FURTHER STUDIES ON THE PLANKTON OF THE INSHORE WATERS OFF MANDAPAM

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CONTENTS

INTRODUCTION

IN an earlier paper the author (Prasad, 1954 *a*) described the characteristics of marine plankton at an inshore station in the Gulf of Mannar based on regular plankton samples collected from a single station. Mandapam is located on a narrow strip of land lying east-west, with the Palk Bay to the north and the Gulf of Mannar to the south. Because of this geographical situation and certain differences in the fisheries of these two areas a comparative study of the plankton of the Gulf of Mannar and the Palk Bay was undertaken. The object of the present investigation is, therefore, to compare the gross changes in the plankton of two stations, one in the Palk Bay and the other in the Gulf of Mannar. In attempting a comparison of this type it should be mentioned that the stations are not considered strictly as representatives of the entire areas because investigations, carried out locally and elsewhere, have revealed the fact that no single station will serve as an adequate index for any particular region. A sufficiently large number of stations, located over a wide area forming a network, could not be operated and an arrangement such as the present one was found necessary owing to various limitations.

The present paper gives a comparative account of the changes in the total net-plankton volume, as estimated by the displacement method, and in the common planktonic groups at the two stations. The hydrological conditions and the general interrelationships of phytoplankton and zooplankton are also briefly discussed.

For the purpose of this investigation a station in the Gulf of Mannar 'G' (located at the same place as Station 'A' of Prasad, 1954 *a*) and another in the Palk Bay 'P' were located at approximately equal distance from the shore (about 2 miles), but the depth at the latter station was nearly 3½ fathoms, whereas at the former it was only about 2½ fathoms (Fig. 1). The waters of the two areas are contiguous and permanent connections exist through the narrow Pamban Pass and the wide gap between Pamban and Mannar Islands. For a general description of the environment and the meteorological conditions of this region reference may be made to Prasad (1954 *b*).

A total of 261 plankton samples, 90 from Station G and 171 from Station P, collected during the period July 1951 to June 1953, formed the material. The methods of collection and enumeration of the various components are the same as those described by Prasad *et al.* (1952), and Prasad (1954 *a*). Facilities available permitted only the recording of many organisms under genera or groups. This is one of the serious limitations of this paper, nevertheless it is felt that this report, together with the one already published, will give a general picture of the changing plankton community at these two stations in the years of survey and also provide a groundwork for more detailed investigations which are in progress. All larval forms have been excluded from the scope of this paper as they have been dealt with elsewhere (Prasad, 1954 *b*).

Net-Plankton Volume

The total net-plankton volume at Station G exhibited well-defined maxima and minima as well as differences from year to year (Fig. 2). In general, the cycle was bimodal, with one peak between January and March

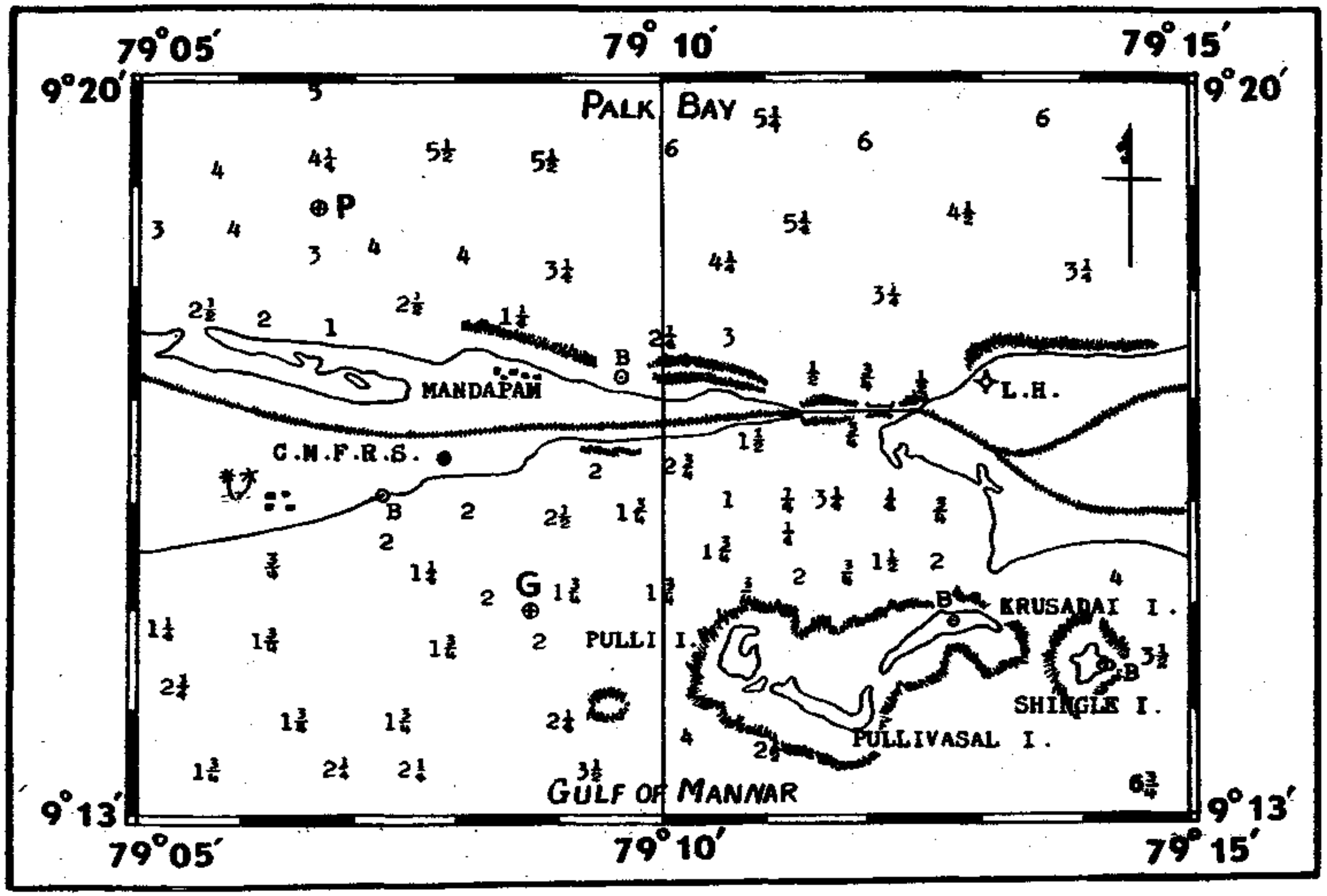

FIG. 1. The location of stations G and P. The numbers in the figure indicate the depth in fathoms.

and another during September-October. The standing crop of plankton was often low during periods of turbulence and relatively high temperature. The present findings are in general agreement with those recorded for the years 1950–51, although the figures for May 1952 are unusually low (Prasad, 1954*a*).

The curves for the standing crop of plankton at Station P present an entirely different picture except in that the distribution is bimodal and the peak of the second half of the year falls during September–October. From January the total displacement volume steadily increased up to May or June and then there was a period of comparatively low standing crop (July–August). Again there was an increase leading to a peak, either in September or in October, followed by a decline. Relatively smaller values were often recorded during January, July, August and December. With the onset of the north-east monsoon (October or November) and the turbulent conditions in the Palk Bay, the volume showed a decrease, but with the resumption of calm conditions it tended to increase. There is a good similarity in trends during the years of this investigation (Fig. 2), but the higher displacement volume throughout the months, July to December 1951, is particularly interesting. A similar phenomenon was observed at the station in the Gulf of Mannar where the standing crop was higher in 1950 than in 1951 for several months (Prasad, 1954 *a*). Comparing the two stations one finds the monthly and annual fluctuations at Station G to be greater than those at Station P. The steady increase in the standing crop from a low level in January to a peak, then a decline with a short interval of low standing crop, followed by a second peak and again a decrease, were in striking contrast to the pattern of changes at Station G, as seen from the undulating nature of the curves for the displacement volume. Another noteworthy feature was that almost throughout the period from April to December (July, October and December, 1952 were the exceptions) a comparatively higher standing crop was recorded at Station P (Fig. 2).

PHYTOPLANKTON

The distribution pattern of total phytoplankton, excluding the blue-green alga, *Trichodesmium erythræum*, at Station G was characterised by sudden fluctuations. In general, there were three peaks which alternated with periods of low populations. Thus, in 1952 and 1953 the phytoplankton population was high in January and there was an appreciable decimation in February–March. In 1952 the concentration increased from April until May, whereas in 1953 there was a more rapid rise in April itself. These peaks were immediately followed by a reduction in the number of phytoplankton. During the period, June to August, phytoplankton was usually low,

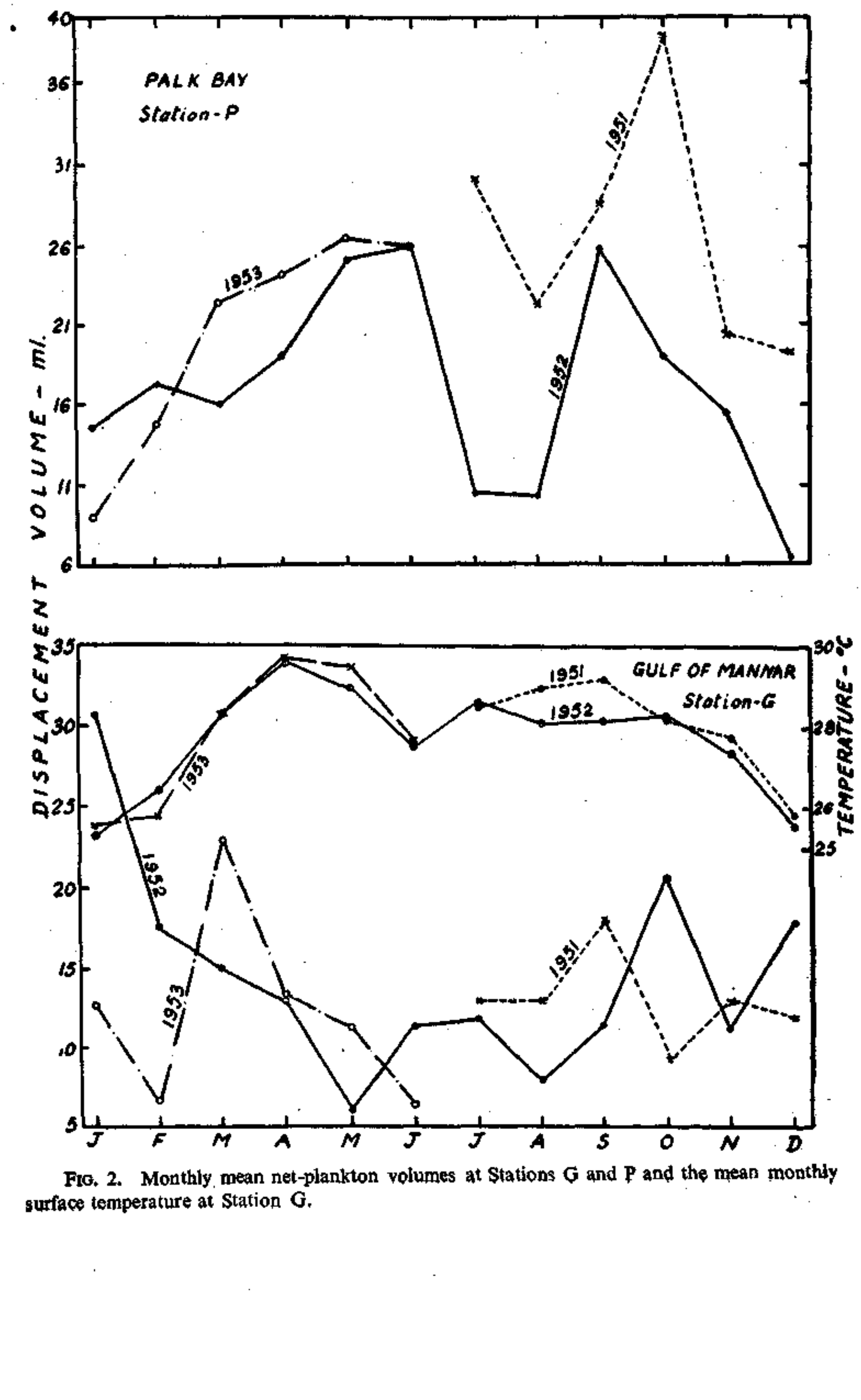

FIG. 2. Monthly mean net-plankton volumes at Stations G and P and the mean monthly surface temperature at Station G.

but it once again increased, reaching a maximum either in October or in November, and then declined (Fig. 3). The remarkably high population recorded in July and August 1951 might be considered as somewhat unusual for the period, as seen from the data already available for the years 1950–53 (*Ref.* also Prasad, 1954 *a*).

