QUANTITATIVE STUDY OF PLANKTON OFF LAWSON'S BAY, WALTAIR

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INTRODUCTION

THE significance of plankton in the productivity of the seas is too well known and it is superfluous to quote here the extensive literature on the subject. In assessing the productivity, exact quantitative methods have to be employed and the observations carried out round the year. The available literature on marine productivity in tropical seas is very meagre and this is particularly true of the seas around India. The existing accounts are mainly of a qualitative nature with some information on the relative abundance of some groups of planktonic organisms during the different months of the year. It is a well recognised fact that the prevailing hydrographical conditions in any zone have a direct bearing on phytoplankton production. Previous workers from this Department have shown (Ganapati and Murthy, 1953, 1955; Ganapati and Rao, V. R., 1954; Ganapati and Rao, T. S. S., 1954) that there is a direct correlation between the abundance of some planktonic organisms and the prevailing hydrographical conditions off this coast.

The present investigation was carried out to assess the plankton production at a fixed station in the 10 fathom line off Lawson's Bay, Waltair.

MATERIAL AND METHODS

The plankton samples were collected from January to December, 1956, twice a week, between 6 and 7 A.M. A known volume of water was filtered through a fine bolting silk net of mesh size No. 30. The concentrated sample was transferred to a glass container wrapped in moist linen and the organisms examined in the living condition in the laboratory. Four such samples were taken till March and an additional fifth sample for the remaining months. Owing to the rough weather conditions the quantitative estimations for the month of May could not be worked out. Quantitative estimations were made as detailed below.

1. *Numerical estimation.*—After a preliminary examination in the living condition the sample was fixed by the addition of sufficient quantity of 40% formalin to make the total strength of dilution of the sample to about 5%. The technique of diluting and counting suggested by Nielsen (1933) was adopted and numerical estimations made by using Utermohl's inverted plankton microscope. The number of organisms in one litre of water was calculated. The macroplankton organisms were separated before counting.

2. *Volumetric estimation.*—The fixed sample was poured into a special graduated conical sedimentation funnel and the organisms allowed to settle for at least 24 hours and the volume of plankton noted.

3. *Pigment extraction.*—Harvey's method of pigment extraction (1934) was adopted using three different solvents: Acetone; Ethyl alcohol and Benzene; and Methyl alcohol. The concentration of the pigment was estimated by using a Lumetron Photoelectric Colorimeter with 420 μ filter.

4. *Total biomass.*—Bogorov's method (1934) of total Biomass estimation was employed. The fixed plankton sample was filtered through a weighed Whatman No. 42 filter-paper disc of 4·5 cm. diameter. The sample was washed with distilled water thrice to free the salt content. The total Biomass was now estimated by taking the constant dry weight of the plankton and expressed as mg./M^3 of sea-water.

5. *Total organic matter.*—Total organic matter was determined, as suggested by Riley (1938 and 1941) and Verudin (1951) by incineration of

the dried plankton and the difference between the constant dry weight, *i.e.*, total Biomass and the ash gives the total organic matter oxidised. The values are expressed as mg./M^3 of sea-water. All the weighings were made in the Metler semi-microelectric balance.

6. *Hydrography*.—Surface temperature was measured with a bulb thermometer of 0·2° C. calibration by dipping the thermometer in the water directly from the Catamaran.

Salinity:	Knudsen's method
Oxygen:	Winkler's method.
Inorganic phosphates	Denige's method as modified by Robinson and Thompson (1948).
Silicates:	Dienert and Wandenbulcke method as modified by Robinson (1948).

TABLE I

Table showing the hydrographical conditions for the year 1956

Months	Rainfall in inches	Temperature ° C.	Salinity ‰	Dissolved oxygen ml,/1.	Phosphates μg. at/1.	Silicates μg. at/1.
January ..	0·10	24·92	28·82	3·68	1·37	7·05
February ..	0·0	25·85	33·08	3·61	0·41	11·68
March ..	0·0	25·79	34·37	5·02	0·79	9·43
April ..	0·95	25·40	34·44	3·87	0·78	10·86
May ..	2·71	27·91	33·75	3·22	0·52	13·62
June ..	4·39	28·12	33·33	1·66	0·82	12·68
July ..	9·05	28·87	31·26	3·20	0·69	11·62
August ..	5·20	28·46	32·15	3·28	0·52	11·08
September ..	11·09	29·50	31·33	3·79	0·53	11·73
October ..	20·05	28·95	17·40	4·16	0·82	29·91
November ..	0·09	27·04	23·95	3·60	0·81	21·84
December ..	0·0	25·04	26·26	4·66	0·70	16·84

HYDROGRAPHICAL CONDITIONS

A series of papers (Ganapati and Murthy, 1954, 1955; Ganapati, La Fond and Bhavanarayana, 1956; La Fond, 1954, 1957; La Fond and Bhavanarayana, 1957; Bhavanarayana and La Fond, 1957; Ganapati and Subba Rao, 1957; Poornachandra Rao, 1957 and Rama Sastry and Balararamamurty, 1957) on the hydrographical conditions of the Bay of Bengal off the east coast of India with particular concentration off Waltair have appeared from the Andhra University and we have now a fairly accurate picture of the prevailing hydrographical conditions and the water movements during the different months of the year. The data collected during the year 1956 have, in the main, substantiated conditions reported for the previous years and the salient features are recorded below. The monthly average values of temperature, salinity, dissolved oxygen, phosphates and silicates are given in Table I and Fig. 1.

Temperature.—A high range of temperature was observed during the year, a maximum of 30·2° C. on 5–9–1956 and a minimum of 24·4° C. on 19–12–1956. A monthly average maximum of 29·5° C. during September and a minimum of 25·04° C. during December were observed. The low temperatures observed during March and April have been shown as due to upwelling (Ganapati and Subba Rao, 1957). The high temperatures during September and October are due to the sinking phenomenon of the surface waters (La Fond, 1954).

