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Distribution of Chlorophyll, Carotenoids and Phytoplankton in Relation to Certain Environmental Factors along the Central West Coast of India

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Abstract

Distribution of chlorophyll pigments, carotenoids and abundance of phytoplankton in relation to certain environmental factors of the nearshore waters off the central west coast of India (latitudes 15°30' to 18°50'N) were studied monthly at 7 stations during 1970/1971. Changes in the hydrographical factors and the biological processes occurring in the region during different months appear to be influenced by the pattern of upwelling along the northern and southern parts of the west coast of India. The pigment concentration shows a marked decrease in October, but is followed by a slow but steady rise, which reaches its maximum in April/May. A slightly smaller maximum is noticed in December/January. The composition of various chlorophyll pigments and carotenoids indicated the physiological state of phytoplankton populations during different months in the region investigated. Abundance of specific phytoplanktonic elements, consisting mainly of diatoms, in space and time, characterises the waters of the central west coast of India, indicating a clear succession of species.

Introduction

Marine fish landings from the Arabian Sea along the west coast of India account for nearly 75% of the total sea food production of the country. Along this coastline, the strip between Quilon in the south and Ratnagiri in the north yields the bulk of the catch, which has been tentatively explained on the basis of the nutrient distribution pattern associated with the occurrence of seasonal upwelling (Panikkar and Jayaraman, 1966).

The upwelling is reported to be prevalent along the west coast of India between latitudes 7° and 16°N during July to early October (Banse, 1959). On the other hand, in the region north of Bombay, the upwelling has been reported during October, November (Jayaraman and Gogate, 1957; Carruthers et al., 1959). Occurrence of this phenomenon along the west coast of India would have a profound influence on the biological processes in the area. Gradual movement of mackerel shoals pursuing food from the Malabar coast in the south to Ratnagiri in the north, varies exponentially with time from September onwards (Selvakumar, 1970); this indicates the dynamic nature of biological production along the central west coast.

Observations on seasonal distribution of chlorophyll pigments, carotenoids, and abundance of phyto-

plankton, in relation to certain environmental factors in these waters, help in understanding, to some extent, the trend of biological processes occurring in the region.

The present study forms part of the program sponsored by the National Institute of Oceanography, India on the central west coast of India in which, besides the authors, Dr. A. B. Wagh and Shri R. A. Selvakumar participated and undertook zooplankton studies. Detailed aspects of hydrography, distribution of zooplankton and their biomass will be published separately.

Material and Methods

During 1970/1971, monthly observations were conducted to study certain environmental factors, phytoplankton abundance, and chlorophyll distribution along the central west coast of India on board a passenger ship sailing between Panaji (Goa) and Bombay. Due to cessation of steamer services during the south-west monsoon, the cruises were possible only from September to May.

The sampling program included observations once a month at 7 coastal stations where the passenger ships had their regular stops (Fig. 1). The depth of the water at the sampling stations near all the ports touched by the ships varied between 4 and 6 m. Precautions against churning and other disturbances were taken, and sampling at all the stations was carried out during day time. The area and actual time of sampling at each station remained about the same throughout the period of observations.

In reporting the observations, 7 ports from south to north between Panaji and Bombay have been discussed in series, i.e., Vengurla, Malvan, Deogad, Vijaydurg, Harnai, Sriwardhan and Janjira, which are coastal areas; the observation points lie approximately within 1 km from the shore.

Surface water samples were collected by a heavy plastic bucket. Temperature was immediately noted. Dissolved oxygen was determined by Winkler's method on board ship, whereas salinity was determined in the laboratory.