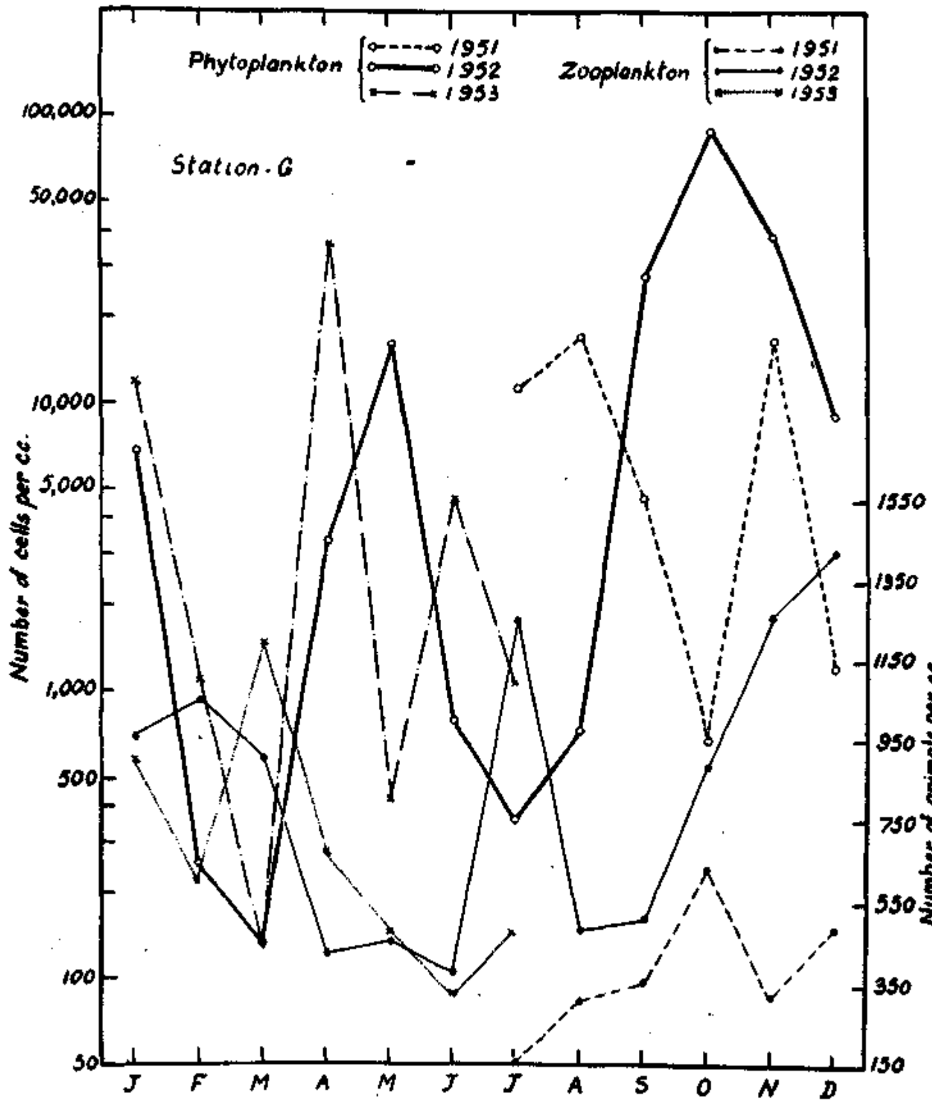

FIG. 3. The mean monthly number of cells, on a logarithmic scale, of phytoplankton and the mean monthly number of zooplankton at Station G. In Figs. 3–9 and 12 the number is per c.c. of the standardized sample.

Against this abruptly fluctuating phytoplankton cycle at Station G we find the more 'stable' distribution of phytoplankton at Station P. Starting from a rather low population in January the phytoplankton community

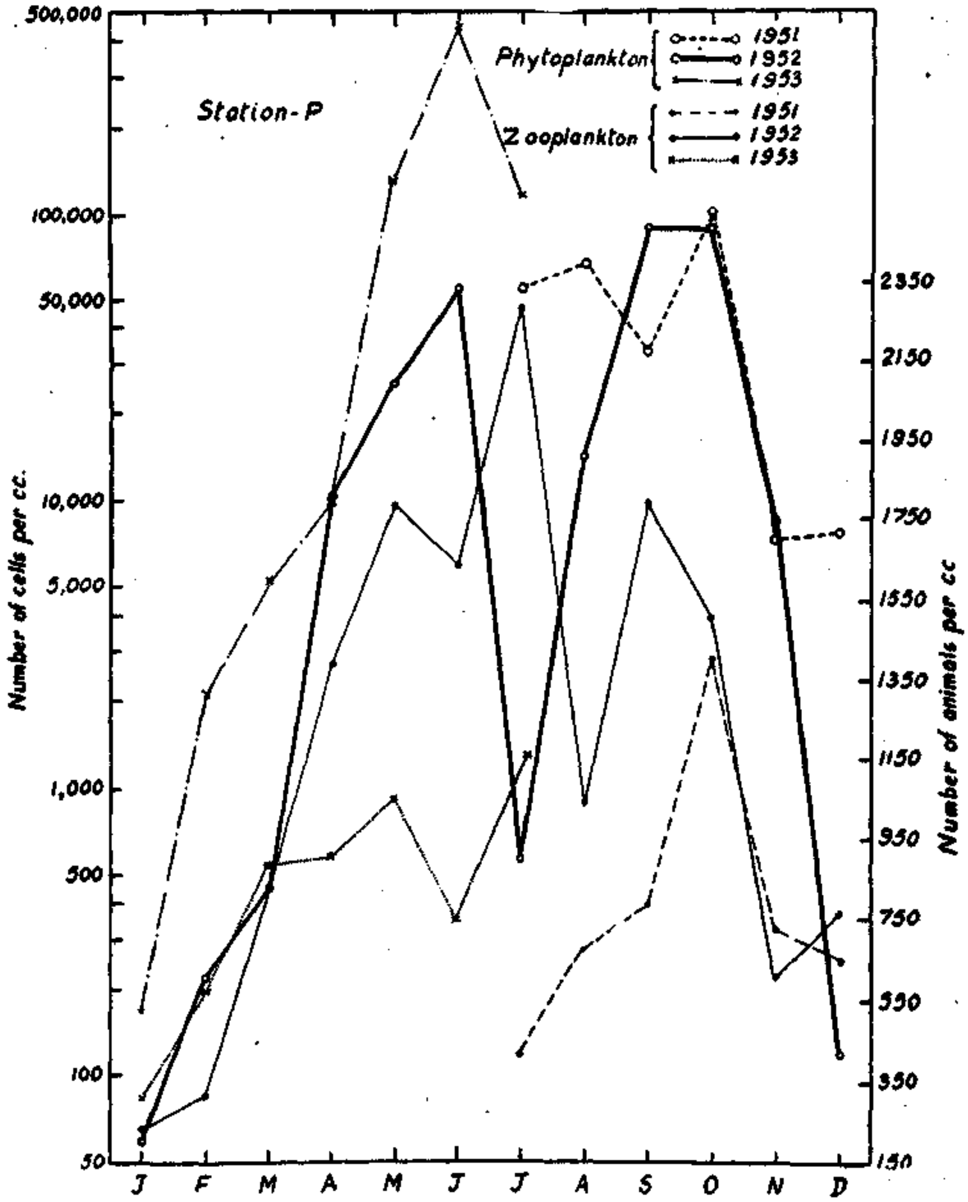

FIG. 4. The mean monthly number of cells, on a logarithmic scale, of phytoplankton and the mean monthly number of zooplankton at Station P.

increased steadily to a high level by May–June and remained high, except for a slight decimation during July–August, up to October, after which there was an appreciable fall. The marked drop in phytoplankton recorded in July 1952 seems to be a departure from the normal condition. It will also be noticed that in May–June of 1952 the phytoplankton population was low compared to that of the same period in 1953 (Fig. 4). During May–July 1952 there was an unusual swarming of *Noctiluca*, particularly at Station P, which reached the maximum in July (Fig. 7). The possible effect of grazing by this large population of *Noctiluca* might, in all probability, have kept down the phytoplankton level during May–June 1952 and this constant grazing over a period of two months together with a sudden increase in the number of *Noctiluca* in July (about one and a half times that of June) must have resulted in the abrupt reduction of phytoplankton in July 1952. It was pointed out in an earlier paper that, when these cystoflagellates were present in great numbers, the diatom level was exceedingly low, which was attributed to the effect of active feeding by *Noctiluca* on the diatoms. This assumption was further supported by certain changes in the hydrological conditions at the same time (Prasad and Jayaraman, 1954).

Summing up, it may be said that at Station P the phytoplankton showed a single prominent peak during the summer months, followed by a slight decrease in July–August and then an increase in October–November. At Station G, on the other hand, there were at least three distinct blooms, with periods of very low phytoplankton levels in between. The first bloom occurred in January, the second during April–May and the third in October or November. At Station P the magnitude of phytoplankton population was higher than at Station G throughout July–December 1951 and also during peak seasons. In fact the total phytoplankton production for a whole year was of a distinctly lower order at Station G as judged from the relative concentration of the standing crop of phytoplankton recorded during the course of this investigation.

(*a*) *Diatoms.*—The monthly fluctuations in the mean number of diatoms at Stations G and P are shown in Figs. 5 and 6. Since these curves resemble very closely those for the total phytoplankton and further the maximal and minimal periods of both total phytoplankton and diatoms coincide, the details of fluctuations are not repeated here.

The trends in fluctuations of total diatoms of the two stations were different, as already noticed, and a detailed examination of the diatom community revealed certain distinct differences and similarities in the species composition and abundance. At both stations, although several species of diatoms occurred, the predominant ones, which constituted the bulk in many months of the year, were species of

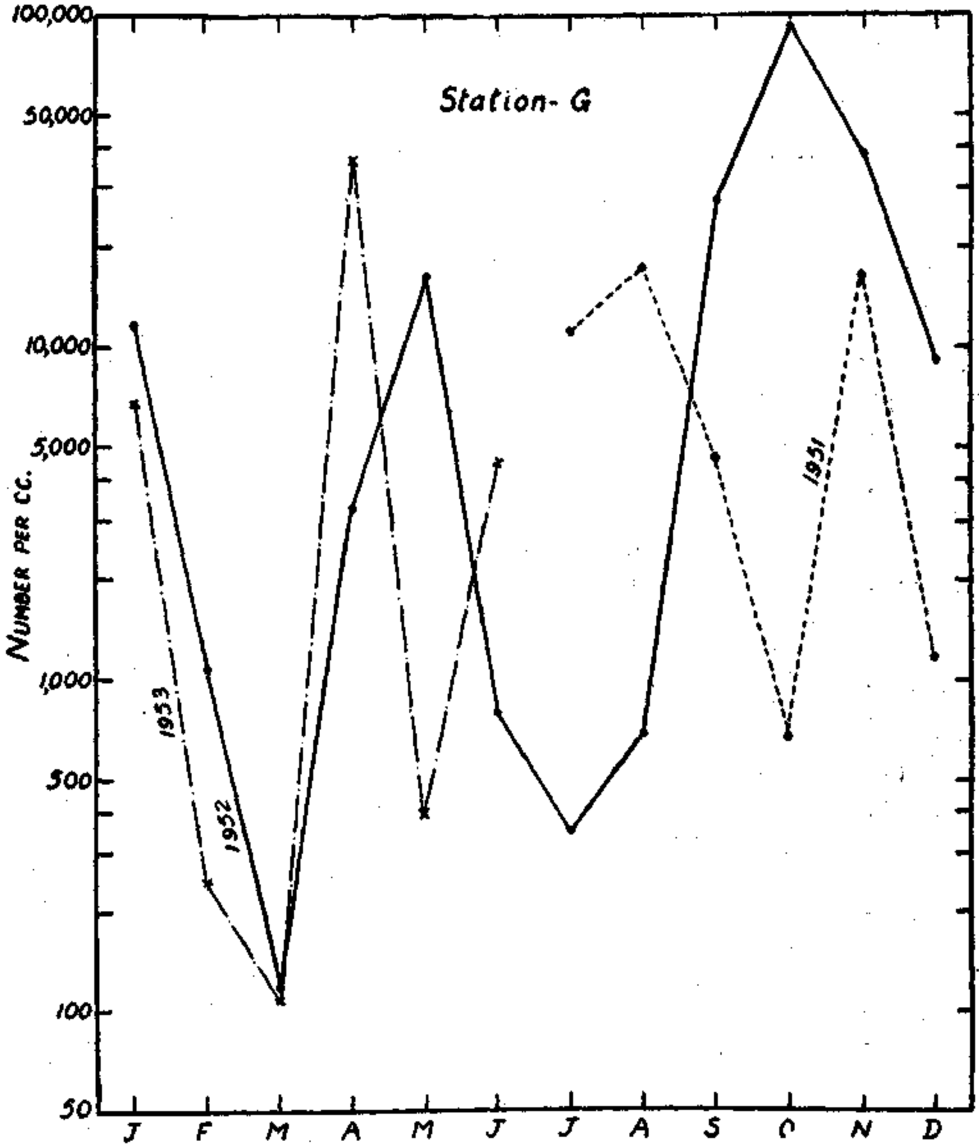

FIG. 5. The mean monthly number of diatoms at Station G. Logarithmic scale.

Chætoceros, *Rhizosolenia alata* Brightwell, *R. imbricata* Brightwell, *R. styliformis* Brightwell, *Thalassionema nitzschioides* Grunow, *Thalassiothrix frauenfeldii* Grunow, *Bacteriastrum hyalinum* Lauder, *B. varians* Lauder and *Biddulphia sinensis* Greville. The abundance and succession of the more important species are shown in Table 1. Species such as *Thalassiosira coramandeliana* Subrahmanyan, *Guinardia* sp., *R. styliformis*, *R. calcar avis* M. Schultze, *R. castracanei* Pèragallo, *Hemiaulus*