Salinity.—A high range of salinity was observed with a maximum of 34·88‰ on 4–4–1956 and a minimum of 13·57‰ on 8–10–1956. A monthly average maximum of 34·44‰ during April and a minimum of 17·40‰ during October were observed. The salinity of the waters is mainly influenced by the currents. The high salinity values during the northerly current period, January to June, are mainly due to incursion of the oceanic waters from the central Indian Ocean (Sewell, 1929); diminution of the flow of the rivers to the south (Sewell, 1929); and upwelling of the highly saline bottom waters (Ganapati *et al.*, 1956 and Ganapati and Subba Rao, 1957). The lowest values during October to November period are due to the dilution by large volumes of fresh-water brought by the southerly current from rivers to the north (Sewell, 1929). An inverse relationship between the salinity and silicates was observed all through the year.

Dissolved oxygen.—The dissolved oxygen content ranged from 5·67 ml./l. on 9–3–1956 to 0·33 ml./l. on 7–6–1956. The monthly average values ranged from 5·02 ml./l. during March to 1·66 ml./l. during June. A direct relationship between the phytoplankton and dissolved oxygen and an inverse relationship between temperature and dissolved oxygen during the period January to June were observed.

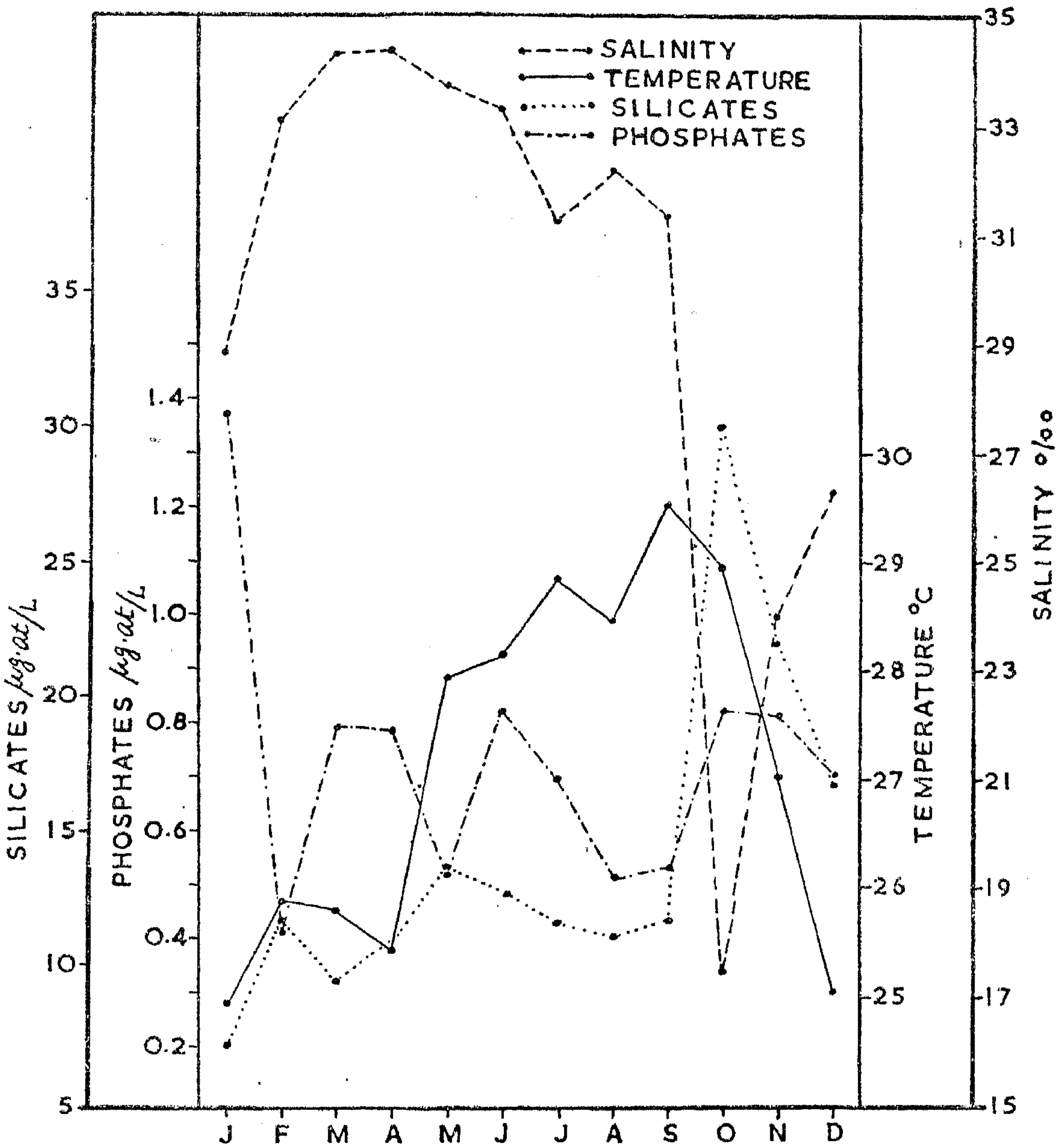

FIG. 1. Showing the mean monthly values for temperature, salinity, silicates and phosphates in the surface waters off Lawson's Bay during the year 1956.

Phosphates.—The phosphate values ranged from 1·8 on 12–1–1956 to 0·32 µg. at./l. on 28–2–1956. The monthly average values ranged between 1·37 and 0·41 µg. at./l. during January and February respectively. Sewell (1932) observes that during January one branch of the bottom Antarctic drift, " Bends towards the north and flows up into the Bay of Bengal along the east coast of India " and this nutrient-rich Antarctic drift may account for the high phosphate value in January. The high phosphate values during October to November may be due to the large quantities of river borne nutrients brought by the southerly current. The low value for February may be due to the rapid utilisation of the phosphates in the surface waters by the spring outburst of phytoplankton which had its major peak during March. The sudden rise in phosphates during the March to April periods is due to the upwelling of nutrient-laden bottom waters (Ganapati and Subba Rao, 1957).

