbriata*. *Cybium guttatum* and *C. commersonii* are the two species of seer occurring locally.

[5] The author wishes to thank the Dept. of Fisheries, Madras State, and Mr. D. A. S. Gnanadoss, Inspector of Fisheries (Madras), Pamban, for making the data available.

The occurrence of pelagic fish showed some variations in the two years. Sardines were caught in abundance from October-March 1950, whereas in the following year they were not obtained in October-November but were abundant from January-March. Also, the landings were more substantial in 1950 than in 1951. It will be noticed that in Fig. 4 the general level of both phyto- and zoo-plankton production in 1950 was relatively higher than in the following year, which may be responsible for the increased landings of sardines in 1950. Seer was caught throughout the period October-March 1951, but was completely absent from the landings of January-March and the landings from October-December 1950 being comparatively small. There is practically little variation in the period of occurrence of *Chirocentrus dorab* in 1950 and 1951 although in the latter year it was caught in larger quantities and the fishing extended up to January as against December in the previous year. There were fairly good catches of *Chorinemus* sp., in January and of *Caranx* sp., in March 1951, but during 1950 both these species were not caught in this area. Seer, *C. dorab*, *Chorinemus* sp., and *Caranx* sp., were landed in greater quantities in 1951, but whether this has anything to do with the fluctuations in plankton it is difficult to say with the data available, as these species are not direct plankton feeders. The occurrence in this area of mackerel is also worthy of note. They generally appear by about December and continue to be present up to March with a peak period during January-February. In addition to the species mentioned above, the Rainbow sardines, *Dussumieria hasseltii*, are caught in shore seines from April-August or September and the maximum landings are in July-August. Small quantities of *S. gibbosa*, *S. fimbriata* and *Stolephorus* sp. are occasionally landed along with *D. hasseltii*. No information on the relative abundance of *D. hasseltii* is available.

A detailed study of the food of many of these fishes has not been possible so far, but the examination of the stomach contents of mackerel collected locally showed that they fed mainly on copepods and also on *Lucifer* sp. Specimens collected during February 1951 had their stomachs gorged with *Lucifer*. Fig. 6 shows that during January-March there is a high copepod population and Fig. 7 shows the abundant occurrence of *Lucifer* in February 1951 in this area. According to Chacko (1949) *S. gibbosa*, *D. hasseltii* and *Stolephorus* feed both on phyto- and zoo-plankton, whereas *C. dorab*, *Cybium commersonii* and *Caranx* spp. are carnivorous, actively predaceous at surface and midwater, depending chiefly on fish and prawns. A fuller discussion on the correlation between the food of these fishes and the nature of plankton will necessarily have to be postponed until sufficient data are gathered. The present observations tend to show that the abundance of

those species of pelagic fish which occur in this area and feed directly on plankton bears, as is to be expected, some direct relation to the level of plankton population.

VIII. Summary

1. The paper deals with the gross qualitative and quantitative changes in the plankton of an inshore station in the Gulf of Mannar. These changes are compared with those observed at other places along the coasts of India.

2. Hydrological and meteorological features of the area are briefly described. Fluctuations in the surface temperature and salinity show similarity in general trends in the two years. The maximum and minimum surface temperatures recorded were 31·50° C. and 24·00° C. in 1950 and 30·60° C. and 24·60° C. in 1951 respectively. In 1950 the surface salinity was highest in May (36·41‰) and lowest in December (29·44‰). During the following year the lowest (29·01‰) was recorded in January. The highest salinity for the year was 36·02‰ in September but no data are available for May 1951.

3. The standing crop was on the whole of a higher order in 1950 than in 1951. It shows two peaks, one in February-March and the other during September-October, the actual months in which the peaks fall varying with the year. In 1950 and 1951 the standing crop reached its lowest level in December and October respectively.

4. The phytoplankton cycle shows more than one maximum during a year and the peak falling either in February or March appears to be the result of local flowering of a single species. In March 1950 the species which bloomed suddenly was *Rhizosolenia alata* but in February 1951 it was *R. imbricata*. Several species of diatoms contribute to the summer as well as the August-November maxima and a list of these species is given. Seasonal variations of the more important species of dinophyceæ and the planktonic blue-green alga *Trichodesmium erythræum*, are described.

5. A bimodal cycle in the distribution of zooplankton with one peak falling sometime during February-April and the other in October is observed. The distribution and fluctuations of tintinnids, chætognaths, cladocerans, copepods, decapods, pteropods, tunicates, larval forms, etc., are discussed. As against the unimodal cycle of copepods described by investigators from other areas along the coast of India, there is a bimodality in their occurrence in the present instance.

6. While the results of the present investigation show that the local plankton has certain distinctive characteristics of its own, it shows some

similarities with the plankton of the east and west coasts of India, the probable reasons for which are briefly discussed.

7. The occurrence of the more important pelagic fish in and around the area of investigation for the two years is compared. It appears that the abundance of those species which feed directly on plankton shows some direct relation to the level of plankton population. The mackerels, when they occur in this area, feed mainly on copepods and *Lucifer*.

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