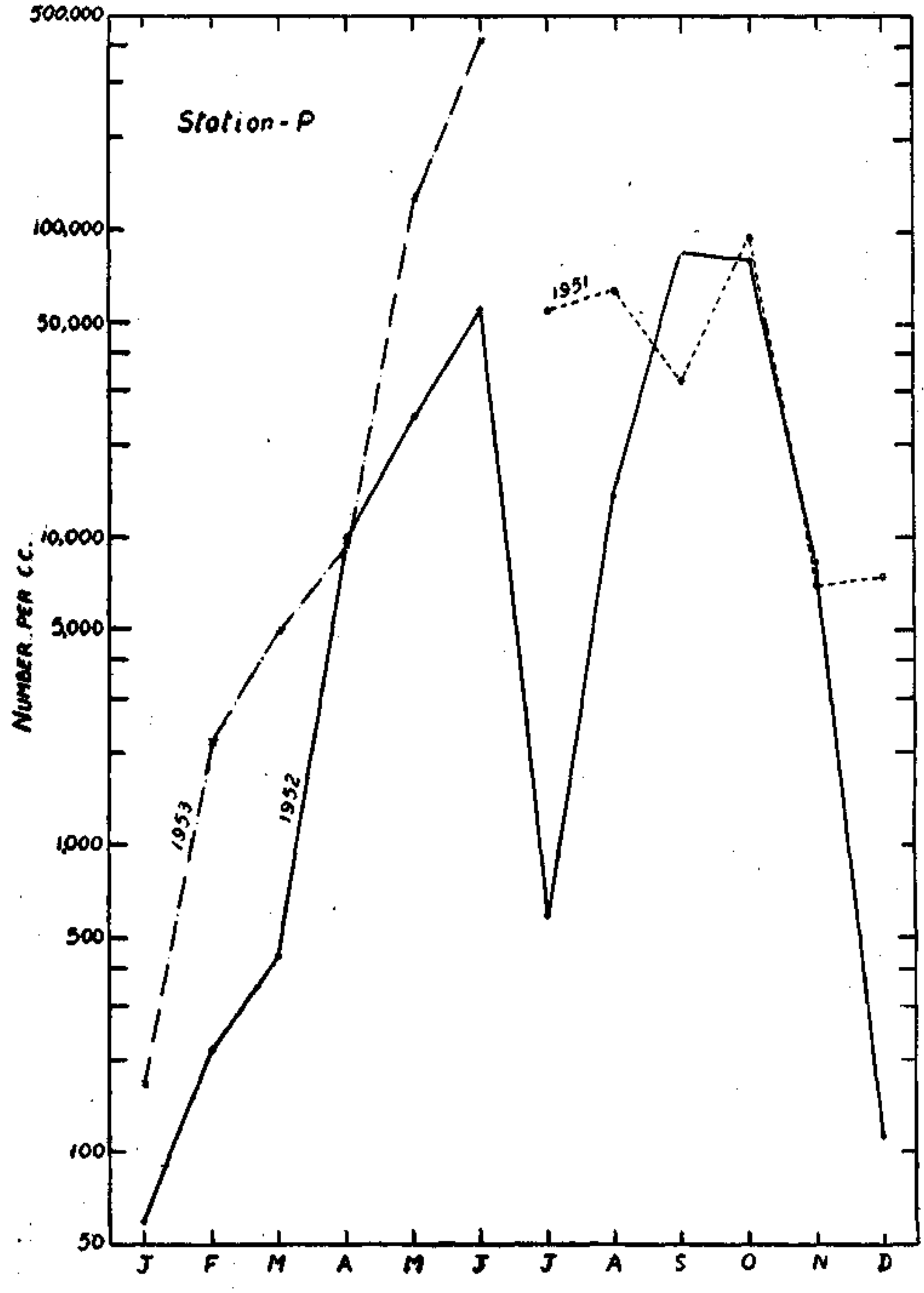

FIG. 6. The mean monthly number of diatoms at Station P. Logarithmic scale.

sinensis Greville, *Bacteriastrum varians*, *Chætoceros denticulatum* Lauder, *Climacosphenia elongata* Bailey, *Asterionella japonica* Cleve, etc., were either found in greater numbers at Station P or were collected only from that station during the course of this investigation. On the other hand, species such as *Chætoceros coarctatus* Lauder, *Ditylum brightwellii* (West) Grunow, *Biddulphia sinensis* and *Hemidiscus hardmannianus* (Greville) Mann were more common at Station G. Again, the time of minima and maxima of many of the species varied between the two stations. Even within the stations, it was observed that the species which occurred during particular seasons of the year might be completely absent or poorly represented during the same period in the preceding or succeeding years as the case may be. Thus, while almost all species showed some variation in their occurrence and distribution, a few species were noticed to exhibit extreme fluctuations. To mention a few examples, there was a fairly high population of *R. alata* in July–December 1951 at both stations, whereas this species was relatively poor at both stations in 1952 and up to June 1953, except in May–June 1953, at Station P. While, on the other hand, *Chætoceros compressus* Lauder was not recorded during July–December 1951 from either of the stations, it was abundant at Station P in June, September, October and also in November 1952 and April–June 1953 and at Station G during October–November 1952 and April 1953. *Leptocylindrus minimus* Gran and *Chætoceros denticulatum* were two species which showed complete absence in one and were found in large numbers in another year. Then there were others, *e.g.*, *B. varians* and *C. lascinosus* Schütt, with their distribution restricted to a few months and still others, such as *B. sinensis*, *Thalassiothrix frauenfeldii*, *Thalassionema nitzschioides* and *Chætoceros lorenzianus* Grunow, which were generally encountered during several months of the year in varying intensities.

From what has already been stated above it is apparent that within and between the stations under investigation there may be considerable variations from year to year in the abundance, composition and succession of diatom species. At both these stations diatoms were generally less abundant in the first two or three months of the year, being below 5,000 cells per c.c. of the standardized sample, except at Station G where a fairly high diatom population was noticed in January 1952 and 1953. It is of interest to compare here the species responsible for these blooms in January 1952 and 1953 with those which caused the blooms in March 1950 and February 1951, because in these two months only a single species of diatom was involved at a time, *R. alata* and *R. imbricata* respectively, and it was suggested that these may be instances of local flowering of a single species (Prasad, 1954 *a*).

In 1952–53 *R. alata* was exceedingly scarce and *R. imbricata* was found in fair numbers from January to February 1952, though not of the same order as that of February 1951, to constitute a peak by itself. The peak observed in January 1952 was a mixture of mainly *Thalassionema nitzschioides*, *Thalassiothrix frauenfeldii*, *Chætoceros* spp., *R. imbricata*, *B. sinensis* and *Bacteriastrum varians*, of which the

TABLE 1

The Abundance and Composition of Diatom Populations at Stations G and P
The Numbers are Averages for the Month

(Fractions have been omitted in Tables 1 to 3 and numbers in italics refer to Station P)

Species	1951						1952												1953					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
Thalassiosira coramandeliana	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *40*	.. *133*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Coscinodiscus gigas	.. *20*	15 ..	29 *17*	118 *7*	.. *3*	19 ..	2 *5*	.. ..	.. ..	.. ..	.. ..	3 *14*	48 ..	11 *1*	.. ..	2 *2*	21 *5*	93 *12*	2 ..	14 ..	.. ..	.. ..	.. ..	.. ..
Coscinodiscus spp.	.. *47*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	240 *12*	23 *5*	.. *43*	.. *60*	160 *50*	.. ..	.. *24*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *1*	112 *23*	80 *452*	.. ..
Schrœderella delicatula	.. ..	.. *20*	.. ..	.. ..	.. ..	.. ..	32 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Leptocylindrus minimus	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	224 *306*	4333 *5394*
Guinardia sp. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *19*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *8*	.. ..	.. ..	.. ..
Rhizosolenia alata	260 *7978*	2506 *2621*	25 *4000*	4 ..	1375 *62*	200 *266*	24 *4*	20 ..	.. ..	.. *37*	.. *7718*	.. *317*	.. ..	.. ..	.. ..	.. ..	.. *19*	16 *2*	5 ..	.. ..	.. ..	.. ..	.. ..	.. ..
R. imbricata ..	4080 *19916*	43 *9785*	25 *572*	.. ..	.. *5*	.. ..	964 *4*	422 ..	50 *81*	.. ..	144 *14213*	.. *242*	.. ..	59 ..	60 *171*	.. *1*	149 *73*	24 ..	6 ..	.. ..	3 ..	9 *1*	1 ..	.. ..
R. styliformis ..	.. ..	5030 *160*	.. *2000*	.. ..	20 ..	.. *146*	.. ..	.. ..	.. ..	.. ..	25 *68*	.. *1453*	.. *7*	.. *1644*	.. *1343*	.. ..	28 ..	.. *18*	.. ..	1 ..	6 ..	40 ..	.. *99*	.. *5900*
R. hebetata ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *2571*	.. *388*	.. ..	204 ..	.. ..	.. ..	.. ..	.. ..	.. ..

R. calcar avis ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 *18*	.. *1387*	.. ..
R. castracanei ..	.. ..	.. ..	.. ..	.. ..	.. *11*	.. ..	.. ..	.. ..	.. *135*	.. *8*	.. ..	.. ..	.. ..	.. *2*	.. ..	.. ..	.. *916*	.. ..	.. ..	.. ..	.. *9*	.. *7*	.. *794*	.. *1455*
Bacteriastrum variens	.. ..	600 *200*	.. *100*	.. ..	.. ..	.. *133*	100 ..	.. ..	.. ..	.. ..	.. *254*	.. *2576*	.. ..	.. ..	.. *64*	.. *1324*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *11946*	4 *9967*
B. hyalinum ..	.. ..	.. ..	.. ..	.. *2933*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *550*	.. *3196*	.. *435*	.. ..	.. ..	11500 *7951*	5250 *200*	.. ..	.. ..	.. ..	.. ..	1040 *5576*	.. *7574*	.. *33725*
Chætoceros coarctatus	310 ..	82 ..	265 *128*	.. ..	.. *129*	6 ..	160 ..	.. ..	6 *7*	.. ..	4280 ..	40 *22*	24 ..	126 ..	1440 ..	.. ..	23 *19*	19 ..	5 *7*	6 ..	14 ..	24 ..	.. ..	69 ..
C. denticulatum	.. *1436*	260 *1236*	400 *310*	.. ..	25 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *8372*	.. *5197*
C. peruvianus ..	50 *5956*	3110 *2107*	300 *4190*	.. *8200*	2400 *260*	.. ..	.. ..	.. ..	.. ..	240 *1288*	.. *1068*	.. *444*	.. *3*	.. *10697*	.. *2576*	900 *1240*	750 *67*	.. ..	.. ..	.. ..	.. ..	1 ..	.. *904*	.. *49060*
C. lorensianus ..	3510 *3945*	188 *4190*	340 *788*	160 *4733*	3000 *464*	100 ..	760 *8*	325 ..	.. ..	1960 *3261*	6200 *608*	240 *6202*	70 ..	252 ..	480 *14968*	41250 *33983*	2250 *695*	.. ..	.. ..	.. ..	.. ..	488 *336*	.. *12329*	6 *30635*
C. indicus ..	1000 *1309*	.. *1927*	.. ..	.. *4600*	3000 *232*	30 *2853*	.. ..	.. ..	.. ..	.. ..	.. *27*	.. *6108*	.. ..	.. *822*	.. *3702*	6000 *6681*	9250 *656*	.. ..	.. ..	.. ..	.. ..	600 ..	.. *24677*	.. *52880*
C. compressus ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *16800*	.. ..	.. ..	.. *5129*	9900 *15384*	3894 *1659*	.. ..	.. ..	.. ..	.. ..	32864 *3860*	.. *31325*	5 *79611*
C. didymus ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *5541*	240 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
C. affinis ..	.. ..	.. ..	.. ..	.. *12333*	.. ..	100 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *33453*	20250 *260*	3000 *1368*	.. ..	.. ..	.. ..	.. ..	280 ..	.. *238*	.. ..
C. lascinosus ..	250 *3509*	.. *883*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1400 ..	.. *5533*	.. ..	.. ..	.. ..	.. *16657*	5634 *680*	4 ..	.. ..	.. ..	.. ..	50 ..	.. *15408*	.. *124611*
C. diversus ..	40 ..	.. ..	.. ..	.. *600*	200 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *733*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	16 ..	.. *301*	.. *7337*
Chætoceros spp.	.. *4000*	3000 ..	1400 *5000*	288 *35500*	4400 *5555*	.. *3733*	1400 ..	.. ..	.. ..	.. *5085*	.. *234*	.. *13595*	.. ..	.. ..	24710 *10792*	.. ..	.. ..	.. ..	38 ..	.. ..	.. ..	.. ..	.. ..	.. ..

TABLE 1—(*Continued*)

Species	1951						1952												1953					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
Bellarochea	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
malleus	*36*	*36*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ditylum	15	5	..	..	..	..	..	..	..	..	7	..	..	4	..	..	..	..	..	..	..	..	..	..
brightwelli	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Biddulphia	370	154	67	24	190	20	244	75	11	..	256	325	..	235	16	..	..	15	6	8	17	..	..	6
sinensis	*106*	*160*	*185*	*133*	*59*	*13*	*2*	..	..	*12*	*271*	..	..	..	..	..	..	..	..	..	..	..	*71*	*228*
B. mobiliensis ..	..	..	..	..	500	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*388*
B. pulchella ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..
	..	..	..	..	..	..	..	*77*	*25*	*8*	..	..	..	..	..	..	*5*	..	*10*	*13*	..	..	..	..
Isthmia enervis	..	..	..	..	..	35	..	..	24	..	..	..	..	..	..	..	..	..	5	12	10	..	..	..
	..	..	..	..	..	..	..	..	*2*	..	..	..	..	..	..	..	..	..	*61*	*1624*	*1264*	..	..	..
Hemiaulus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
sinensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*195*	*3097*
Hemidiscus	420	..	..	..	..	20	8	5	3	..	..	33	..	..	..	..	..	8	7	51	..	4	..	151
hardmannianus	..	..	..	*266*	..	..	..	..	*21*	..	..	*6*	..	..	..	..	..	*8*	*1*	..	*3*	*2*	*13*	*20*
Rhabdonema sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	13	151	37	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*7*	*41*	..	..	..
Climacosphenia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
elongata	..	*18*	*7*	*6*	*8*	..	..	*11*	..	..	..	..	..	*13*	..	*33*	*504*	..	*11*	..	..	*4*	..	..