Silicates.—A high range of silicates was observed with a maximum of 39·71 on 21–10–1956 and a minimum of 5·0 μg. at./l. on 9–1–1956. The monthly average values ranged from 29·91 to 7·05 μg. at./l. during October and January respectively. The fairly high values during March to April periods in spite of the major phytoplankton bloom are due to the upwelling of the bottom nutrient-rich waters (Ganapati, *et al.* 1956; Ganapati and Subba Rao, 1957). The maximum values during October to November period may be attributed to the influx of the river waters brought by the southerly current. The influx of fresh-water is also indicated by considerable lowering of the salinity during this period.

PLANKTON

(*a*) *Numerical*

Phytoplankton.—The phytoplankton cell numbers vary from 25405/l. in March to 94/l. in December (Table II, Fig. 2). There is a gradual increase in their numbers from January to March when the primary peak is reached. From April onwards there is a steep fall until July. In August there is a slight increase which becomes pronounced from September onwards leading to a secondary peak in October to November. This is followed by a steep fall in December. The main bulk of the phytoplankton is constituted by the diatoms, the dinoflagellates occurring only in small numbers during both the bloom periods.

Zooplankton.—The zooplankton shows a major peak in March coinciding with the phytoplankton peak. There is a rapid fall in their numbers from April onwards with a small increase during August and November. The total zooplankton numbers varied from 414/l. to 16/l. during March and December respectively as given in Table II and Fig. 5.

(*b*) *Volume*

A high range of plankton volume was observed during the period of study with the maximum value of 375·0 c.c./M^3 of sea-water on 25–10–1956

TABLE II

The planktological conditions for the year 1956

Months	Pl. Vol. c.c./M^3	Phy. pl. orgs. Nos./1		Zoopl. orgs. Nos./1	Pigment units/M^3 of S.W.			Total Bio. mg./M^3.	Total org. mat. mg./M^3
		Diatoms	Dinofl.		Acetone	Alco-Benz.	Meth. Alco.		
January ..	55·94	1273	71	68	736·619	580·535	..	123	28
February ..	63·12	3084	177	239	1587·5	1738·437	..	1230	712
March ..	107·81	24432	973	414	7722·5	9752·656	8834·83	1171	664
April ..	89·37	3915	471	198	8425·625	8325·0	8125·0	432	144
May ..	..	..	..	..	1212·5	..	..	..	..
June ..	26·25	1986	166	164	1335·0	2037·19	1508·125	534	467
July ..	9·16	166	108	144	412·708	211·41	407·916	252	144
August ..	6·46	1023	100	169	153·83	196·409	193·229	131	45
September ..	6·25	881	101	118	119·322	154·718	121·987	559	164
October ..	194·16	3980	116	60	1882·291	1517·875	1573·666	359	132
November ..	129·99	3724	88	70	665·818	808·118	765·416	966	595
December ..	14·55	80	14	16	66·5	107·209	104·721	402	77

and a minimum of 2·5 c.c./M^3 of sea-water on 7th June, 18th August and 13th September 1956. The monthly average values ranged from 194·16 c.c./M^3 to 6·25 c.c./M^3 of sea-water during October and September respectively. Fairly high values of plankton volumes were observed during March, April and November. The volumetric values of plankton closely followed and ran parallel with those obtained by other methods of estimation.