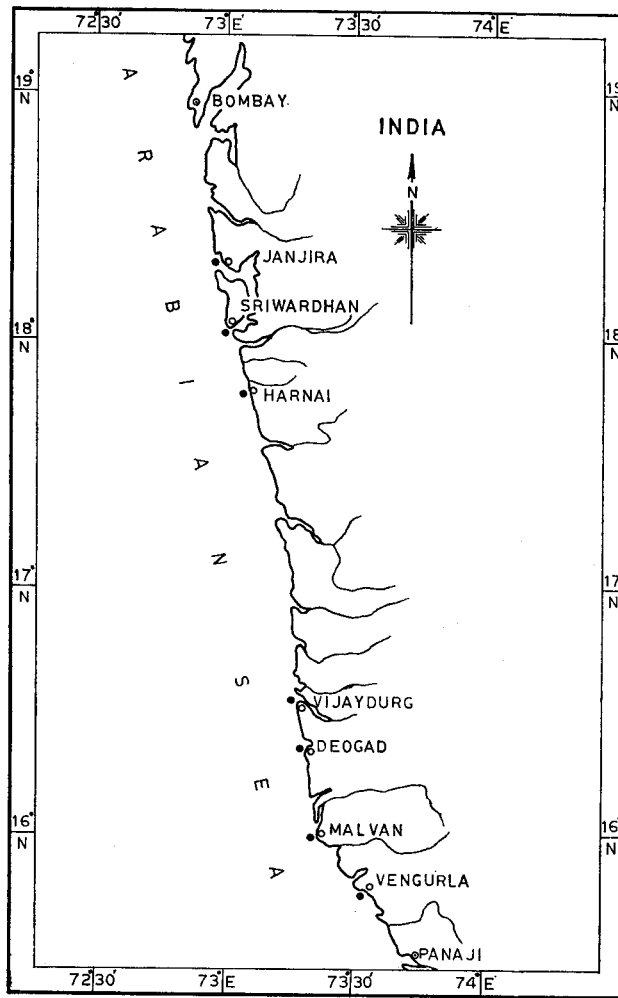


Fig. 1. Station positions along Goa-Bombay Coast, central west coast of India

For phytoplankton studies, a 1 l sample of surface water was collected, and the organisms were preserved by adding 10% formalin. The preserved samples were left undisturbed for about 1 week until fully settled. Later, the settled substrate was made up to 5 ml with water. For quantitative estimation of phytoplankton and their relative abundance, a subsample was taken and organisms were counted. These were computed to the total volume of the water sample taken.

Chlorophyll pigments and carotenoid contents of phytoplankton were determined after Richards with Thompson (1952) on a VSU-2 spectrophotometer, using the equations proposed by Strickland and Parsons (1965).

Results

Temperature

All along the section connecting the 7 stations from south to north, the temperature in September was low,

ranging from 25° to 27 °C, and suddenly rose in October simultaneously at all stations, ranging then between 30.5° and 31.0 °C (Fig. 2). From November onwards, there was a gradual fall in temperature at all stations. The lowest values of 24.4° to 26.5 °C were recorded during December and January, after which the temperature rose steadily until it reached a maximum of 28.75° to 32.0 °C by April/May. However, the lowest temperature of the season, at Vengurla, was recorded in November.

Salinity

Surface salinity during September at all the stations was uniformly low (4.0 to 18.6‰) (Fig. 2). From October onwards, the salinity stabilized in the range of 32.3 to 36.85‰ at all stations.

Salinity values showed two distinct peaks, in December and April, respectively, with a significant drop observed during January/February.