Fragilaria sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*1832*	..	..	..
Thalassionema	**590**	**1000**	**400**	**252**	**120**	**310**	**6547**	..	..	**540**	**2440**	**6**	**150**	**16**	**108**	..	..	..	**2293**	..	..	**197**	**77**	**16**
nitzschioides	..	*218*	*5720*	*13500*	*17*	..	*36*	*4*	..	..	*19*	..	*8*	..	..	..	..	..	..	*46*	*40*	..	*291*	*1834*
Thalassiothrix	**50**	**1330**	**1500**	**24**	**1400**	**270**	**1336**	..	..	**560**	**1292**	..	**10**	..	..	**456**	**1217**	**9163**	**4160**	**4**	**4**	**604**	**64**	..
frauenfeldii	*600*	*1214*	*8045*	*14513*	*120*	*266*	..	..	..	*518*	*48*	..	..	..	..	*82*	..	*72*	*12*	..	..	*122*	*12230*	*6364*
Asterionella	**100**	**6**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	**4770**	..	..	..	..	..	..	..
japonica	*312*	*37796*	*1705*	*1333*	..	..	..	..	*134*	..	*120*	..	*62*	*1134*	*28*	*37*	*1170*	..	*38*	*342*	*1873*	*9*	..	*302*
Pleurosigma spp.	..	..	..	..	**40**	..	**8**	..	..	..	..	..	..	..	..	**531**	**1**	..	..	..	..	..	..	..
	109	..	..	..	*28*	..	..	..	..	..	..	*66*	..	..	..	..	*80*	..	..	..	..	..	*1320*	*1194*
Bacillaria	..	..	..	..	..	..	..	..	..	..	**250**	..	**51**	..	..	..	**1970**	..	..	..	..	**66**	..	..
paradoxa	..	..	*400*	..	*142*	*366*	..	*99*	..	..	..	..	..	..	..	..	..	..	*25*	*74*	..	..	..	..
Nitzschia spp. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	**3000**	..	..	..	..	**4**	**35**	*17*	..
	..	..	*67*	..	*7*	..	..	*15*	..	..	..	*4*	*12*	..	..	..	..	..	..	*9*	*7*	*2*	..	*3760*

first two species together constituted a little over two-thirds of the total diatom population of the month. In January 1953 the significant species were *Thalassiothrix frauenfeldii* and *Thalassionema nitzschioides* with a few *Rhizosolenia hebetata* (Bailey) Gran. Since February 1951 there were no further instances at Station G of the blooming of a single species of diatom which resulted in a peak and since this investigation was started such a phenomenon was not observed at Station P during any part of the year. Following the period of low phytoplankton of the early part of the year there was an increase. On the whole, the diatom populations were appreciably higher at both stations during the second half of the year, but declined towards the very end. There was a noticeable reduction in the diatom population at Station G soon after the summer maximum succeeded by a rapid increase, but at Station P the high level attained during the summer months was maintained until October when the decline commenced (Figs. 3 and 4). At the time of maxima several species bloomed either simultaneously or in quick succession; thereby the peaks of two or more species often coincided and resulted in a remarkable increase in the diatom population.

(*b*) *Trichodesmium erythræum*.—The presence of large quantities of *T. erythræum* Ehrenberg, particularly during summer, at Station G was noticed. Their distribution exhibited notable fluctuations, as seen from the records available since 1950. In 1950 and 1951 they were found in several months (Prasad, 1954 *a*), but in 1952 and part of 1953 the distribution was restricted to about three months. On the other hand these blue-green algæ were not represented at Station P in any of the samples collected during 1951. In 1952, except in April when there were about 600 filaments per c.c., only a few filaments were present in February, September and November. They were again scarce in 1953, although small numbers occurred continuously from February to May (Fig. 7).

(*c*) *Dinophyceæ*.—The proportion of dinophyceæ in the samples was extremely small and, as these were net hauls, it is not unlikely that the smaller dinophyceæ, which might have escaped through the meshes of the net, were considerably more abundant than what was actually present in the samples. The distribution of total dinophyceæ at Stations G and P (Fig. 7) indicated two maxima, but the number of dinophyceæ reached a higher level in summer. The seasons of abundance somewhat coincided with those of diatoms (*cp.*, Prasad, 1954 *a*). From January to March and in December they were scarce, although a few members of the group were invariably found throughout the year. The species composition and their relative abundance are shown in Table 2. The most important species were those belonging to the genus *Ceratium*, particularly *C. trichoceros* Kofoid and *C. massiliense* Gourret at Station G, these and *C. fusus* Ehrenberg and *C. furca* Ehrenberg at Station P. Of these, *trichoceros* and *massiliense* were the most common.

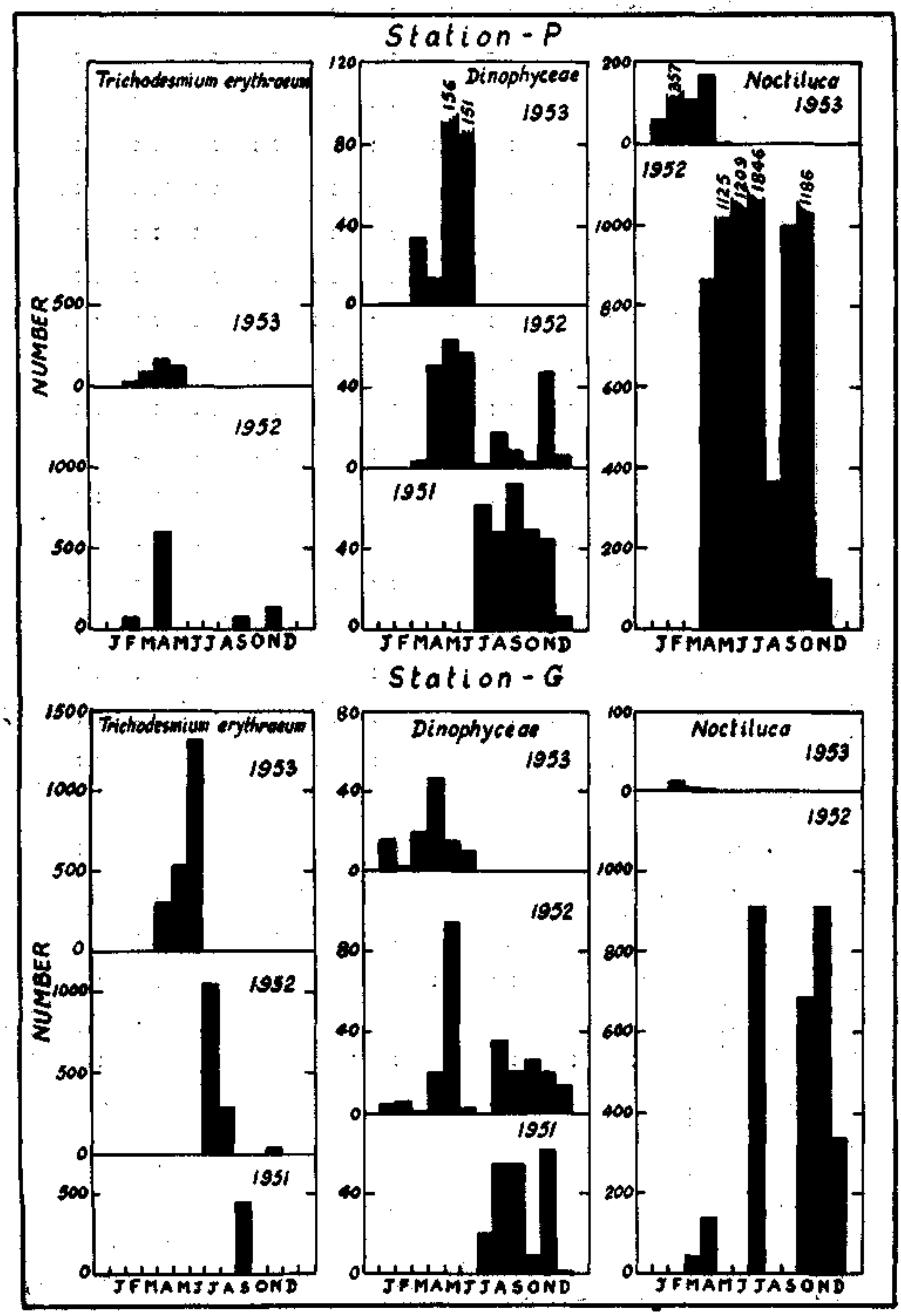

FIG. 7. The distribution of *Trichodesmium erythræum* (number of filaments per c.c.), dinophyceæ and *Noctiluca* at Stations G and P.

8

Table 2

The Abundance and Composition of Dinophyceæ at Stations G and P

Species	1951						1952												1953					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Ceratium trichoceros ..	14 *27*	31 *27*	41 *37*	8 *13*	23 *15*	1 *6*	1 ...	.. ..	.. *1*	.. *34*	70 *46*	3 *29*	.. *1*	35 *14*	18 *4*	14 ..	5 *27*	9 ..	6 *1*	1 ..	8 *17*	33 *11*	13 *106*	6 *52*
C. massiliense ..	5 *28*	17 *8*	14 *12*	.. *27*	30 *19*	.. ..	1 ..	4 ..	1 *2*	16 *5*	22 *12*	.. *17*	.. ..	.. *1*	.. *3*	.. *1*	11 *18*	4 *6*	7 ..	2 ..	12 *16*	10 *2*	.. *15*	2 *7*
C. tripos ..	.. *1*	.. ..	.. ..	.. *1*	5 *1*	.. ..	.. ..	.. ..	.. ..	4 ..	.. ..	.. *1*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *8*
C. furca ..	.. *1*	.. ..	.. ..	.. ..	.. *3*	.. ..	.. ..	.. ..	.. ..	.. *5*	.. ..	.. ..	.. ..	.. ..	2 ..	.. ..	.. *1*	.. ..	1 ..	.. ..	.. ..	1 ..	.. *7*	.. *10*
C. fusus ..	1 *1*	1 *5*	.. *8*	.. *1*	.. *4*	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. *5*	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *17*	.. *22*
C. flatum ..	.. *1*	6 *1*	.. *8*	.. ..	2 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *4*	.. *3*	.. ..	1 *1*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 *2*	.. *22*
C. schmidti ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	2 ..	2 *1*	.. ..	1 ..	.. ..	.. ..	.. ..	.. *2*	.. *4*
Peridinium depressum ..	.. ..	.. *4*	.. *4*	.. *1*	2 ..	.. ..	2 ..	.. ..	.. ..	.. *5*	2 *1*	.. ..	.. ..	.. ..	.. ..	7 ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..	.. *22*
Peridinium spp. ..	.. ..	.. *1*	.. ..	.. *3*	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	2 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. *5*	.. *1*
Dinophysis homunculus ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..

They appeared to be dicyclic, with maxima during April–May and September–November, although smaller numbers of these occurred during several months. Station P was comparatively richer in individuals but the same species occurred at both places.

ZOOPLANKTON

The distribution and fluctuations of total zooplankton at Stations G and P are shown in Figs. 3 and 4. The curves for the period July–December 1951 showed striking similarity; the zooplankton started from a low level in July, reached a peak in October and then declined. Contrary to this, the distribution patterns at these stations differed widely in 1952. At Station G the zooplankters were fairly high from January to March, low in April, May and June and then rapidly increased in July. In August–September the number of zooplankters was again low but a steady increase commenced by October and continued up to December. During the same year the zooplankton population was exceedingly low, at Station P in January–February, but this was followed by a steady rise which led to a maximum in July. The number of zooplankters registered a fall in August. In September there was an increase, but by October the trend was once again to decrease. Except for a slight fall in number during February 1953 the pattern of distribution from January to July 1953 at Station G resembled that for the same period of 1952. Likewise at Station P the curves showed very close similarity between the two years, only that there were fewer zooplankters during April–July 1953, which might be attributed to the absence of a large *Noctiluca* population like the one that existed during these particular months in 1952. Thus, the two stations showed different patterns; at Station G there was a high zooplankton population from January to March (with a maximum in February or March), but the zooplankton population at Station P during this period, particularly January–February, was relatively low. Again, when there was a decline in zooplankton from April to June at Station G, the opposite was observed at Station P, and also during several months the population was relatively higher at the latter station.

(*a*) *Protozoa*.—Many of the smaller protozoans are not adequately represented in the samples because they easily escape through the meshes of the net and therefore no attempt has been made at a detailed analysis of these forms. Radiolarians *Acanthometra* sp., were sometimes abundant in June–July.

The cystoflagellate, *Noctiluca miliaris* Suriray, was sometimes common in the plankton. The swarming of these was noticed to create adverse effects on some of the inshore pelagic fisheries and also bring about changes in the planktological and hydrological conditions (Bhimachar and George, 1950;

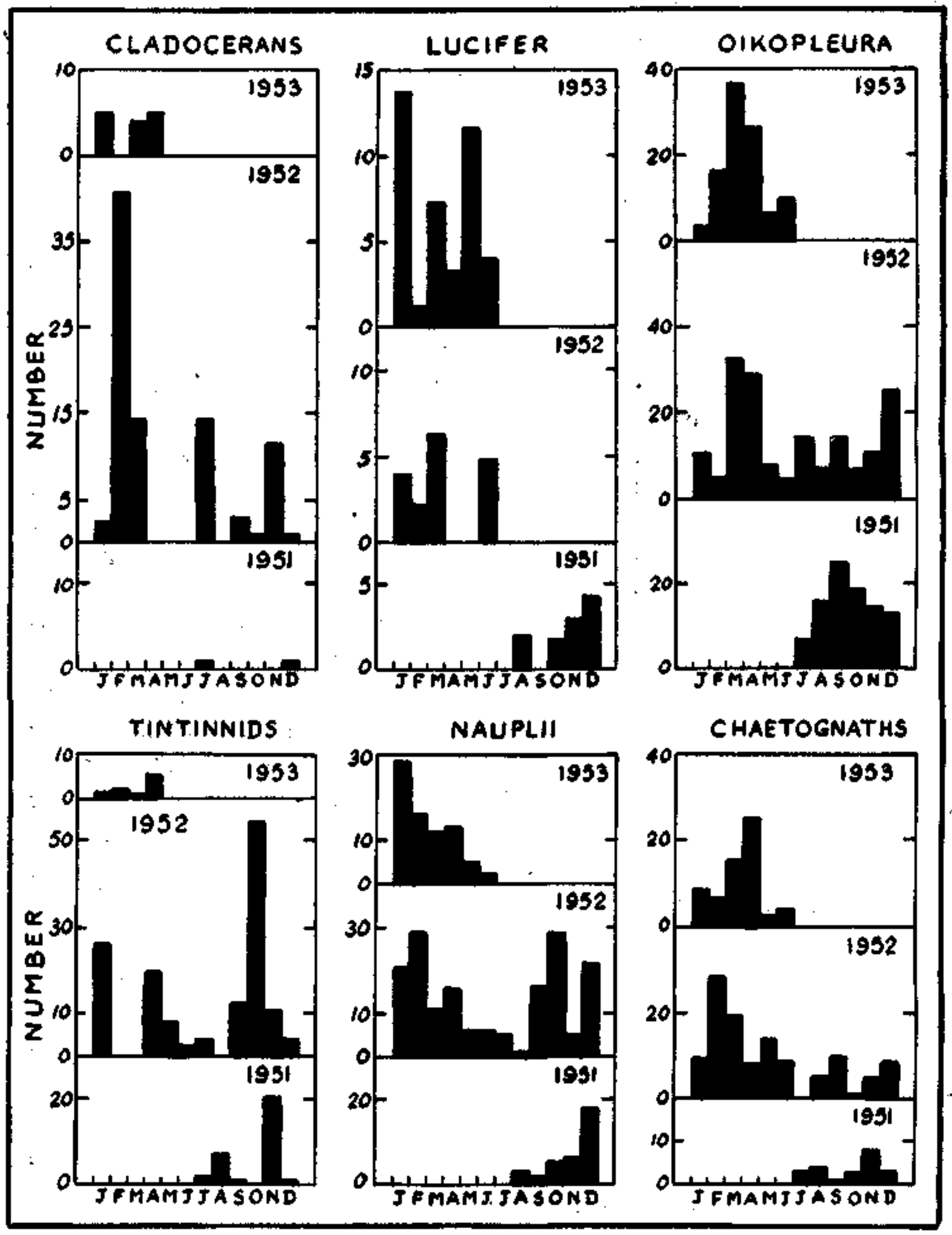

FIG. 8. The distribution of tintinnids, cladocerans, *Lucifer* and *Oikopleura* at Station G.

