

OBSERVATIONS ON CERTAIN ENVIRONMENTAL FEATURES AT THE DONA PAULA POINT IN MARMUGAO BAY, GOA

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ABSTRACT

The Marmugao Bay, which is an estuary of the river Zuari, showed marked seasonal changes in temperature, pH, salinity, oxygen, turbidity and light penetration. These are largely induced by the south-west monsoon.

Primary productivity showed a similar seasonal pattern and increased by about two to three times during pre-monsoon and post-monsoon months. Fluctuations in the phytoplankton abundance seem related to the cycle of primary productivity.

Short-term changes in some of these parameters induced by the tides and day and night conditions were well marked. These are also considerably influenced by the local precipitation and land run-off during south-west monsoon.

INTRODUCTION

IN regard to waters of Goa region, very little work has so far been done and hence not much information is available. With the establishment of the National Institute of Oceanography at Panjim, Goa, it became possible to make regular studies on seasonal and diurnal changes in certain oceanographic parameters of the inshore waters around Goa.

The area selected was the Dona Paula point in the Marmugao Bay which is an estuary of the river Zuari. It is situated along Lat. $15^{\circ} 27' N$ and Long. $73^{\circ} 48' E$ (Fig. 1). On the eastern side, the Zuari river flows into the Marmugao Bay. On the southern side of the Bay is Marmugao Harbour. Along the northern point of the Bay, a prominent headland called Cabo Point marks the western extremity of the main Panjim Island. The Panjim Island is situated in between the two estuarine systems, the

Marmugao Bay and the Aguada Bay of the Zuari and Mandovi rivers respectively. North of the Marmugao Bay, facing the Marmugao Port Harbour, is the Dona Paula point which marks the south-west extremity of the Panjim Island. The Marmugao Bay, along its north-eastern side, has a depth of 5 to 8 metres whereas near Dona Paula at the Zuari bar, the minimum depth is about 2 metres.

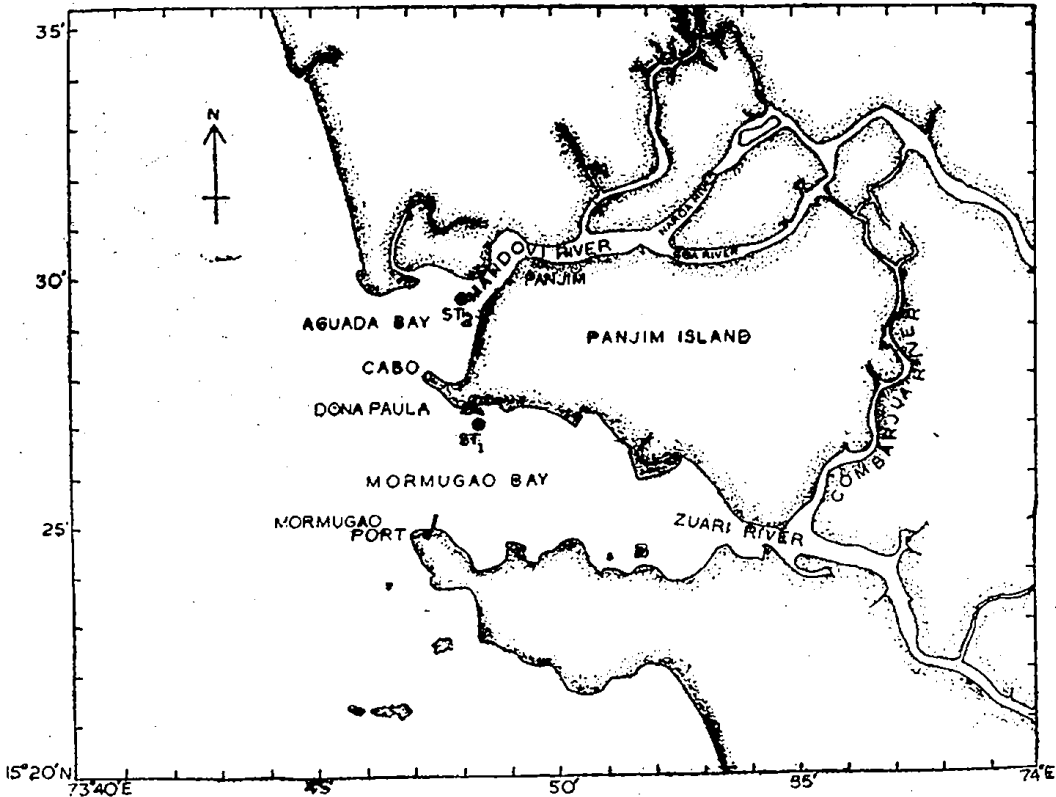


FIG. 1. Map showing Marmugao Bay and the Zuari estuary connected with the Arabian Sea. Closed circle indicates the station for seasonal and diurnal observations.