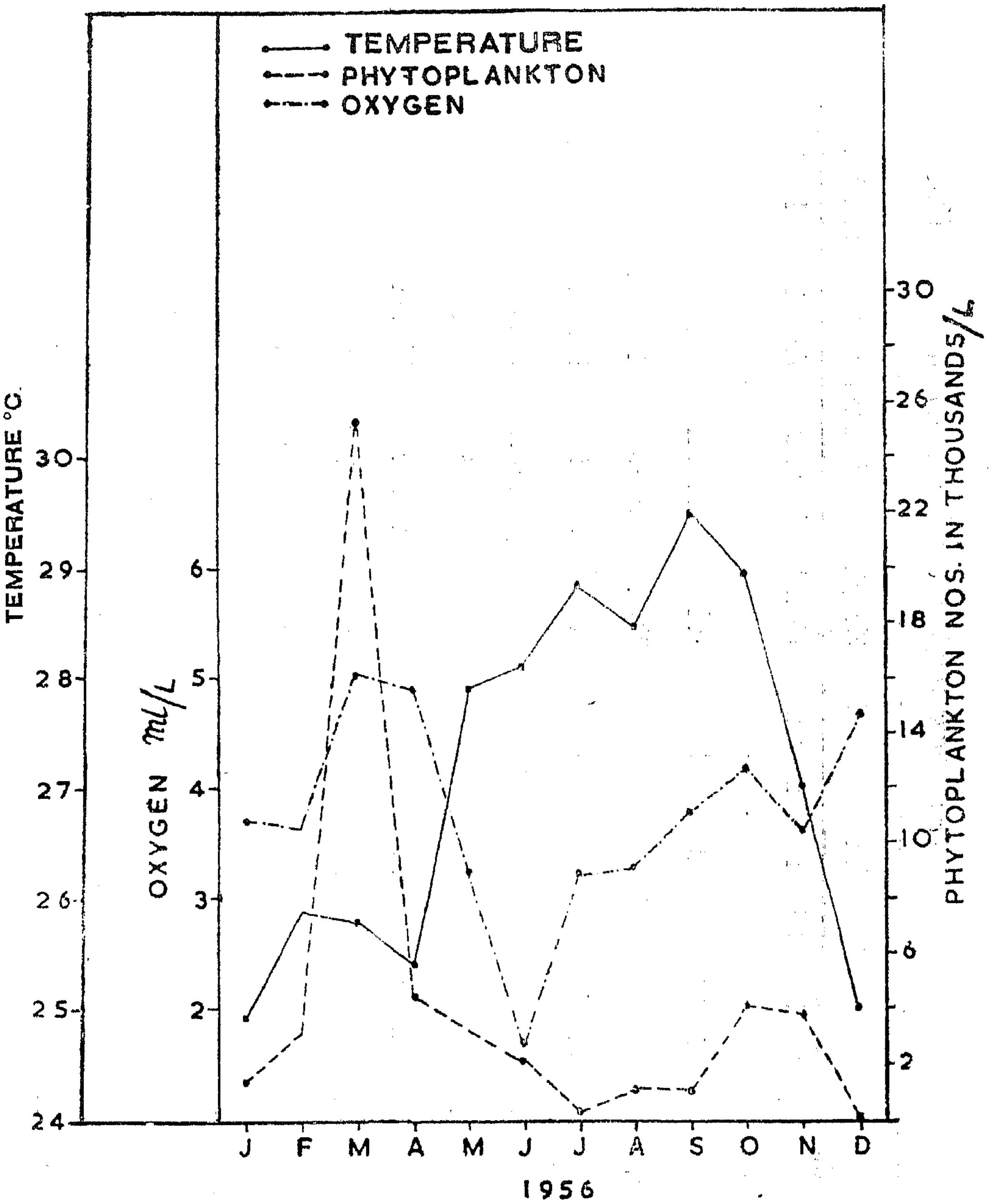

FIG. 2. Showing the mean monthly values for temperature, oxygen, and phytoplankton organisms in the surface waters off Lawson's Bay during the year 1956.

During periods of rich plankton volume the phytoplankton was present in appreciable quantities. However, the higher values recorded during October and November are largely due to the occurrence of big medusoids like *Aequorea* in the collections. From January onwards the plankton volume gradually increased, up to March, followed by a steep fall after April. The total plankton is poor from May to September with a slight increase in June.

(*c*) *Pigments*

Riley (1941) made a comparative study of the various methods of estimation of plankton like numerical, volumetric, gravimetric and finally pigment extraction also. He calculated the correlation between the different methods and found that the pigment extraction is more accurate than other methods, to know the synthetic potentialities of the sea. Tucker (1949) observed that this method had the advantage of being simple and more rapid than any other method of estimation and he correlated the counted numbers of the plankton and the density of the pigment extraction. Gardiner (1943) suggested that acetone cannot extract all the chlorophyll pigments from certain phytoplankton organisms like *Ceratium* and some other dinoflagellates. He recommended alcohol-benzene as a better solvent than acetone. So far there are only two works on chlorophyll estimations of phytoplankton from Indian waters. The first is that of Thompson and Gilson (1937) during the "John Murray Expedition", for a few stations in the Indian Ocean, and the other that of Ramamurthy (1953 *c*) off Madras. The values are relative as they are based on townet collections. In the present work acetone and ethyl alcohol-benzene were used as solvents throughout and in addition methyl alcohol (in hot) from March onwards. As suggested by Graham (1943 *a*) the solvent was added every time just sufficient to extract the pigments. The values are shown in Table II.

A high range of pigment units with acetone as the solvent was seen. The maximum of 18550 H.U./M^3 and a minimum of 27·5 H.U./M^3 were seen on 16th March and 19th December respectively. The monthly average values ranged between 8425·625 H.U./M^3 and 66·5 H.U./M^3 during April and December respectively.

With ethyl alcohol-benzene a maximum of 27050 H.U./M^3 on 9th March and a minimum of 28·125 H.U./M^3 on 5th January were observed. The monthly average values ranged from 9752·656 H.U./M^3 to 107·209 H.U./M^3 during March and December respectively. Fairly high values have been observed during April also.

Pigment units with methyl alcohol as the solvent ranged from 24192 H.U./M^3 to 55 H.U./M^3 on 9th March and 9th December respectively. The monthly average values ranged between 8834·83 H.U./M^3 and 104·721 H.U./M^3 during March and December respectively.

In general the pigment extraction method ran parallel with the plankton production as estimated by other methods. From January onwards there is a gradual increase up to March–April periods when the major peak of phytoplankton production was observed. There is a gradual fall from June up to September. A minor peak was observed during October to November period following which a steep fall was seen during December when the minimum value was observed.

It is interesting to note that the mean monthly maxima of the pigment units with different solvents differed. With acetone the maximum values are in April, while with alcohol-benzene and methyl alcohol it is during March. The monthly minimal values agree to fall during December with all the three solvents.

It is interesting again to note that the pigment values with alcohol-benzene from February to June are higher than those obtained with either acetone or methyl alcohol. During the same period the dinoflagellates were more abundant than in the other months and it is possible that the higher values with alcohol-benzene may be due to the capacity of this solvent to extract the pigments more completely from the dinoflagellates than the other two solvents (Table II).

In general the cell count and the pigment values parallelled each other during the period of study except during the summer months when the pigments were significantly higher than the cell counts. Conover (1956) and Riley (1952) also observed a discrepancy between the cell numbers and the chlorophyll value during the summer months and this, according to these authors, may be due to the presence of large numbers of flagellates which are not preserved after fixation. Conover (1956) based on the observations of Atkins and Parke (1951) further states that " a population containing large cells would show small cell numbers relative to chlorophyll while population containing small cells would give a large ratio of numbers to chlorophyll ". Harvey (1953) also observes that differences in the physiological state of the cells can affect the amount of chlorophyll present. The same author (Harvey *et al.*, 1935) states that no exact relationship can be expected between the pigment and diatoms of greatly different sizes. However, a relationship could be worked out between cell numbers and chlorophyll if the cell size is also taken into account.