Prasad, 1952 and Prasad and Jayaraman, 1954). There was an almost complete absence of *Noctiluca* during July–December 1951 at both stations, but an enormous number of these was present from April to October 1952 with

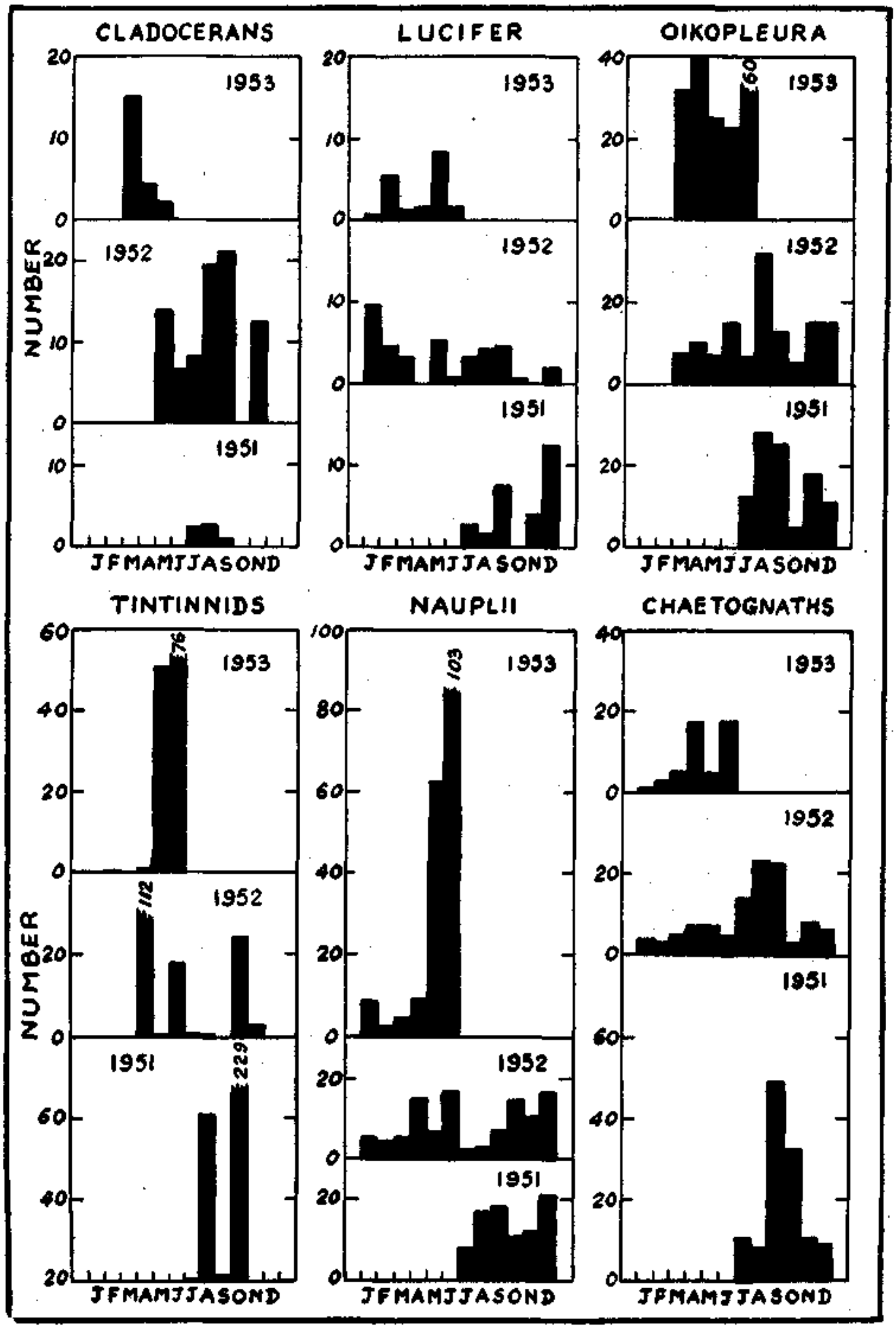

FIG. 9. The distribution of tintinnids, cladocerans, *Lucifer* and *Oikopleura* at Station P.

TABLE 3

The Monthly Mean Number of Tintinnids at Stations G and P

Species	1951						1952												1953					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Tintinnopsis tocantinensis ..	..	..	..	..	**2**	..	..	..	..	..	..	..	..	..	..	**4**	**8**	..	..	..	..	..	..	..
	12	*27*	*2*	*61*	..	..	..	..	..	*29*	..	*1*	..	..	..	..	..	..	..	..	..	..	*12*	*23*
T. radix ..	**1**	..	..	..	**4**	..	**2**	..	..	**8**	..	**1**	..	..	**6**	**8**	**1**	..	..	..	..	..	..	..
	..	..	*2*	..	..	..	..	..	..	..	..	..	..	..	..	..	*1*	..	..	..	..	..	*12*	..
T. gracilis ..	**1**	**1**	..	..	**10**	..	**15**	..	..	..	**2**	..	**1**	..	..	**10**	..	**1**	..	..	**1**	..	..	..
	5	*5*	*2*	*93*	..	..	..	..	..	*20*	..	*8*	..	..	..	*5*	..	..	..	..	..	*1*	*1*	*12*
T. mortensenii ..	..	..	..	..	..	..	..	..	..	..	**2**	..	..	..	..	**4**	..	..	..	..	..	..	..	..
	..	..	*1*	*4*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*4*
T. nordqvisti ..	..	..	..	..	..	..	..	..	..	**12**	..	..	**2**	..	**4**	**2**	..	**3**	..	..	..	**1**	..	..
	..	*1*	..	*4*	..	..	..	..	..	*51*	..	..	..	..	..	..	..	..	..	..	..	..	..	*11*
T. dadayi ..	..	..	..	..	..		**6**	..	..	..	..	..	..	..	..	..	..	..	**1**	..	..	..	..	..
	..	*6*	*4*	*28*	..	..	..	..	..	..	..	*6*	..	..	..	..	..	..	..	..	..	..	..	..
T. karajacensis ..	..	..	..	..	**2**	..	..	..	..	..	..	..	..	..	..	**5**	..	..	..	..	..	..	..	..
	..	..	..	*16*	..	..	..	..	..	..	..	..	..	..	..	*1*	..	..	..	..	..	..	*2*	*4*
Cyttarocylis ehrenbergi ..	..	**3**	**1**	..	..	**1**	**1**	..	..	..	**4**	..	**1**	..	..	**1**	..	..	**1**	**2**	..	**4**	..	..
	..	*6*	*1*	..	..	..	..	..	..	*6*	..	..	..	..	..	*3*	*1*	..	..	..	..	..	*13*	*5*
Codonella ostenfeldii ..	..	**3**	..	..	**2**	..	..	..	..	..	..	..	..	..	**2**	**20**	**1**	..	..	..	..	..	..	..
	2	*13*	*8*	*20*	..	..	..	..	..	*5*	..	*1*	..	..	..	*13*	..	..	..	..	..	..	*9*	*13*

a reduction in August at Station P and in July and October–November 1952 at Station G (in 1950 and 1951 small numbers of these were recorded during January–April, Prasad, 1954 *a*). From January to May 1953 they continuously appeared at Station P, although by May their number was reduced to as low as 4 per c.c., and in June they were practically absent. In February, March and April 1953 a few individuals only were found at Station G. It should be further noticed that the population of *Noctiluca* at Station P was almost always of a definitely higher magnitude than at Station G (Fig. 7).

The tintinnids were found during several months of the year at both stations. They were very common during the summer months (April to June) and again often abundant especially in October–November (Figs. 8 and 9).

The following twelve species (Fig. 10), all of which are neritic, were obtained. For descriptions of these species reference may be made to Brandt (1906 and 1907) and Kofoid and Campbell (1929).

Tintinnopsis radix (Imhof) Brandt
T. dadayi Kofoid var. *loricata* Brandt
T. dadayi Kofoid var. *c* of Brandt
T. tocantinensis Kofoid and Campbell
T. gracilis Kofoid and Campbell
T. karajacensis Brandt
T. mortensenii Schmidt
T. nucula (?) (Fol.)
T. nordqvisti var. *a* of Brandt } *Leptotintinnus nordqvisti* (Brandt)
T. nordqvisti var. *b* of Brandt } Kofoid and Campbell
Cyttarocylis ehrenbergi (Claparede and Lachmann) = *Favella panamensis* Kofoid and Campbell

Codonella ostenfeldii Schmidt

Of the species mentioned above *T. tocantinensis*, *T. gracilis*, *T. dadayi* and *C. ostenfeldii* were the commonest. Detailed data on the distribution, abundance and fluctuations of the various species are shown in Table 3. The tintinnids on the whole were scarce in 1952, particularly at Station P where usually a greater number of these was found. In general, it appeared as though there was often a greater concentration of these ciliates during the months of October-November.

(*b*) *Coelenterata*.—Larval forms such as planulæ, Semper's larvæ and Ceriantharian larvæ were present in the plankton of both stations (*vide* Prasad, 1954 *b*), but the most conspicuous members of the phylum were the numerous hydromedusæ. Occasionally enormous numbers of one or two species might occur in the plankton. Figure 11 shows the distribution of total hydromedusæ at Stations G and P. The maximum number, it could be seen, was present during the summer months at both stations, followed by

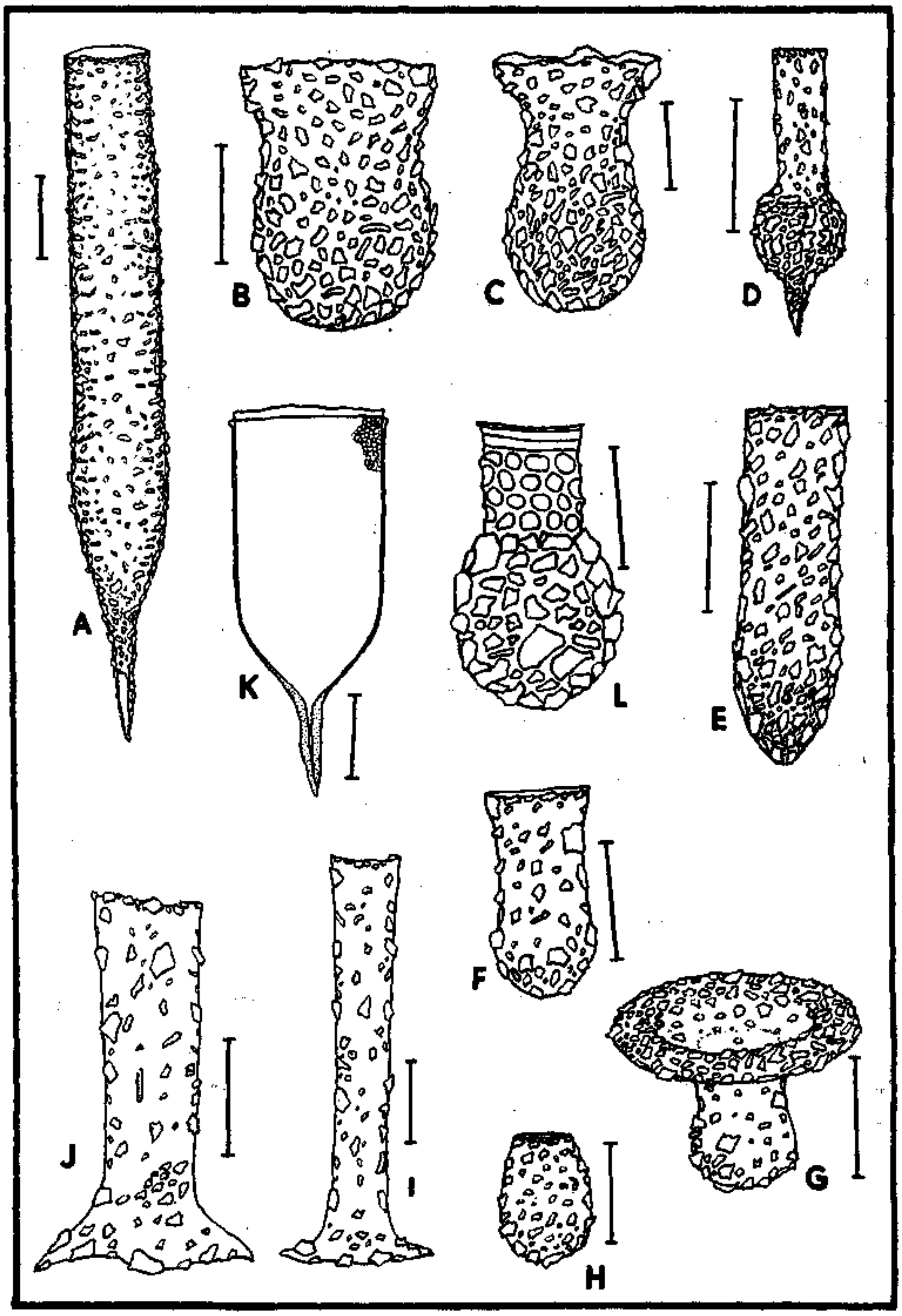

FIG. 10. The tintinnids collected from stations G and P.