During the monsoon months (June to September) the estuary is turbid due to heavy discharge of freshwater laden with silt from the river Zuari. The annual rainfall of Goa is about 3,000 mm. of which nearly 80% occurs from June to August (Fig. 2). The average monthly maximum and minimum atmospheric temperature (Fig. 2) remained more or less uniform except in January.

In the Marmugao Bay the tides are of mixed semidiurnal type with maximum range of about 2 metre. Two high and two low waters occur in every 24 hours period with considerable difference in range and time,

The observations were made from a single station fixed near the Dona Paula jetty (St₁, Fig. 1). The depth of water at the station varies between 3 and 5 metres with the tidal range.

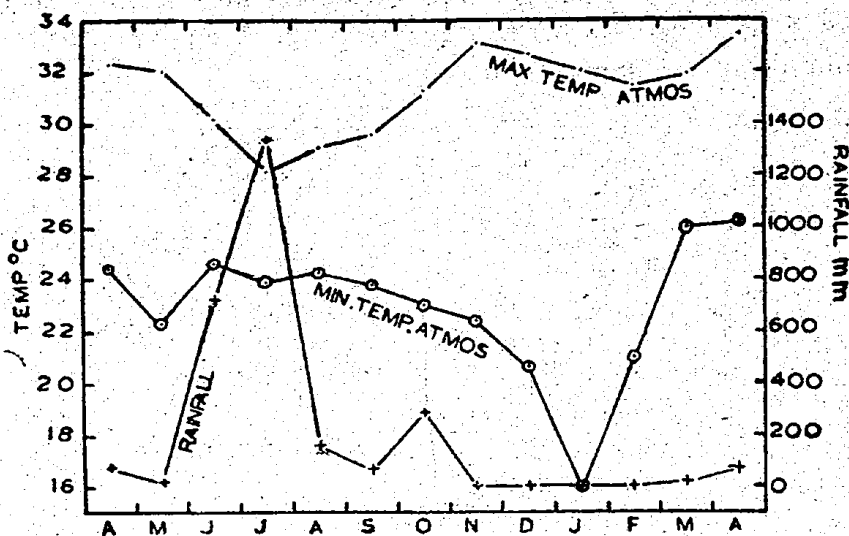


FIG. 2. Seasonal variations in atmospheric temperature and rainfall in Goa from April 1968 to April 1969.

MATERIAL AND METHODS

Water samples were collected from the surface. For seasonal studies weekly collections were made in the morning between 0700 and 0800 hours, whereas during the pre-monsoon and post-monsoon periods for diurnal changes, observations were made at three-hour intervals for 25 hours. Studies on diurnal variations were planned during the spring tide so as to assess maximum differences in the environmental features caused by the tides. The seasonal observations were made on 12th–13th May 1968 and on 25th–26th July 1968.

Since the tides have a marked influence on various physical and chemical factors of the estuary, seasonal observations on different environmental features were made under similar tidal conditions, *i.e.*, at the flood, so as to permit a fair comparison of the data.

All samples were analysed within six hours of collections. A plastic bucket was used for the collection of water samples from which the temperature was read off immediately. Other determinations included the measurement of pH using Philips pH meter, salinity using Mohr's techniques and Winkler's method for oxygen. Turbidity was measured with the help

of a Turbidometer. The extinction coefficient of light (k) was calculated from the secchi disc reading using the equation $k = 1.7/D$ which is a modification over Poole and Atkins (1929) suggested by Qasim *et al.* (1968) for turbid waters. For estimating total solids during diurnal studies a sample of 100 ml. water was evaporated to dryness at about 60° C. in an oven until a constant weight was obtained.

Phytoplankton and zooplankton collections were made by filtering 75 litres of water through a net of Bolting nylon of 0.065 mm. mesh width and organisms collected were preserved in 5% formalin solution. These were left undisturbed for about a week until fully settled. Later the substrate was made to 5 ml. and examined. For quantitative estimation of plankton a subsample was taken and the organisms were counted. These were computed to the total volume of water filtered.

Primary production was studied by using 'light'- and 'dark-bottles' oxygen technique. The water sample collected for the purpose was at first passed through a coarse plankton net material to remove larger zooplankton organisms and then this was distributed in 60 ml. 'light'- and 'dark-bottles' which were suspended just below the surface from a float and incubated *in situ* for a period of 8 hours.

Rate of gross and net primary production were calculated by converting the oxygen values to carbon assimilation using a factor 0.375/PQ and taking the value of PQ as 1.2 (Strickland and Parsons, 1965).

Meteorological data on rainfall and atmospheric temperature were obtained from the Meteorological Observatory at Panjim. Predicted tide time and heights were followed from the Tide Tables issued by the Captain of Ports Department, Panjim, Goa.