(d) Total biomass and total organic matter

Zenkewitch (1931) explained the biomass as the quantity of living substance of organisms per unit volume. The measurement of the quantity of living substance by weight—biomass—is very useful in comparing productivity of different seas. The total biomass of a community is the community biomass which is the sum total of many species biomasses. Allee *et al.* (1950) have pointed out that we have no complete biomass data for any given community and the best approach at present to community biomass is that of Juday (1942). No work on the total biomass and total organic matter has been done in the Indian Ocean except that of Thompson and Gilson (1937) for a few stations during the " John Murray Expedition". The total biomass and total organic matter values obtained during the period of study are given in Table II and shown in Fig. 3.

A maximum of 3107 mg./M^3 of total biomass was observed on 16-2-1956. The monthly maximum value of 1230 mg./M^3 and a minimum of 123 mg./M^3 of sea-water were observed during February and January respectively. The monthly average values of organic matter ranged from 712 mg./M^3 during February to 28 mg./M^3 of sea-water during January 1956.

From the figure and table showing the total biomass and total organic matter variations, it may be seen that there is general agreement between these values and total plankton production. A major peak of biomass was observed in February and a minor peak in November. The lowest values were obtained in January and August, preceding the major and minor peaks respectively. The total organic matter closely followed the total biomass values with their minimal values in January and August.

Discussion

It is well known that the productivity in any particular zone of the sea is assessed by the estimation of the standing crop which in its turn is largely influenced by the prevailing hydrographical conditions, during the various seasons. From the data presented already it is clear that the production of phytoplankton at the fixed station in Lawson's Bay shows a major peak in the March to April period and a minor bloom in October and November. The zooplankton shows a major peak more or less coinciding with the major phytoplankton peak.

It has been already stated in an earlier part of the paper that an inverse relationship between temperature and dissolved oxygen and a direct relation between the phytoplankton production and oxygen were observed during the January to June period. Jayaraman (1951) indicated dissolved oxygen as "a fairly good index of the activity of the phytoplankton" while Ramamurthy (1953 *a*) working in the same area, off Madras, states that "the oxygen content was mainly influenced by water temperature rather than by photosynthetic activity". During the July to December period there is a steady increase in oxygen except in November, which may be due to the high dilution consequent on the influx of considerable volumes

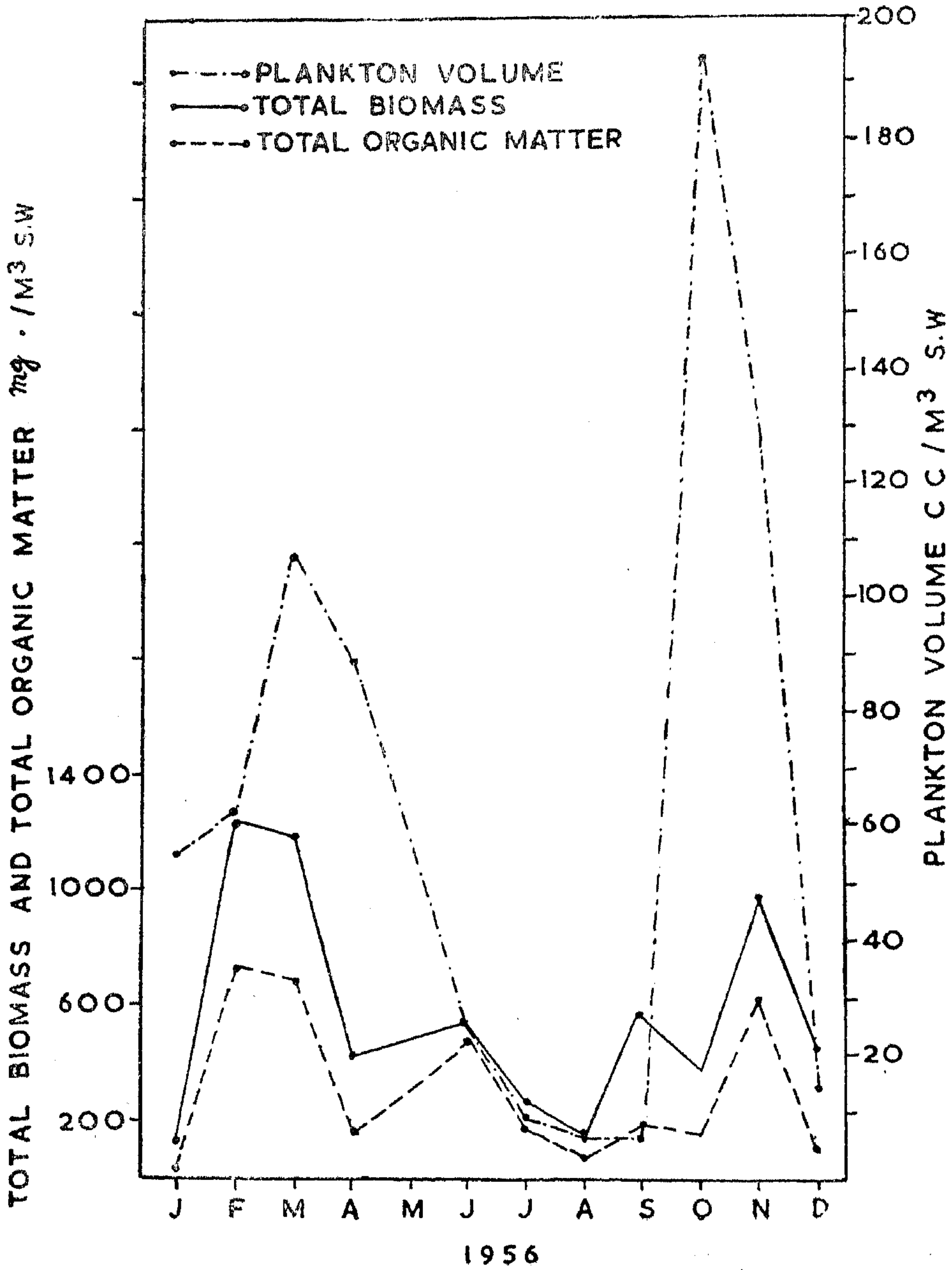

FIG. 3. Showing the mean monthly values for total biomass, total organic matter and lankton volume in the surface waters off Lawson's Bay during the year 1956.