A. *Tintinnopsis radix*; B. *T. dadayi* var. c; C. *T. dadayi* var. *loricata*; D. *T. tocantinensis*. E. *T. gracilis*; F. *T. karajacensis*; G. *T. mortensenii*; H. *T. nucula* (?); I. *T. nordqvisti* var. a; J. *T. nordqvisti* var. b; K. *Cyttarocylis ehrenbergi*; L. *Codonella ostenfeldii*. All magnification lines represent 50 micra.

a period of relative scarcity and towards the end of the year there was an increase, although not always very marked. It was also noticed that during the peak seasons there was a comparatively higher population at Station P. The distribution at Station G in 1953 was perhaps exceptional in that the hydromedusæ were exceedingly rare during the summer months when, according to the previous years, they should have been at their maximum. The following species were collected during the course of this investigation.

Cytæis tetrastyla Eschscholtz occurred in varying numbers at both stations and showed a distinct maximal period. From Station G they were collected in January, February, July and November–December, with a maximum in November, and from Station P in January, February, May, August–September and November, with a maximum in February.

Bougainvillia fulva Agassiz and Mayer, another common Anthomedusa, had a comparatively restricted seasonal distribution. So far they were obtained from Station G in January and May and Station P in January, March, May and September. The data available do not indicate any distinct maximum or minimum.

Stomotoca (Amphinema) dinema L. Agassiz were not so abundant as the other two Anthomedusæ and were collected from Station G during June to August.

Among the various hydromedusæ, members of the Order Leptomedusæ were the most well-represented in the collections and occasionally such forms as *Phialucium* and *Octocanna* were seen in large numbers.

Obelia sp. occurred at irregular intervals, in January–February, April–July and again from October to December at Station G. The period of their occurrence at Station P included March, June–August and December.

Clytia geniculata (?) Thornely.—Stray specimens of this were obtained once from Station P in June. The present species differed from those described by Mayer (1910). It is possible that the species concerned is *geniculata* because Thornely (1904) has recorded the hydroid from this region.

Phialucium virens Mass, one of the most common Leptomedusæ of this region, were present during several months of the year. From January onwards they continued to be present up to July at Station G and reached a maximum in June. At Station P they were found in January, February and April–July with a maximum some time during April–May.

Pseudoclytia gardineri Browne.—A few specimens of this were collected from both the stations generally in June.

Eutima curva Browne showed an extremely restricted period of occurrence. They were collected in June and January from Stations G and P respectively.

Eutima (Octorchis) orientalis (Browne) were found along with *E. curva*.

Phortis (Irene) palkensis (Browne) were collected from Station G in January and June.

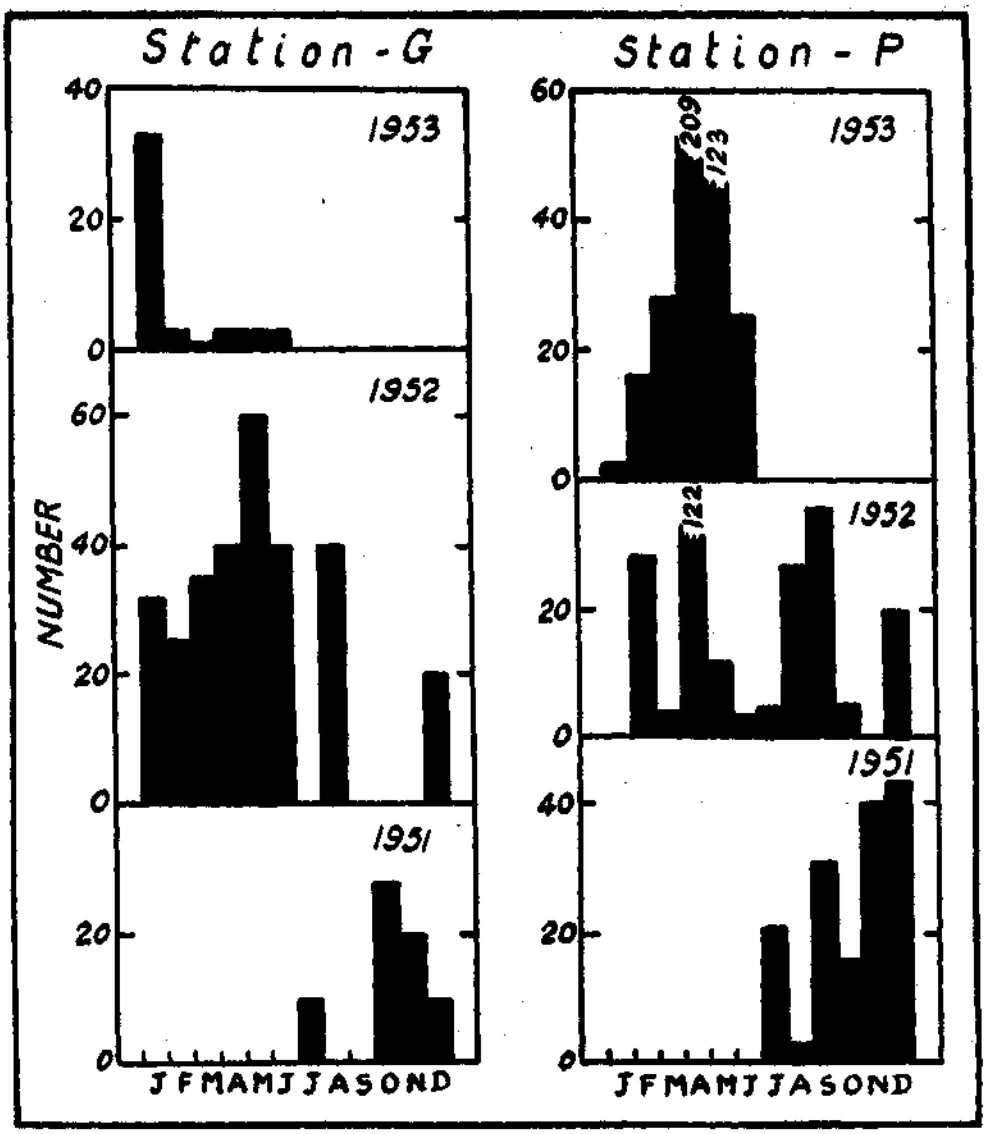

FIG. 11. The mean monthly number of hydromedusæ per 10 c.c. of the sample at Stations G and P.

Irenopsis hexanemalis Götte.—At Stations G and P they were often seen from April to May, but occasionally also in June and September at Station P. However, they never occurred in large numbers.

Octocanna polynema (Haeckel), like *Phialucium virens*, were at times obtained in considerable numbers from Station G in February, March and June, with a maximum in June and from Station P during April–July with a maximum in April.

Aequorea parva Browne.—Occasional specimens of *A. parva* were seen in the plankton of Station P in May.

The only member of the Order Trachymedusæ, recorded during the course of this investigation, was *Liriope tetraphylla* Gegenbaur. On certain days they were collected in large numbers, especially from Station P where they occurred from April to July with a maximum during April–May. From Station G they were obtained from January to July and again in November–December, the maximum number recorded being in November.

Although the larger Scyphomedusæ are not usually obtained in the regular plankton hauls, a list of the common local species, together with their period of occurrence, is given for the sake of completeness.

Carybdea xymacana Conant.—Two specimens of this were obtained from the Gulf of Mannar during November–December 1951.

Dactylometra quinquecirrah L. Agassiz.—Large numbers of this appeared regularly from April to July particularly in the Palk Bay.

Cephea sp.—Two specimens were collected in August 1952 from the Palk Bay.

Mastigias papua Maas.—A few specimens of this were obtained in May–June from the Palk Bay.

Lobonema smithi Mayer were found in the Palk Bay from May to July.

Rhizostoma sp. occurred at intervals between May and September.

Rhopilema hispidum Maas showed a distinct periodicity in their occurrence and since 1950 they were seen regularly in the Palk Bay between June and July. During the same period they were found in the Gulf of Mannar also but in smaller numbers. A carangid fish, an ophiuroid and sometimes a portunid crab were found in association with the jelly-fish (*q.v.*, Panikkar and Prasad, 1952).

Among the siphonophores, members belonging to both the suborders Physophorida and Calycophora were present. There were at least five Physophorida. *Stephanomia* sp., and *Forskalia* sp., occurred during March to May, *Physalia utriculus* La Martiniere were common at Station G during June to September and at Station P from December to March, *Porpita pacifica* Lesson, though not as abundant as *P. utriculus*, occurred at Stations G and P in July and November–January respectively and *Velella* sp., were extremely rare and the stray specimens seen were those washed ashore on September 5, 1952. Only one species belonging to Calycophoræ, *Diphyes chamissonis* Huxley, was obtained. This was common from April to June and occasionally found even as early as January.

(*c*) *Ctenophora*.—The two common ctenophores were the cydippid, *Pleurobrachia globosa*, Moser, and the beroid, *Beroë* sp., but invariably they did not show any distinct periodicity in their occurrence. Of the two, *P. globosa* were more abundant and were observed at intervals during January–May and in December at Station G and from January to July and again in November at Station P. At about the same time *Beroë* sp. were also obtained from these stations.

(*d*) *Annelida*.—The vast majority of polychætes were represented in the plankton by their larval stages. However, stray specimens of such adult pelagic polychætes as *Tomopteris* sp., and *Alciopa* sp., were encountered. Occasionally specimens of *Autolytus orientalis* Willey were obtained from Station G and invariably the females were seen carrying eggs in their egg-sac. For an account of the seasonal distribution of polychæte larvæ refer Prasad (1954 *b*).

(*e*) *Chætognatha*.—In varying numbers chætognaths occurred at both the stations practically at all times of the year but showed well-defined periodicity (Figs. 8 and 9). At Station G chætognaths were more abundant during the early part of the year and reached a maximum in February 1952 and April 1953. Following this there was a decimation in their number and during the later part of the year they remained at a low level but with occasional minor pulses. As against this, the chætognath population at Station P was, as a whole, low during the first half of the year, but by about June or July it increased and reached a maximum in August–September.

Comparing the distribution patterns observed at the two stations one could see the important difference in the time of occurrence of maximum, which is February–April at Station G and August–September at Station P. The population, however, was invariably low from November to January at these stations. This difference in the time of maximum was apparently caused by the variations in the numerical proportion of the species present at the time of maximum and a preliminary examination showed that the most abundant species found at the time of maximum were *Sagitta robusta* Doncaster at Station G and *S. neglecta* Aida at Station P in 1952. According to Varadarajan and Chacko (1942) *S. neglecta* and *S. robusta* reached a maximum during September–December off Krusadai. John (1937) has recorded that these species are conspicuous and reach their maximum in July off Madras. George (1952) has remarked that *S. neglecta* was obtained throughout the year along the Malabar Coast but in large numbers soon after the south-west monsoon, whereas *S. robusta* reached a peak in June and declined steadily afterwards. In the present instance also *S. neglecta* reached a peak at Station P soon after the south-west monsoon. There was a significant difference in the salinity between the periods of chætognath maxima. It was low during February to April and high during August to September. Thus, *S. robusta* was found in abundance when water of low salinity was present and *S. neglecta* predominated during the period of high salinity. It should, however, be noted that, although the range of salinity at the two stations was almost the same, the abundance of a particular species was restricted to one station. A detailed study of the composition, abundance and succession of the chætognaths of this area in relation to the hydrological conditions is in progress, which might yield some information as to whether the phenomenon noticed is indicative of water movements.

(*f*) *Mollusca.*—A greater part of the pelagic molluscan fauna of the two stations was meroplanktonic, mostly larval stages of various gastropods and lamellibranchs. Barring a few individuals of what is believed to be a species of Gymnosomatous pteropod, *Clione*, which were obtained from Station G on March 3, 1950 and Station P on September 24, 1951, the most common adult pelagic mollusc was the pteropod, *Creseis acicula* Rang. They usually occurred at Stations G and P during January–April and again from August to December although their distribution during these months mentioned above was not always continuous. The maximum was reached in March or April.

Large numbers of the pelagic gastropod, *Janthina roseola* Reeve, were also seen sometimes washed ashore during June–July along the Gulf of Mannar and January to February along the Palk Bay side.

(*g*) *Echinodermata.*—Except for stray specimens of small echinoids, the other members of the phylum, which occurred in the plankton, were all larval stages. The distribution and fluctuations of these have been discussed by Prasad (1954 *b*).

(*h*) *Crustacea.*—It is well known that the crustaceans form the most important element of zooplankton and of these the copepods rank first. The significant role played by the copepods in the economy of the sea has been discussed by Clarke (1934) and Russell (1934). Copepods were present throughout the year in the plankton samples of the two stations and formed the dominant component of the crustacean holoplankton. The crustacean plankton was also characterised by a number of larvæ and the cirripeds and stomatopods were represented only by their larval stages. The distribution of the nauplii is shown in Figs. 8 and 9. They were present throughout the year and showed two distinct maxima at both stations, one in January–February and the other in October–December at Station G and in June and December respectively at Station P. Amphipods and Cumaceæ were not very common and occurred sporadically, the latter between February and May and the former, mostly hyperids, during February to May and July to November. *Eocuma taprobanica* Calman, *Iphinoë macrobrachium* Calman (*I. crassipes* Hensen) and (?) *Leptocuma* sp., were the common Cumaceæ.

Although not as abundant as the copepods, another group of holoplanktonic crustaceans was the Cladocera. Two species of cladocerans were recorded from both the stations and the distribution of the two species together is shown in Figs. 8 and 9. There are noticeable differences in their distribution pattern between the two stations, they being more abundant at Station G in February–March and at Station P in August–September. Of the two species recorded *Evadne tergestina* Claus was more common and occurred at Station G generally during January–July, with a maximum in January–March and occasionally during September–November. The same species was found at Station P from March to December, though not necessarily continuous in their distribution during this period, with a peak some time between March and May. The other species, *Penilia avirostris* Dana, was absent from Station G during July–December 1951 and in 1952 they were seen in July–October and December. From January to June 1953 they were found in January, March and April. They were collected from Station P in August 1951, June–September 1952 and March–April 1953.