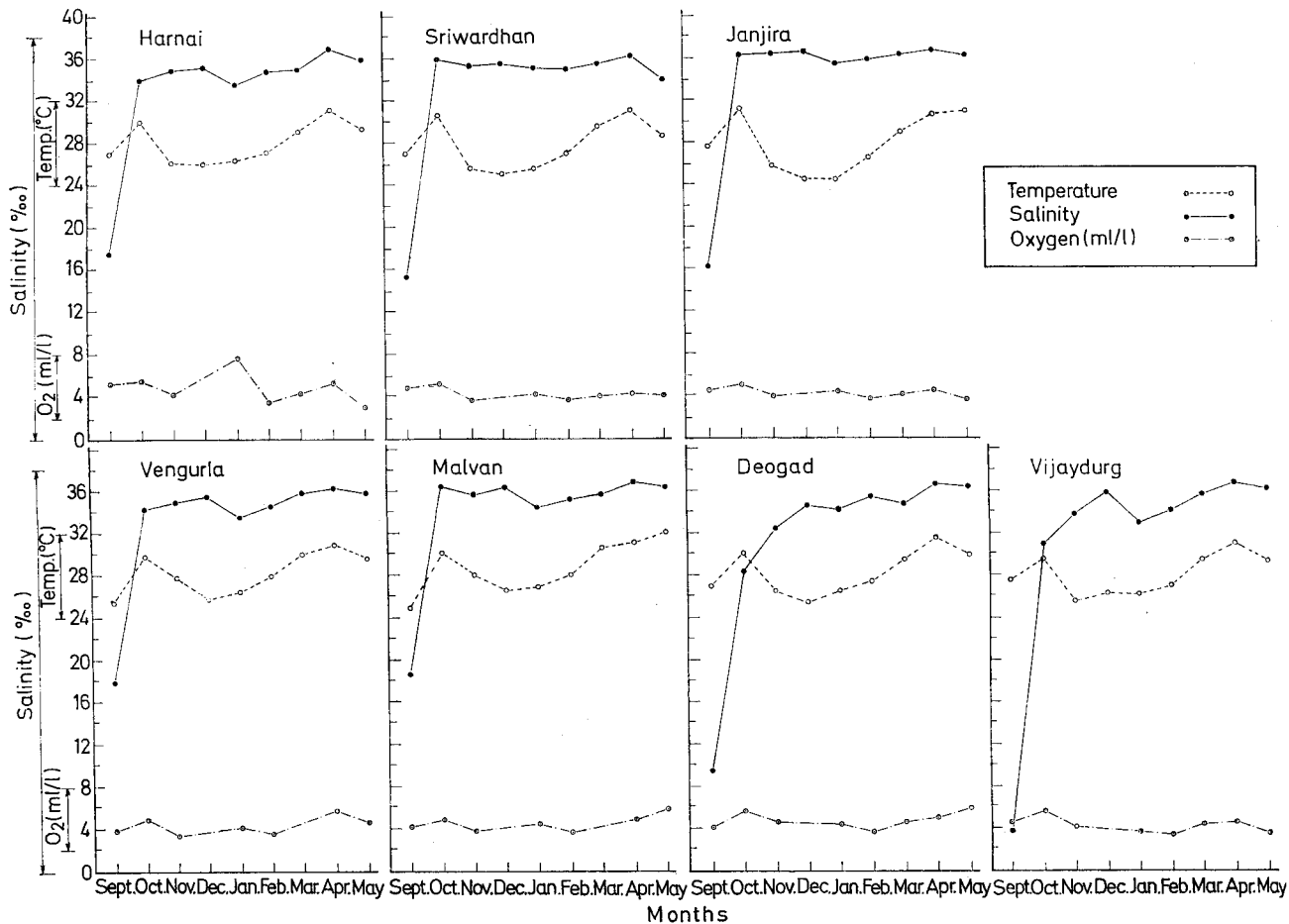


Fig. 2. Monthly changes in environmental factors at 7 stations along central west coast of India

Dissolved Oxygen

Oxygen values in September at all 7 stations ranged between 4.0 and 5.25 ml/l (Fig. 2). In October there was a uniform rise in oxygen concentration at all stations; average between 4.8 and 5.8 ml/l. Thereafter, through November to March, the fluctuations in the oxygen concentration were small until April/May, when the second peak was evident, with oxygen values as high as 6 ml/l.

Chlorophyll Pigments

Monthly variations in chlorophyll *a*, *b*, *c*, and carotenoid concentration from surface water samples at the 7 stations are shown in Fig. 3.

The values of chlorophyll *a* at the 7 stations showed generally 3 peaks during the period of observations from September to May. Immediately after the monsoon, in September, the chlorophyll *a* concentration was high, ranging from 2.3 to 8.2 mg/m³; this was followed by a sudden drop in October at all stations,

particularly at Vengurla, Harnai, Sriwardhan and Janjira. From November, the steady rise in chlorophyll *a* values resulted in peak concentration at the majority of stations by November/December and, in some cases, by January (Harnai), when the values ranged from 2.4 to 18.8 mg/m³. The highest values of this period were recorded at Vengurla, Deogad, Harnai, Sriwardhan and Janjira. At Malvan and Vijaydurg, the range of variations in chlorophyll *a* values was moderate (0.75 to 4.4 mg/m³), except in May when, at Malvan, chlorophyll *a* rose to 9.5 mg/m³.

A successive decrease in chlorophyll *a* at Vengurla, Malvan, Deogad and Vijaydurg occurred in January and February. At Harnai, Sriwardhan and Janjira, the decrease occurred during February/March; this decrease was considerable, and was followed by a gradual and steady rise in chlorophyll *a* values by April/May.