of river water. The presence of a large population of photosynthetic organisms which pass through the ordinary filtering net used has been suggested by Graham (1943) to account for the excess of oxygen for some of the northern stations in the Pacific where the phytoplankton population was very scanty. Raghuprasad (1956) did not find any consistent relationship between quantities of phytoplankton and oxygen saturation off Mandapam, in the Gulf of Mannar, while Kasturirangan (1957) found off the Malabar coast a correlation between high phytoplankton production and high oxygen values during the monsoon months June to July and August.

It is generally believed that the nutrients will be low during periods of intense phytoplankton production. This assumption is largely based on work carried out in temperate waters. Our observations showed that there is no inverse relationship between nutrients and the phytoplankton. Raghuprasad (1956) at Mandapam and George (1953) at Calicut did not notice any such inverse relationship. Ramamurthy (1953 *a*) observed in Madras waters no well-marked seasonal cycle in the phosphates coincident with the absence of a marked seasonal growth in diatoms. Graham (1943) has drawn attention to the fact that any correlation between phytoplankton production and abundance of nutrients would largely depend on the stage of development of the phytoplankton pulse. He has described three such distinct stages, an initial one when there is sparse phytoplankton population and high concentration of nutrients, a middle stage where there is dense phytoplankton population and high concentration of nutrients and a final stage where there is dense phytoplankton population but low nutrient concentration. According to him there is direct relationship between density of phytoplankton and concentration of nutrients only in the middle stage of the pulse whereas in the initial and final stages the relationship is inverse. A fourth stage when there is a high concentration of nutrients in the surface layers, owing to active regeneration from the organic detritus, followed by a minor phytoplankton pulse has also been indicated by Graham. These phytoplankton pulses according to the same author (Graham, 1943) "can run its course only when there is a single supply of nutrients which is not augmented during the pulse" which is characteristic of cold temperate sea regions. Judging from our observations, during the major phytoplankton bloom off this coast, we have found that the correlation between the phosphate values and the phytoplankton density followed more or less on the lines indicated by Graham (Fig. 4). The first stage of high phosphate content and low phytoplankton population was observed in the third week of March followed by a rapid rise both in phosphates and phytoplankton towards the end of the month. These two stages correspond to the first two stages described by Graham. The third stage when the phosphate values came down while the phytoplankton values continued to be high was observed in the first and second weeks of April. However, the phosphate value was appreciably higher than one would expect during the period, which is due to the upwelling of the bottom waters already reported by us (Ganapati and Subba Rao, 1957). A small increase in phosphates was observed in the third week of April presumably owing to regeneration, while the phytoplankton density continued to drop. A slight pulse in the