The distribution of total copepods (this includes the copepodid and adult stages of all species) is shown in Fig. 12. It will be noticed from this figure that the general trends in fluctuations at Stations G and P were different except for the period, July to December 1951, when the trends were almost alike. At Station G the fluctuations were apparently dicyclic (*cp*., Prasad, 1954 *a*). The copepod population was often high from January to March (maximum in January 1952 and March 1953) and then it showed a downward trend. The population remained low during April to July. Following this there was an increase up to September or October and a sharp fall in the next month (either in October or November as the case may be) again followed by an increase. As against this, the copepod population at Station P, in general, started from a low level and continuously increased until it reached a maximum in September or October and then declined. Besides these differences in the distribution pattern, mention might also be made of the relatively higher population of copepods observed during the period July to December 1951 at Station P. But the noteworthy feature was that the total standing crops of copepods at Station P for 1952 and for the period January–June 1953 were only three-fourth or even slightly less than those for the corresponding periods at Station G.

The following is a list of the more common species of copepods recorded from the two stations:—

Acartia erythræa Giesbrecht
Tortanus spp.
Calanopia spp.
Labidocera sp.
Centropages dorsispinatus Thompson and Scott
C. tenuiremis Thompson and Scott
Pontella danæ var. *ceylonica* Thompson and Scott
P. securifer Brady
Paracalanus parvus Giesbrecht

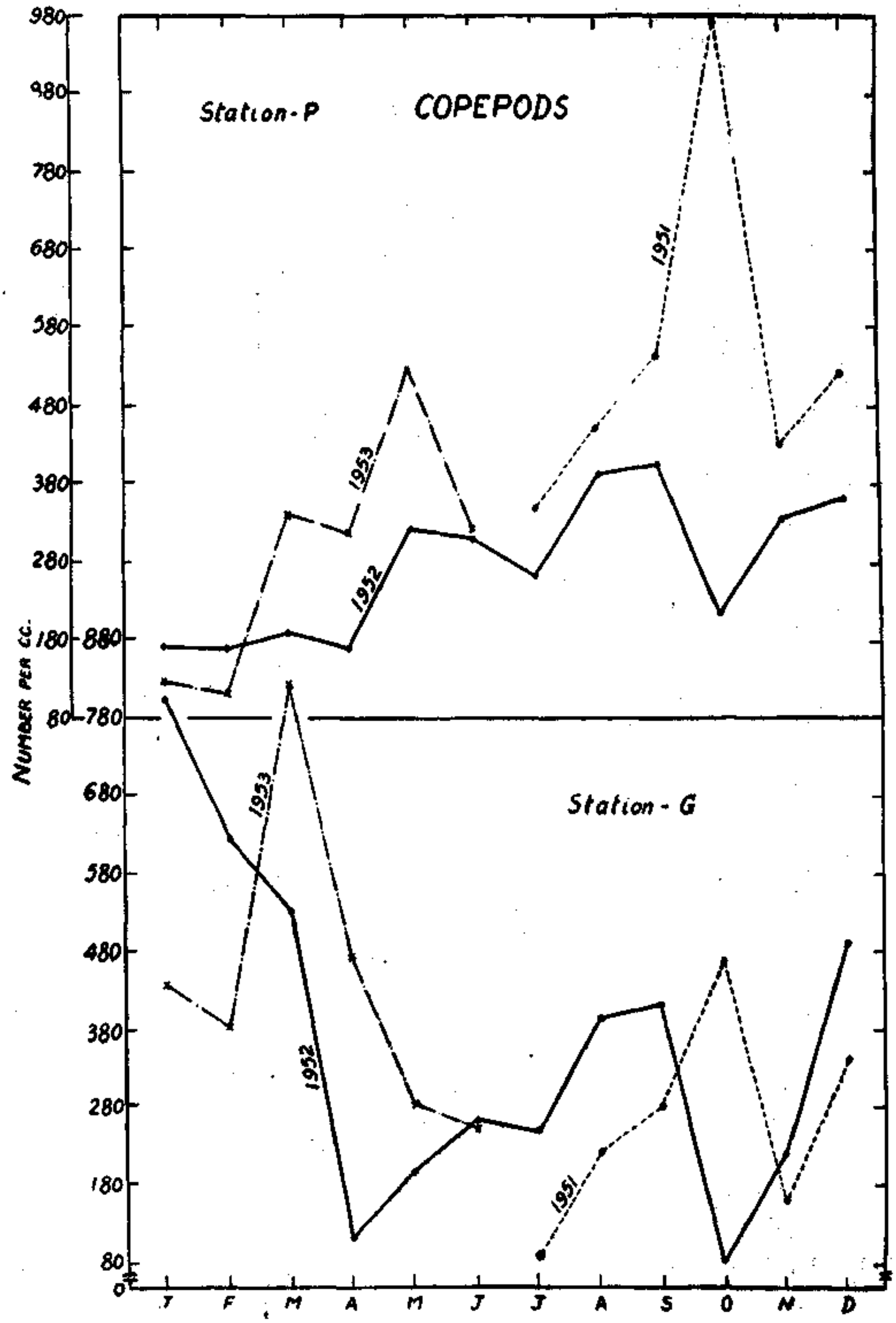

FIG. 12. The distribution of copepods at Stations G and P.

Canthocalanus pauper (Giesbrecht)
Acrocalanus sp.
Eucalanus sp.
Euterpina acutifrons (Dana)
Metis jousseaumei forma *major* Sewell
Microsetella rosea (Dana)
Macrosetella gracilis Dana
Oithona spp.
Corycæus sp.

It is of interest to record here the occurrence of the peculiar copepods, the monstrilloid *Thaumaleus tropicus* Wolfenden, at the stations. These copepods were first obtained from Station P on September 14, 1951. Subsequently they were found in February and March, 1952 and March 20, 1953. The same species was collected from Station G only once, on February 4, 1953. *T. tropicus* was first recorded by Wolfenden (1906) from the Maldive and Laccadive Archipelago.

The bulk of decapods, found in the plankton, was composed mostly of larvæ, belonging to several families, in various stages of development and an account of the distribution and fluctuations of these will be found in Prasad (1954 *b*). The adult planktonic decapods were the sergestids, *Lucifer reynaudi* (Milne-Edwards) and *Acetes* spp., the former being the more common. In varying numbers *L. reynaudi* occurred at Stations G and P (Figs. 8 and 9) during several months with a maximum in the early part of the year. Their complete disappearance during the second half of 1952 seems to be somewhat unusual (*cp.*, Prasad, 1954 *a*). *Acetes* spp. were not as abundant as *Lucifer* and only occasional specimens were seen in the plankton samples.

(*i*) *Chordata*—Members of the three classes, *viz.*, Larvacea, Thaliacea and Ascidiacea, were present in the plankton, but of these the last was represented mostly by their larvæ. Of the other two, Thaliaceæ were not very common and a few specimens of *Thalia democratica* (Forskal), *Jasis zonaria* (Pallas) and *Salpa cylindrica* Cuvier alone were obtained from the two stations. Appendicularians were present all through the year at Station G and their distribution was dicyclic with a peak in March and another one between September and December (Fig. 8). At Station P they were present in all months except January-February with a single peak either in July or August and so the distribution was apparently different from that at Station G (Fig. 9). Three species of Appendicularians, *Oikopleura diocia* Fol., *O. cophocerca* Gegenbaur and *O. parva* Lohmann, were usually found in the plankton samples of the two stations and occasionally specimens of *Fritillaria* sp. were obtained during March–April.

In addition to these, stray specimens of young *Amphioxus* were encountered in the plankton. Several young ascidians, probably belonging to the family

Molgulidæ, were once seen (February 29, 1952) in the plankton samples collected from Station P.

(*j*) *Larval forms*.—Plankton from Stations G and P contained a wide variety of larvæ in varying intensities almost throughout the year. There are no significant differences in the types of larvæ found at these two stations, but the larval populations showed considerable variations in their intensity, percentage composition and, in some instances, in the time of occurrence of maxima and minima. As mentioned earlier, a detailed account of the larval forms has already been published and for details reference may be made to Prasad (1954 *b*).

PHYTOPLANKTON-ZOOPLANKTON RELATIONSHIP

Investigations at many places have often demonstrated that generally, but by no means always, there is an inverse relation between the quantities of phytoplankton and zooplankton. This may especially be so when any one limited area is taken, but Riley and Bumpus (1946) have pointed out that comparisons of different oceanic regions often suggest a direct relationship. Several hypotheses have been put forward to explain the phenomenon of inverse relationship and a conspectus of these has been given by Bainbridge (1953) who himself has proposed a hypothesis involving both migration and grazing. He considers "....that plankton animals must migrate both horizontally and vertically into patches of phytoplankton and, when present in sufficient numbers, graze these down very quickly. In the mean time fresh growths of phytoplankton will have occurred in neighbouring areas of sea now devoid of animals and the inverse relationship will be re-established. This changing cycle of distribution is thought to be continuous."

An examination of the data collected during the present investigation shows some very interesting facts. At Station G the relationship between the quantities of phytoplankton and zooplankton appeared to be generally, but not always, inverse, as could be seen from the average values shown in Fig. 3. On the contrary the relationship was direct during most of the time at Station P (Fig. 4) where, with the gradual upward trend in the phytoplankton, the zooplankton increased, but, when the latter reached a maximum, the former showed a decline in 1952 as well as 1953. In October 1953, however, the peaks of both phytoplankton and zooplankton coincided. The abrupt drop in the quantity of phytoplankton recorded in July 1952 was, as already mentioned, due to the remarkable increase in the proportion of *Noctiluca* and, with the decrease in the total zooplankton in August (mainly caused by the disappearance of *Noctiluca* from the area, *q.v.*, Fig. 7), the phytoplankton population began to increase rapidly (Fig. 4). Riley and

Bumpus (1946) observed that in the case of correlations of the more important groups of zooplankters with total phytoplankton the " seasonal minimia were generally accompanied by zero or positive correlations, and in most cases there was a positive correlation at the time when the species was beginning to increase. In each case there was a negative correlation with phytoplankton at the time when the species reached its seasonal peak". Although at Station P the average values and trends showed a somewhat direct relationship between phytoplankton and zooplankton, an examination of the quantities of these present in individual samples more often showed an inverse relationship, particularly when the population level of either phytoplankton or zooplankton is high. Fleming (1939) has remarked that the likelihood of finding a large zooplankton population in association with a dense diatom population is little when samples are collected at intervals of more than a few days. Several factors, including the interval at which samples are collected, will contribute to the nature of relationship observed and the differences noticed in the present instance may very well be due partly at least to the differences in the interval at which samples were collected from the two stations.

Grazing is perhaps one of the most important causes of the inverse relationship and, copepods being the largest single group of grazers, it may be of interest to examine the relationship between copepods and diatoms. Clarke (1939) has discussed in detail the relation between diatoms and copepods as a factor in the productivity of the sea. The traditional belief is that copepod production depends upon and follows diatom growth. Whatever be the sequence of events, it is now well established that grazing is an important factor in the control of diatom populations. Bainbridge (1953) has suggested a scheme of grazing and migration cycle and remarked that the speed with which this cycle of events takes place must depend on several variables such as the densities of animals and plants, the speed of migration and the rate of cell division of the plants and of removal by grazing. The copepod-diatom relationship, which existed at Station G, included both inverse and direct, *e.g.*, in February, April and September–December the relationship appeared to be inverse, during June–August almost direct, while January, March and May showed either direct or inverse relationship (Figs. 5 and 12). In contrast to this, the relationship observed at Station P seemed to be more often direct than inverse (Figs. 6 and 12). It should, however, be pointed out that the nature of relationship observed in the present instance during particular months need not necessarily be repeated year after year, as was evident by comparing the data collected now with those obtained in 1950 and 1951 from Station G (*q.v.*, Prasad, 1954 *a*).

According to Bainbridge (1953) the inverse relationship in the sea is never absolute, often not clearly marked and sometimes completely reversed and the latter state, where high concentrations of both animals and plants occur in the same area, cannot be explained on the exclusion hypothesis, nor would it be expected on a simple theory of grazing. He adds that a dense concentration of animals and plants are mutually incompatible entities and their occurrence together must produce a situation of instability. Therefore, he suggests: "The possibility of their having grown up together is surely much less likely than that of the animals having only recently come into the area, and being at that point in the cycle immediately prior to overcoming the rate of division of the plant cells. This state of distribution, the more common reverse one, and the intermediate ones can all be accounted for on a combination of migration and grazing, as can also the various experimental observations."

In general, it should be said that the relationship between quantities of diatoms and copepods was invariably direct at lower population densities and also during the beginning of diatom increase, but the relationship was often, though not always, inverse when the copepods and diatoms reached their peaks, except at Station P where, even at very high densities, direct relationship was sometimes noticed. A satisfactory explanation for the differences observed in the nature of relationship between the two stations is not within the scope of the present work. It is apparent that the rate of grazing at Station P does not exceed the rate of diatom increase and it is possible that the lower copepod and higher diatom populations recorded at Station P are indicative of this.

Hydrological Conditions and Plankton

An account of the hydrological conditions at the two stations has been given by Jayaraman (1954). The data on phosphates, nitrates, silicates, oxygen saturation and salinity of the surface waters of the two stations are shown in Figs. 13 and 14. It is often believed that the normal relationship between plankton and the nutrients is inverse, although the converse has also been observed (Riley, 1941). This assumption of inverse relationship is based primarily on the observations made in temperate areas and very little information is available on the nature of relationship that exists between plankton and the various nutrient salts in tropical areas.

The nutrients at both stations are distinctly lower compared to temperate regions and further they do not show such violent fluctuations as are characteristic of temperate waters. The monthly average phosphate values at Station G varied from 0·09 to 0·30 μg.-at. P/L, whereas at Station P the range was slightly lower, 0·14 to 0·25 μg.-at. P/L. At Station P the fluctuations in nitrates were greater, the monthly average values ranged from 1·6 to 5·0 μg.-at. N/L and at Station G the values varied from 1·9 to 4·7 μg.-at. N/L. The silicate content of the surface waters showed wide fluctuations. Jayaraman (1954) has remarked that the total annual turnover of silicates seems to be far higher in the Palk Bay than in the Gulf of Mannar. At Station G the monthly average values for silicates ranged from 3·3 to 14·8 μg.-at. Si/L and at Station P from 5·3 to 17·9 μg.-at. Si/L. During the period covered by this investigation it was observed that there were occasions when there was practically complete exhaustion of nitrates from the surface waters, but there were no such instances in regard to phosphates and silicates.