At Vengurla, Deogad, Harnai, Sriwardhan and Janjira, the pre-monsoon peak of chlorophyll *a* was secondary in magnitude; the values ranged from 2.7

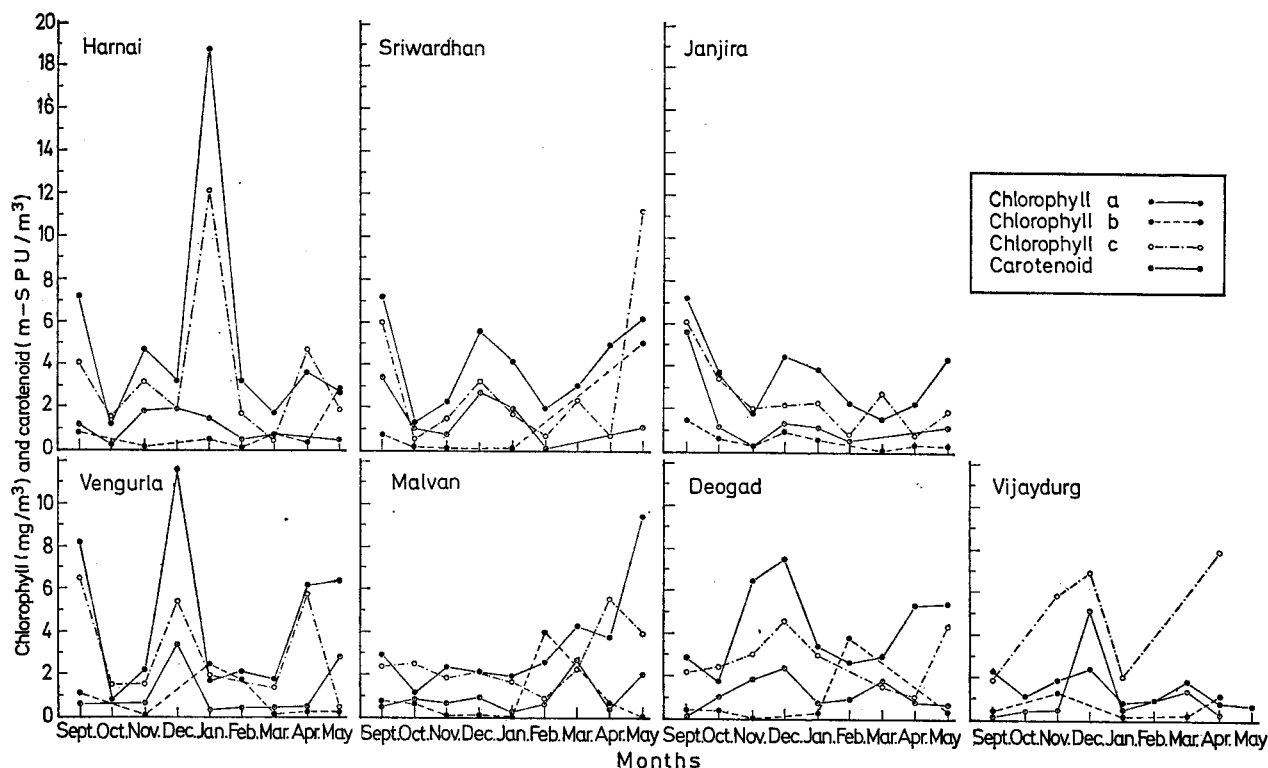


Fig. 3. Monthly variations in chlorophyll and carotenoid concentration at 7 stations along central west coast of India. (m-SPU/m³ = milli-specified plant pigment unit)

to 6.4 mg/m³, while at Malvan and Vijaydurg, the pre-monsoon period peak of chlorophyll *a* was highest, ranging between 7.9 and 9.5 mg/m³.

Corresponding monthly values of chlorophyll *c* were generally lower than chlorophyll *a* at all stations except Vijaydurg, where chlorophyll *c* formed the major constituent of the total plant pigments throughout the period of observations from September to May. At Vijaydurg, chlorophyll *c* showed two major peaks, one in December and the other in April, ranging from 2 to 8.0 mg/m³. Similarly, at most stations in October, chlorophyll *c* content attained slightly higher values than the corresponding chlorophyll *a* content. Again, during the pre-monsoon period, at Malvan, Harnai, Sriwardhan and Janjira, chlorophyll *c* exceeded chlorophyll *a* considerably.

Values of chlorophyll *b* were generally low at all stations, but occasional dominant peaks during various months were noticed (particularly during January and February at Vengurla; during February and March at Malvan and Deogad; and during March and April at Sriwardhan and Janjira), indicating an apparent succession in time from south to north along the central west coast.