SEASONAL CHANGES

Temperature.—The water temperature at the surface ranges from 26° C. to 31° C. (Fig. 3). Two peaks, one during October to December and the other during April–May, were recorded. Marked seasonal decrease occurred during July–August (monsoon) and January–February (post-monsoon).

The monthly variations in the water temperature at the surface showed a double oscillation and broadly corresponded with fluctuations of the atmospheric temperature (Fig. 2).

Most of the Bay being shallow, the thermal conditions of the water seem to be governed by the atmospheric temperature.

pH.—The monthly variations of pH are shown in Fig. 3. The values ranged between 7.8 and 8.2 in the waters of Marmugao Bay. Similar range of pH was recorded by Sankaranarayanan and Qasim (1969) at the entrance channel of Cochin Harbour.

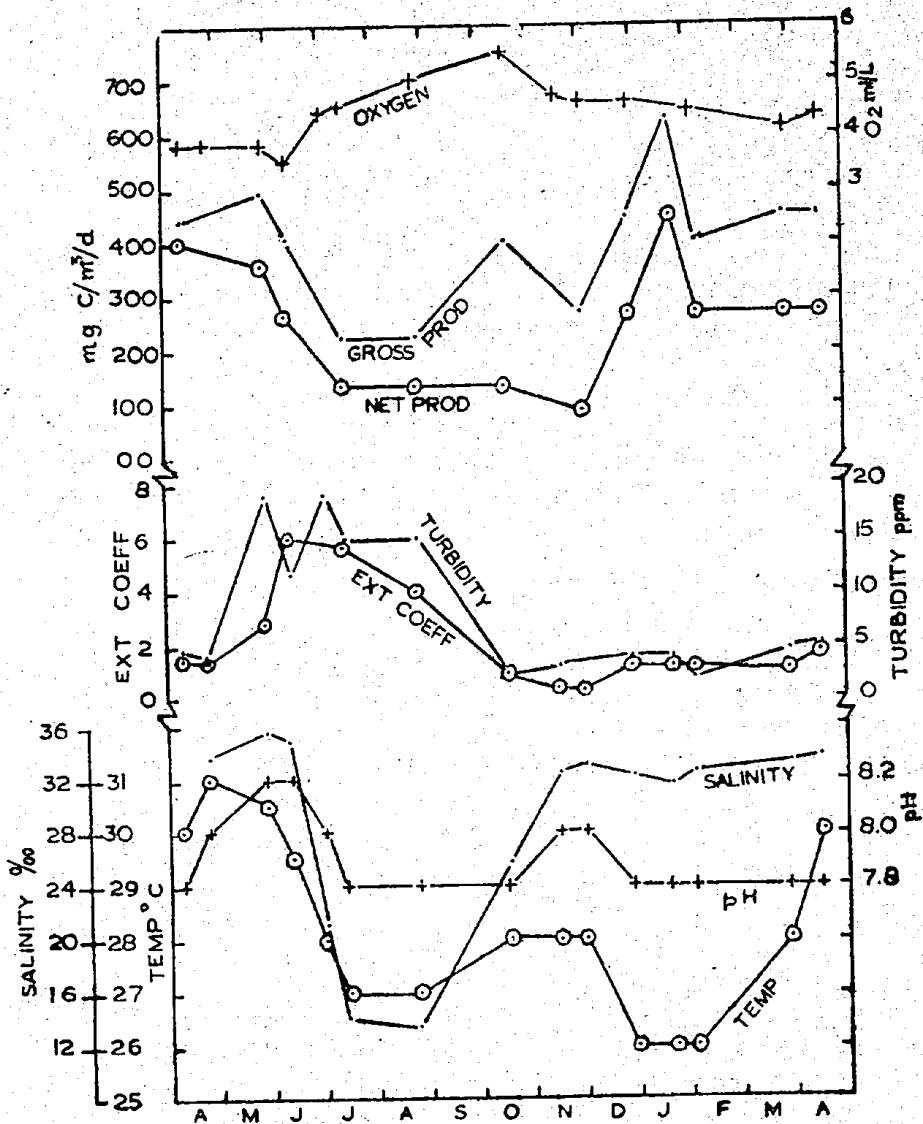


FIG. 3. Seasonal changes in various environmental factors at Marmugao Bay from April 1968 to April 1969.

High values of pH in Marmugao Bay during the pre-monsoon and post-monsoon periods and low pH during the south-west monsoon were noticed. High pH was associated with high seasonal temperature, high

salinity and low oxygen during the periods when the estuary remained marine-dominated and thus showed a double oscillation in its seasonal variations.

Salinity.—Considerable monthly variations of surface salinity (Fig. 3) from 13.45‰ to 35.00‰ were observed in the Bay. These were induced by the south-west monsoon during June to October when the rainfall is maximum (Fig. 2). But for the south-west monsoon period, the surface salinity during high water throughout the year remained high indicating that the estuary becomes merely an extension of the adjoining sea. The region showed a single oscillation of salinity changes throughout the year.