The relationship between the quantities of phytoplankton and the nutrient salts may be said to be, in general, inverse, but direct relationship has also been observed at these two stations. Although the curves of average values of both phytoplankton and nutrient salts (Figs. 3, 4 and 13, 14) do not show the nature of relationships very clearly, an examination of the data plotted on a sample to sample basis suggests the inverse relationship on several days particularly so at the higher levels, *i.e.*, high nutrient concentrations accompanied by poor phytoplankton and *vice versa*. An instance of an unusual increase in the silicate concentration in this area during the time of *Noctiluca* swarms has been discussed by Prasad and Jayaraman (1954). The relationship between nutrient salts and phytoplankton being highly complex, phenomena other than mere utilization-production relationship may be involved (Riley, 1941). For instance, there is reason to believe that the nitrate cycle of this area under investigation may be considerably affected by the action of denitrifying bacteria (Jayaraman, 1954). Investigations conducted at these two stations have revealed the presence of large numbers of denitrifying bacteria in the surface waters (Velankar, 1955).

The pH values generally varied from 8·4 to 8·7 at both stations. No definite correlations between the fluctuations of plankton and pH were apparent from the data available.

The percentage saturation of dissolved oxygen in the surface waters showed greater fluctuations and a wider range at Station P where the average values varied from 52 to 86% and saturation as low as 30% and as high as 102% was recorded. At Station G the averages ranged from 59 to 89%, while the maximum and minimum saturation observed were 94 and 50% respectively. The quantities of phytoplankton and oxygen saturation did not show any definite relationship. There was apparently an overall lower oxygen saturation at Station P in spite of the higher phytoplankton population. The probable factors contributing to this may be, (1) comparatively

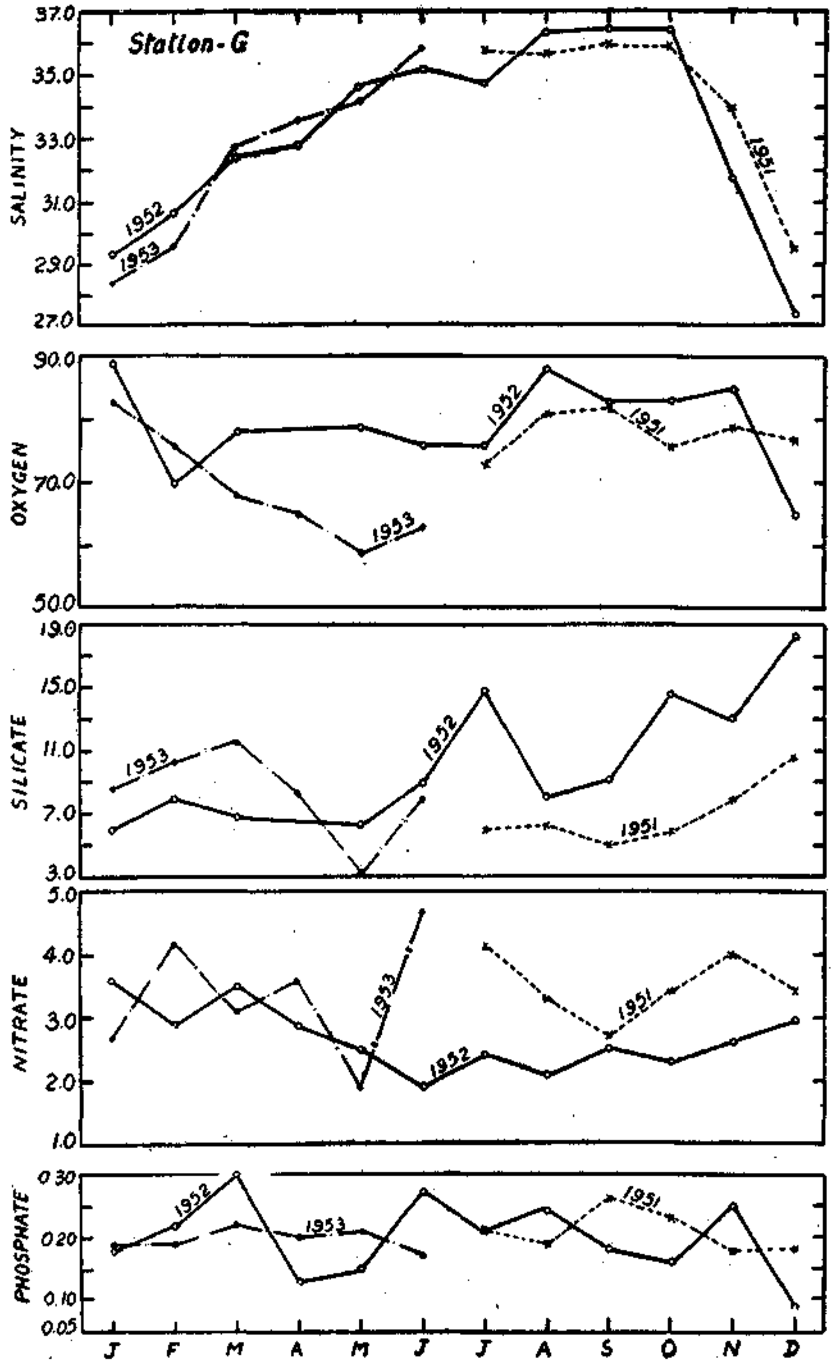

FIG. 1. Mean monthly values of phosphates, nitrates, silicates, oxygen and salinity for the surface waters at Station G.

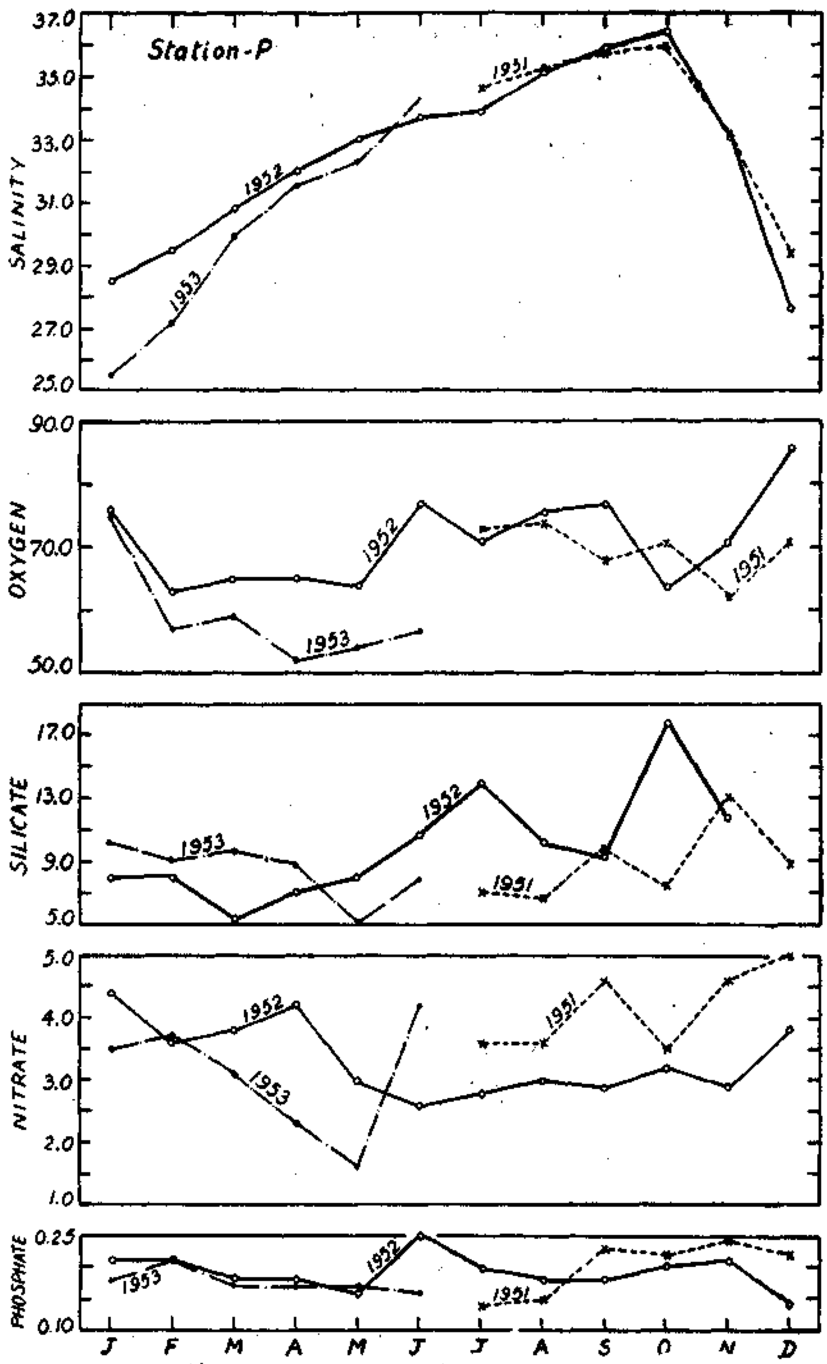

FIG. 14. Mean monthly values of phosphates, nitrates, silicates, oxygen and salinity for the surface waters at Station P. In this and Fig. 13 phosphates are expressed as µg.-at. P/L, nitrates as µg.-at. N/L, silicates as µg.-at. Si/L, oxygen as percentage saturation and salinity as parts per thousand.

fewer coral reefs in the Palk Bay and consequently lesser quantity of " imprisoned phytoplankton " or coral zooxanthellæ, which produce considerable quantity of oxygen during photosynthesis. The studies of Verwey (1931) and Yonge *et al.* (1932), have shown that in shallow water the production of oxygen by coral zooxanthellæ during daytime is relatively high and according to Verwey (1931) it is almost two to five times as great as the consumption of oxygen through corals and zooxanthellæ together, (2) the higher total zooplankton population as mentioned in an earlier section of this paper, and (3) the higher bacterial population. A study of the latter at the two stations has suggested that the total bacterial population is distinctly higher at Station P (Velankar, personal communication). But whether these factors alone are responsible for the lower oxygen saturation of the surface waters at Station P or whether there are others operating cannot at present be decided with certainty. In such shallow areas as the present one, the wind may prevent an effective stabilization of water masses for any length of time, but factors such as temperature, velocity of wind, solar radiation, the amount of biological activity, bacterial action and chemical oxidation of reducible material taking place at the bottom may also considerably affect the oxygen saturation of the surface waters.

The trend in salinity variations at Stations G and P showed similarities, but the salinity was consistently lower at Station P from January to September. It is interesting to note that the zooplankton in general showed more often an inverse relation with salinity at Station G, while the opposite was the case at Station P. Almost similar relationships were also noticed between copepods and salinity at these two stations (Figs. 3, 4, 12, 13 and 14).

Data on surface temperature are available only for Station G (Fig. 2). The correlation between the temperature curves and plankton was not striking. However, it was observed that the standing crop of plankton was often low during periods of relatively high temperature; the major phytoplankton peaks invariably coincided with high temperature periods, while the zooplankton was generally low during such periods.

SUMMARY

A comparative study of the intensity, distribution and fluctuations of plankton at two inshore stations G and P in the Gulf of Mannar and the Palk Bay respectively, was made. 261 Samples, 90 from Station G and 171 from Station P, collected during July 1951 to June 1953, formed the material for this study.

The fluctuations in the net-plankton volume from month to month were greater at Station G than at Station P and during several months a relatively higher standing crop of plankton was recorded at the latter station,

The phytoplankton cycles at Stations G and P showed distinct differences and further, the magnitude of phytoplankton population in several months as well as the total annual production, as judged from the standing crop, was distinctly higher at Station P. The abundance and succession of many species of diatoms showed variations between and within stations. In the distribution almost all species showed some degree of annual variation, but a few species exhibited extreme fluctuations. One such interesting example is that of *Rhizosolenia alata* and *R. imbricata* which were noticed to cause local blooms in March 1950 and February 1951 respectively. In 1952 and 1953, although there were blooms of diatoms in the Gulf of Mannar, they were not caused by a single species as in 1950 and 1951 and further *R. alata* was scarce in 1952–53 and *R. imbricata* was found only in fair numbers during January–February 1952.

Large quantities of *Trichodesmium erythræum* were noticed at Station G particularly in the summer months, but these were relatively scarce at Station P.

At both stations the dinophyceæ showed two maxima with the primary peak in the summer months. Although the same species occurred at both the stations, Station P was comparatively richer in individuals. Details of species composition and distribution of various species have been given.

The distribution pattern of total zooplankton differed widely at the two stations. When the zooplankton was high at Station G it was relatively low at the other and *vice versa*. A comparatively richer zooplankton was characteristic of Station P during several months. The distribution and fluctuations in the various groups have also been given.

Distinct differences were noticed in the time of occurrence of chætognath maxima which were during the early part of the year at Station G and towards the second half of the year at Station P. Preliminary analysis showed that the dominant species at the time of maximum were different, one species occurred when the salinity was low and the other during high salinity period.

The distribution of copepods at Station G was dicyclic as against a unimodal distribution at Station P. It was observed that the total annual copepod population at Station P was only three-fourth or even slightly less than that of Station G.

The nature of relationship between the quantities of phytoplankton and zooplankton in general and copepods and diatoms in particular has been briefly discussed. The phytoplankton-zooplankton relationship appeared to be normally inverse at Station G, whereas it was often direct at Station P. Similarly, while the copepod-diatom relationship was more often inverse at Station G, that at Station P was direct on several occasions.

The hydrological conditions have been very briefly mentioned. The relation of phytoplankton to the nutrient salts appeared to be in general inverse, but direct relationship also was noticed. The pH and oxygen saturation did not show any clear-cut relation with phytoplankton. The total zooplankton and copepods showed an inverse relation with salinity at Station G, but a direct one at Station P. It was also observed that the standing crops of total plankton and zooplankton were generally low during periods of high temperature, and the major peaks of phytoplankton coincided with the high temperature periods.

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