Carotenoids (m-SPU/m³)¹ contents showed month-

¹ milli-specified plant pigment unit.

ly variations in close relation to chlorophyll *a* and *c*, and indicated corresponding peak values at all the stations. However, again at Vijaydurg, the carotenoid value exceeded the value of chlorophyll *a* in December and was close to that of chlorophyll *c* (5.2 m-SPU/m³).

Phytoplankton Abundance

Monthly variations in the counts of phytoplankton per litre were recorded at all 7 stations from September to May (Fig. 4).

Observations beginning from September showed high density of phytoplankton at all stations except Malvan, where the counts were generally low, but consistent, until February. At Vengurla, the occurrence of phytoplankton was consistently high until February/March, whereas at Deogad, the values fluctuated, with moderate peaks in November, January and April.

At the stations in the northern region of the coast, namely Vijaydurg, Harnai, Sriwardhan and Janjira, the phytoplankton density was high in September, with a marked decrease in October, followed by a significant rise in December/January.

It may thus be seen that, throughout the central west coast of India, there is a pre-monsoon peak of

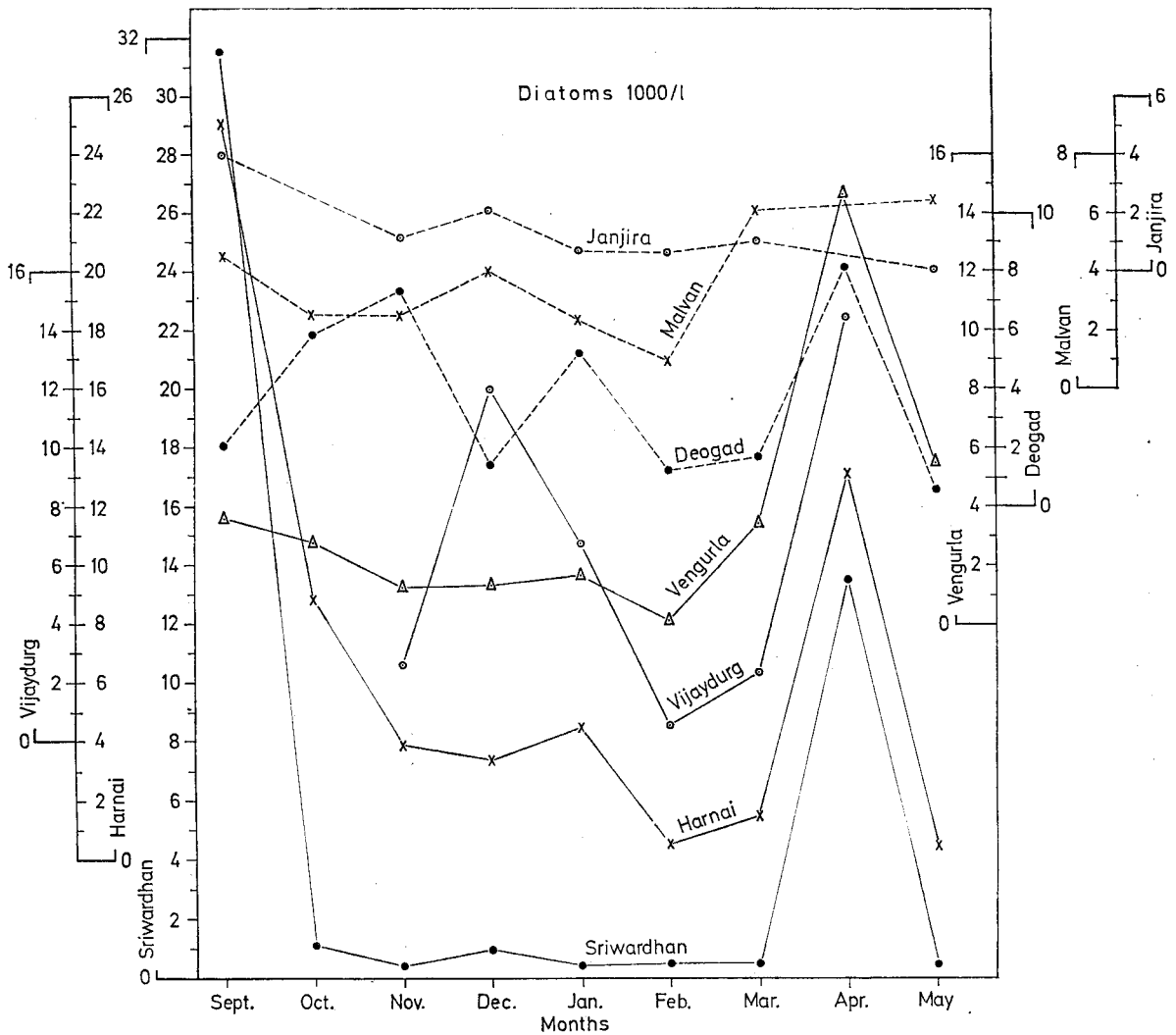


Fig. 4. Monthly variations in diatom counts at the 7 stations

phytoplankton bloom in the months of April and May.

Some differences in the phytoplankton distribution in the waters of this region were observed during September to May 1970/1971. In September, *Nitzschia* spp. and *Thalassiosira* spp. were dominant. The phytoplankton crop, mostly consisting of *Thalassiosira* spp., was meagre in October; in November, however, a sudden bloom of *Melosira* spp. characterised the coastal waters in the southern end, whereas *Thalassiothryx* spp. dominated in the northern region. The phytoplankton crop mainly consisted of *Thalassiothryx* spp. and *Nitzschia* spp. in December, although a variety of other diatoms were also noted. *Pleurosigma* spp. appeared in January in the southern region, whereas *Coscinodiscus* spp. dominated in the northern region of the central west coast.

In February, a sudden bloom of green algae occurred accompanied by diatoms, mostly *Aulacodiscus* spp.

During March/April/May, the southern region of this coast showed an abundance of *Thalassiothryx* spp., *Thalassiosira* spp., *Coscinodiscus* spp., *Asterionella* spp. and *Chaetoceros* spp., whereas in the northern part, *Chaetoceros* spp., *Eucampia* spp. and *Thalassiosira* spp. were present.

Discussion

The main environmental factors in the waters along the central west coast of India follow a seasonal cycle. The changes in the hydrographical parameters and the biological production in the region appear to be very much influenced by the pattern of upwelling occurring along the southern as well as the northern