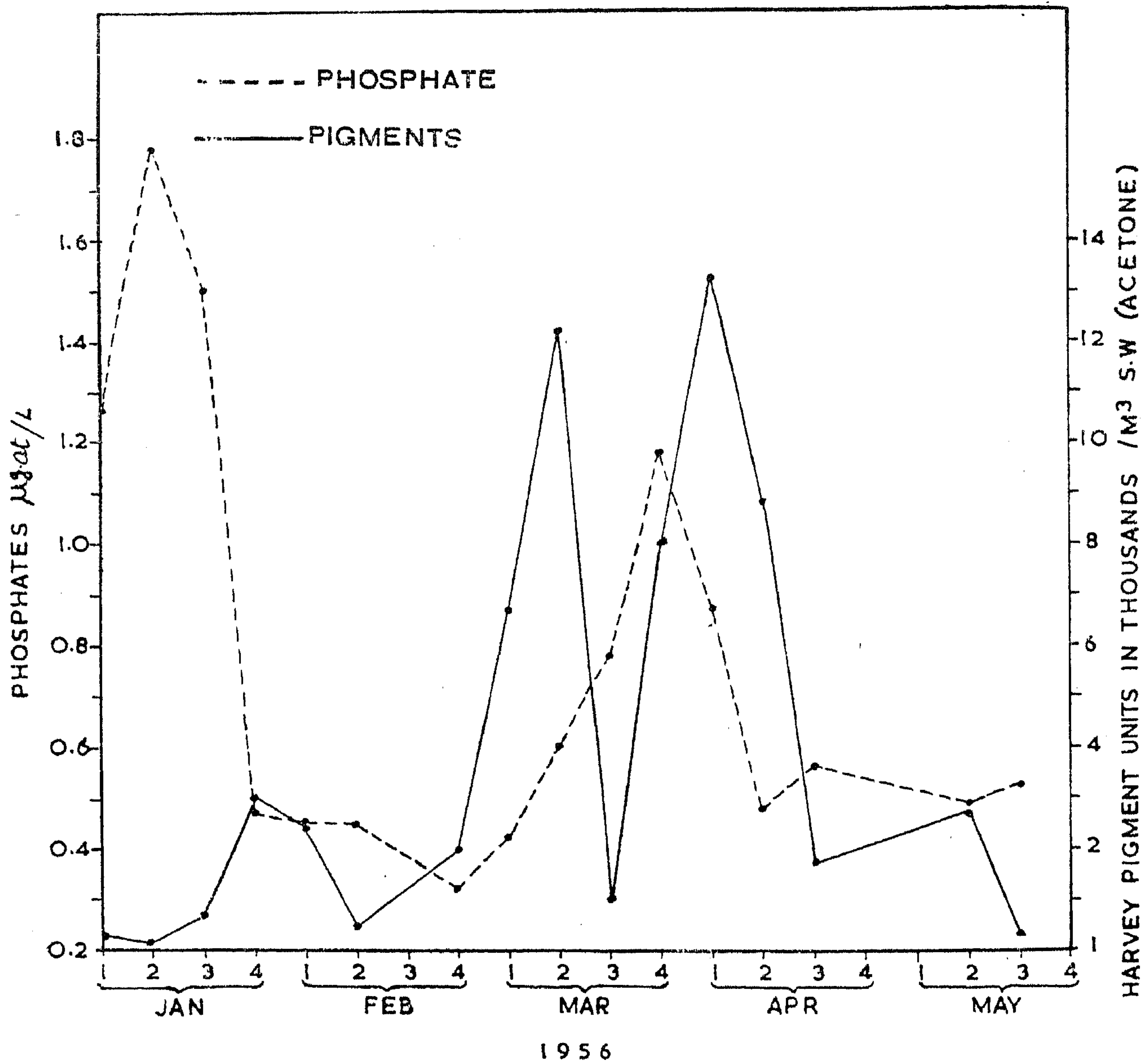

FIG. 4. Showing the mean weekly values for phosphates and pigments in the surface waters off Lawson's Bay during the period January to May 1956.

phytoplankton was observed in the second week of May soon followed by a rapid drop. This stage may be compared to the fourth stage described by Graham.

The zooplankton numbers were at their maximum when the temperature was low and the salinity high. They were in poor numbers during October and November when the salinity was at its minimum and the temperature fairly high. The Chætognaths off this coast were found by Ganapati and Satyanarayana Rao (1954) to occur in their maximum numbers during the month of March when the salinity was high and the temperature low. The same authors (Ganapati and Rao, V. R., 1954) found that the copepods also showed a similar relationship to the hydrographical conditions. Ramamurthy (1953 *a*) off Madras, and George (1953) off Calicut, observed similar relationships between the copepods, salinity and temperature. Raghuprasad (1956) found no consistent relationship between salinity and zooplankton. While at station G in the Gulf of Mannar, this relationship was inverse, a direct relationship between the two was observed at station P in the Palk Bay.

Ganapati and Rao (1953) observed that there is a regular sequence in a north to south direction in the commencement of the primary maximum of phytoplankton on the east coast of India. At Waltair it commences in February, at Madras during March (Menon, 1931) and at Krusadai in the Gulf of Mannar during June (Chacko, 1950). From the observed data on the surface salinity conditions at Waltair and Madras it is interesting to note that there is a time lag in a south to north direction of the maximum salinity values at the two stations during the northerly current period (January to June). At Madras it is during March to April (Jayaraman, 1951; Ramamurthy, 1953 *a*) and at Waltair the maximum values are during the April to May period. The time lag noticed for the maximum salinity values depends to some extent with the distance and the speed of the current. The succession of the phytoplankton blooms observed by Ganapati and Rao (1953) is from north to south whereas the current is from south to north during the same period as indicated by the salinity succession. Riley and Conover (1956) at Long Island Sound studied the distribution of the phytoplankton in relation to the hydrographical conditions. Based on the chlorophyll values they found an east-west gradient the maximum concentration being observed in the north-west part of the Sound. With respect to nutrients and salinity they have obtained the opposite situation. As we have at present no data on the nutrient gradients for the other centres on the east coast for the same period, it is not possible to generalise the reasons for this succession in a direction opposite to that of the prevailing current.

It may not be out of place to mention about the succession of the salinity and the silicate values at the same centres in a north to south direction during the southerly current period, July to December. Owing to the influx of large volumes of river waters from the north the salinity values are very low and the silicate values very high. The influx of the fresh-waters during the southerly current was first felt at Waltair during October, then at Madras during November (Jayaraman, 1951 and Ramamurthy, 1953 *a*) and lastly at Mandapam during January (Jayaraman, 1954). Nash (1947) suggested that the silicates can be used as a tracer of fresh-water just as salinity is used as a tracer of the sea-water carried up the estuary. From the above observations it can be suggested that the high silicate values together with the low salinities can be used as tracers of fresh-water. The influence of the fresh-waters from rivers to the north during the southerly current is greater than the incursion of the oceanic waters during the northerly current.

Lebour (1917) and Herdman (1922) and several other workers have observed in the temperate seas a regular succession of the maxima of the three major components of the plankton, namely, spring and early summer maximum for diatoms, a summer maximum for dinoflagellates and early winter maximum for copepods. From the data presented by us it may be observed that there is a spring diatom outburst with which both the dinoflagellate maxima coincide (Table II, Fig. 5). Off Madras coast also the diatom and dinoflagellate maxima are reported to coincide (Menon, 1931; and Ramamurthy, 1953 *a*). Marshall, Nicholls and Orr (1934) investigating the biological conditions of the Clyde Sea area found that the spawning of *Calanus finmarchicus* coincided roughly with the diatom flowerings. The copepod succession after diatoms need not be the case always as observed by Jacob Somme (1934) in Norway, Clarke and Zinn (1937) at Woods Hole and Wimpenny (1936) in the North Sea. Wimpenny (1936) points out that " the metabolism of the thickly massed plant cells might be expected to produce an environment attractive to animals ready to spawn and favourable for the development of the newly hatched young ". Some investigators like Fish and Johnson (1937) and Bigelow (1926) have reported that the copepod populations are present in areas where diatom flowerings were seen. Menon (1931) and Ramamurthy (1953) off Madras, and Raghuprasad (1954, 1956) in the Gulf of Mannar, for Station G, have observed an inverse relationship between phytoplankton and zooplankton, On the contrary Raghuprasad (1956) observed during most of the period at Station P, a direct relationship between phytoplankton and zooplankton. Fleming (1939) is of the view that there is little likelihood of finding a large zooplankton population in association with dense diatom population if the samples are