part of the west coast of India, as has been reported by several workers. Although it is still too early to make a definite statement, it appears that the waters along the central west coast of India constitute a zone of transition between two upwelling regions.

Occurrence of upwelling off Calicut along the south-west coast of India, up to 15°N has been discussed by Banse (1959). Rao and Jayaraman (1970) recently reviewed the oxygen distribution in the Arabian Sea, and indicated Goa as the northernmost boundary of the upwelling influence, occurring during the south-west monsoon off the south-west coast of India. Earlier, on the basis of the study of the phosphorus cycle and the total phosphorus distribution in the surface water off the Indian coasts, Jayaraman and Seshappa (1957) presented evidence that upwelling in some form occurs up to as far as 18°N. Off Calicut, Banse (1959) and Ramasastry and Myrland (1959) reported that the effect of upwelling near the coast is felt mostly from July to September. On the other hand, in the region north of Bombay, the occurrence of upwelling during October and November has been reported and its possible effect on the lower latitudes also surmised (Carruthers et al., 1959).

Double seasonal oscillations of temperature, salinity and oxygen concentration of the surface water along the central west coast of India were noted. The period of sudden lowering of temperature and oxygen values and the simultaneous rise in the salinity of the waters in the region between 15°30' and 18°30'N (Vengurla to Janjira) during November/December and January followed that of the phenomenon of upwelling (with similar influences) off the south-west coast of India and that observed off Bombay. However, the high oxygen concentration during April and May in the entire region could be due to photosynthetic activity of the abundant phytoplankton in the water.

Most of the work to date on biological production along the west coast of India concerns the south-west coast only. Recent studies on the waters of Goa (Dehadrai, 1970), and other reports covering the west coast from Calicut to Bombay (Bal and Pradhan, 1946; Gonzalves, 1947; George, 1953; Subrahmanyam and Sarma, 1960; Ramamurthy, 1965) indicate that the production potential in Goa waters (as well as that in the north of the region) is high, and there appears to be a northerly succession in the peak of production rates in space and time along the entire west coast of India from Cochin to Bombay after the south-west monsoon. Humphrey (1966) reviewed the distribution of chlorophyll *a* and *c* in the South East Indian Ocean, but no correlation of recorded chlorophyll distribution pattern with environmental factors exists for the Indian Ocean.

Marked lowering in the concentration of chlorophyll pigments during October at all the stations coincides with the similar abrupt lowering of temperature and oxygen values, and increased salinity during October.

Thereafter, the rise in the chlorophyll pigments during November/December in the southern zone (Vengurla) and during December/January in the northern zone of the region (Janjira), and the phased maxima of the chlorophyll pigments in the southern and northern zones of the central west coast, appear to be associated with the upwelling phenomena emanating from off Calicut (Banse, 1959) and off Bombay (Carruthers et al., 1959), respectively.

Later, in April/May, the high values of chlorophyll pigments and peak abundance of phytoplankton almost throughout the central west coast could be regarded as a passive culmination of the process of slow but steady growth of the phytoplankton population initiated after cessation of the south-west monsoon.

Percentage composition of various chlorophyll pigments and carotenoids indicates, to some extent, the physiological state of phytoplankton populations in the waters of the central west coast during different months (Fig. 5).

The chlorophyll *a*: carotenoid ratio is known to be more constant than the chlorophyll concentration by itself, and a low ratio of chlorophyll *a* to carotenoid would certainly indicate a chlorotic, unhealthy phytoplankton population (Ketchum et al., 1958). However, wide variations in the ratio are observed under different conditions in the sea. Particularly phosphorus and nitrogen deficiencies have been shown to produce these variations (Yentsch, unpublished, in: Ketchum et al., 1958).

In September and October, the relative concentrations of chlorophyll *a* and carotenoid were fluctuating highly at different stations, but in November, the carotenoid content stabilized to low values until February, accompanied by a high concentration of chlorophyll *a* and *c*, indicating a healthy crop in the waters of the central west coast.

Again in March, the phytoplankton population appeared highly chlorotic and unhealthy, with a high carotenoid content in relation to chlorophyll *a*. It is possible that the high algal blooms of the January/February period may have caused considerable nutrient depletion in the environment. By April/May, however, the phytoplankton population appeared to revive, with an abundance of chlorophyll *a* and *c* and a small amount of carotenoid. The dominance of chlorophyll *c* in the plant pigments at different stations may be due to the abundance of diatoms and dinoflagellates.

Abundance of specific phytoplanktonic elements in space and time characterises the waters of the central west coast of India as observed at the 7 stations. Marked differences in the species composition of the phytoplankton crop, consisting mostly of diatoms in the waters of southern and northern regions of the central west coast of India, are significant. Moreover, the seasonal changes in the dominant groups of the phytoplankton indicate clear succession of species.