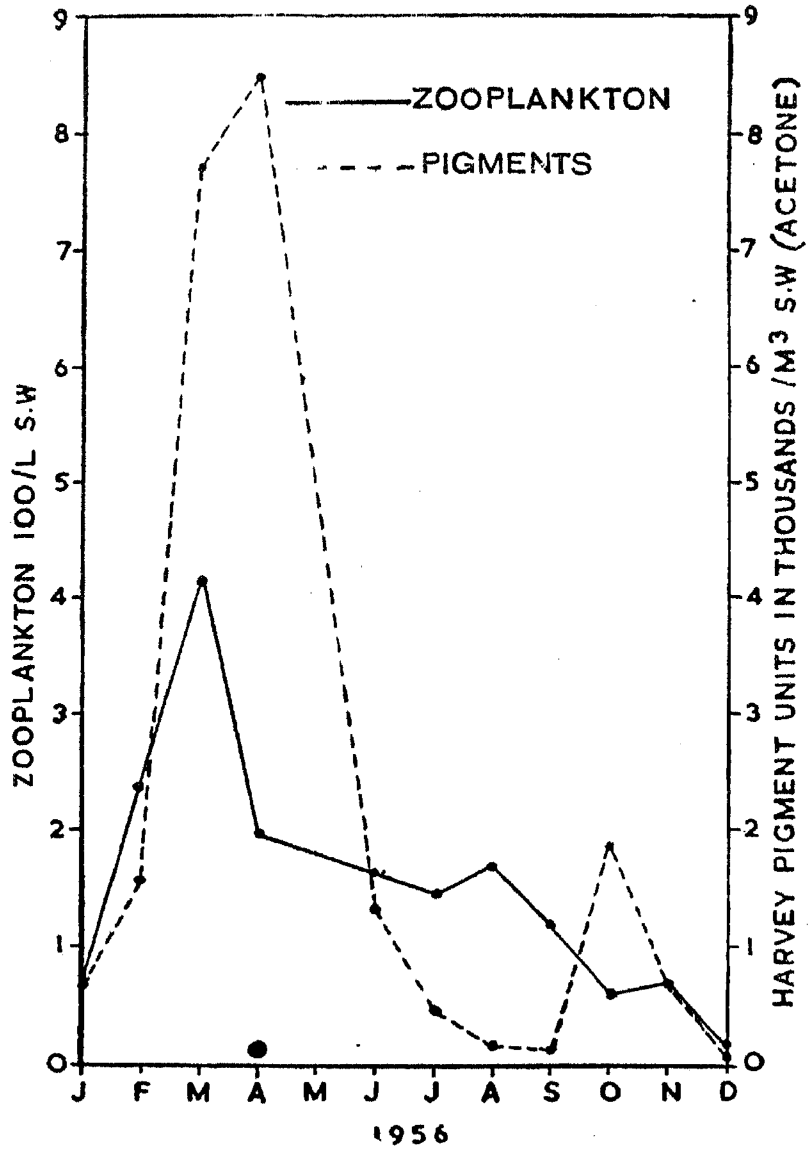

FIG. 5. Showing the mean monthly values for pigments and zooplankton organisms in the surface waters off Lawson's Bay during the year 1956.

collected at closer intervals. The abundance of the invertabrate larvæ, however, coincided with the phytoplankton peaks indicating a nutritional relationship between the larvæ and the phytoplankton. A similar relationship between invertebrate larvæ and phytoplankton have been reported by Aiyar (1936) and Ramamurthy (1953 *a*) off Madras and Raghuprasad (1954 *a*, 1956) in the Gulf of Mannar and George (1953) off Calicut.

From the above discussion it may be concluded that the productivity of the local waters is mainly controlled by the two currents. The hydrographical conditions are more favourable and stable during the northerly current system in the January to June period when there is enrichment of the surface waters by upwelling of the subsurface waters. The northerly current also brings in the enriched oceanic waters of the bottom Antarctic drift which upwells near the Carlsberg ridge and bifurcates into two branches one of which enters the Bay (Sewell, 1932). During the southerly current system, from July to December, the inshore waters in the Bay present nearly estuarine conditions and the general low production during the period may be attributed to the drastic fluctuations in hydrographical conditions. There is, of course, enrichment of the nutrients which are washed down by the great rivers to the north and a minor peak of phytoplankton is observed in the October to November period.

SUMMARY

Observations on the hydrographical and planktological conditions of the surface waters at a fixed station located at the 10 fathom line in the Lawson's Bay, Waltair, have been made for the year 1956.

The influence of the prevailing currents on the hydrographical conditions in the inshore waters of the Bay of Bengal is discussed. A north to south succession of the periods of low salinity and high silicate content at three stations Waltair, Madras and Mandapam on the east coast of India has been observed during the southerly current period, July to December. A similar succession of the high salinity values in a south to north direction during the northerly current period, January to June, has also been observed at Madras and Waltair.

Quantitative plankton estimations have been made by counting, volume estimation, pigment extraction, total biomass and total organic matter for known volumes of water. There was general agreement between the data using the different methods.

A major phytoplankton peak during March to April and a minor phytoplankton peak during October to November were observed. The diatom and dinoflagellate maxima coincided with each other.

Pigment extraction was made with three different solvents and it was found that ethyl alcohol-benzene mixture was a better solvent than acetone and methyl alcohol.

A general discussion is given on our observed data of plankton production in relation to the hydrographical conditions and inferences drawn in the light of similar investigations from Indian waters and elsewhere.

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