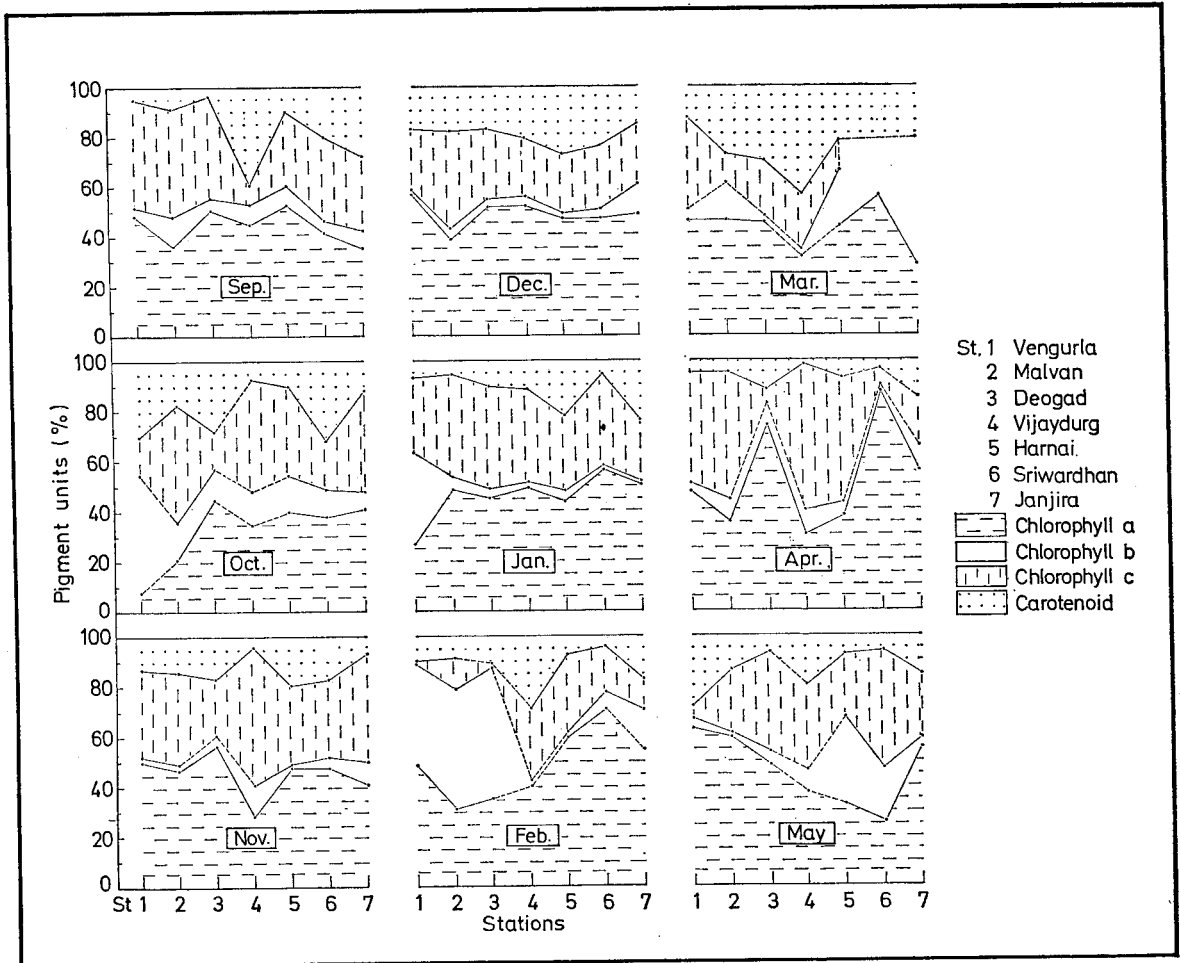


Fig. 5. Composition of chlorophyll pigments and carotenoids during different months at the 7 stations

However, it is interesting to note that the green algal bloom occurred only in February.

The biological processes in relation to certain environmental features occurring in the region appear to be broadly influenced by the upwelling phenomena which start at the southern and northern ends of the central west coast after the southwest monsoon. However, for a detailed understanding of the ecology of the region, observations on depth profiles of certain environmental factors and biological production processes in relation to fresh-water drainage from numerous rivulets and tidal creeks, as well as the overall larger influences of the south-west monsoon causing upwelling in the area are necessary.

Summary

1. Double seasonal oscillations of temperature, salinity and oxygen concentration of the surface waters are noted in the nearshore waters of the central

west coast of India. The sudden lowering of temperature and oxygen concentration values and the simultaneous rise in salinity during November to January follows the phenomenon of upwelling.

2. The values of chlorophyll *a* are high at all 7 stations in September, followed by a drop in October, thereafter they show a steady rise, with a peak in November/December. However, the highest value of chlorophyll *a* (18.8 mg/m³) was recorded in January at Harnai.

3. Values of chlorophyll *b* are generally low at all 7 stations.

4. Chlorophyll *c* values are generally lower than that of chlorophyll *a* except at Vijaydurg, but in October and again in the pre-monsoon period at a few stations, chlorophyll *c* values exceed the chlorophyll *a* values.

5. Carotenoid contents show monthly variations in close relation to chlorophyll *a* and *c*, but at Vijaydurg, the carotenoid values exceed the values of chlorophyll *a*

in December and are close to those of chlorophyll *c*.

6. The phytoplankton bloom occurs at most of the stations in April, except at Malvan and Janjira, where variations are small.

7. The distribution of chlorophyll in relation to temperature, salinity and oxygen values appears to be associated with the upwelling reported to emanate from off Calicut and off Bombay.

Acknowledgements. We express our gratitude to Dr. N. K. Panikkar, Director, National Institute of Oceanography, Panaji, India, for his constant encouragement and his interest throughout the program. Our thanks are due to Mr. R. Jayaraman and Dr. S. N. Dwivedi of the Institute at Panaji, for their help and interest in the program. We are also thankful to Dr. R. Raghu Prasad, for critically going through the manuscript and for giving valuable suggestions. The work could not have been possible without the facilities accorded by Messrs. Ghowgule Steam Ships Company, which we acknowledge with grateful thanks.

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Date of final manuscript acceptance: July 3, 1972. Communicated by N. K. Panikkar, Panaji