Dissolved oxygen.—Seasonal changes in dissolved oxygen in the waters of Marmugao Bay ranged from 3.8 ml/L to 5.5 ml/L (Fig. 3). High values of dissolved oxygen (4.5 ml/L–5.5 ml/L) was observed from July to October. This was probably due to the effect of south-west monsoon. From November to April, the values of dissolved oxygen were between 3.8 ml/L and 4.5 ml/L.

However, the surface water contained dissolved oxygen nearly to a saturation point and showed an inverse relation with the salinity curve (Fig. 3). The monthly variations of the dissolved oxygen indicated a single oscillation.

Turbidity and extinction coefficient.—Monthly fluctuations of turbidity and extinction coefficient were high. The former ranged from 10 to 19 ppm and the latter 3 to 6 during the period May–August, but low values of turbidity (2–5 ppm) and extinction coefficient (0.4–1.8) were recorded from October to April (Fig. 3).

The light penetration was greatly reduced during the south-west monsoon because of high turbidity. Lack of correlation between attenuation coefficient and suspended matter in Cochin Backwater has been discussed by Qasim *et al.* (1968). Semi-logarithmic graph in Fig. 4 shows a non-linear relationship between the turbidity and extinction coefficient in Marmugao Bay waters. In the present observations, the high turbidity values beyond 10 ppm in Marmugao Bay occurred only during south-west monsoon when there was enormous quantity of debris and suspended matter in the water.

Primary productivity.—Seasonal changes in gross and net production rates have been shown in Fig. 3. The seasonal increase does not appear to exceed 2–3-fold.

Two peaks of high productivity were noticed and these corresponded with the pre-monsoon (April–May) and post-monsoon (December–January) months. During the period of rainfall, the productivity values were low.

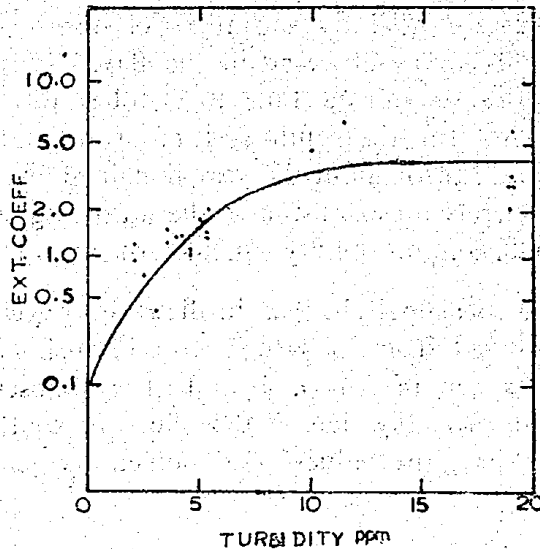


FIG. 4. The relation between turbidity and extinction coefficient of light.

The marked seasonal increase in the productivity during April and January coincided with calm and clear water with peak salinity. But the pre-monsoon peak of productivity occurred when the water temperature was highest while the other peak in January occurred when the water temperature was lowest of the year. It seems difficult to explain two pulses of high productivity during such contrasting temperature conditions.

A marked difference between gross and net production rate of phytoplankton and microbes in the Bay remained high all the year round.

Plankton.—The major phytoplankton organisms showed two maxima during the year, *i.e.*, a pre-monsoon peak from February to April and a secondary rise in December (Fig. 5). These two peaks coincided with similar rise in primary productivity.

On the west coast, phytoplankton peak at Bombay harbour has been reported to be from September to February (Gonzalves, 1947) while off Calicut the maximum bloom was observed from May to September (George, 1953; Subrahmanyam and Sarma, 1960). In Goa waters, the plankton maximum appears to occur from February to April which is later than further north and earlier than further south.

Seasonal fluctuations in Copepoda abundance were similar to those of phytoplankton and showed a single maximum during March–April (Fig. 5). Theoretically speaking the phytoplankton peaks should be followed by the zooplankton peaks, since the former is known to serve as food for the latter but in the present case the two peaks coincided. Probably tidal currents and vertical turbulence might also be partly responsible for this coincidence (Riley and Bumpus, 1946).

A short-term secondary rise in Copepoda counts during December with sudden decrease in January similar to phytoplankton was noted which coincided with the cessation of pelagic fishery (mackerel and sardines) for the season in Goa region (personal communication, Directorate of Fisheries, Panjim).

Low concentration of phytoplankton and of zooplankton during the peak monsoon season (July–August) was an interesting feature which appeared to have direct relation with excessive turbulence, high turbidity, insufficient light penetration, low pH and low surface salinity in the waters of the Marmugao Bay.

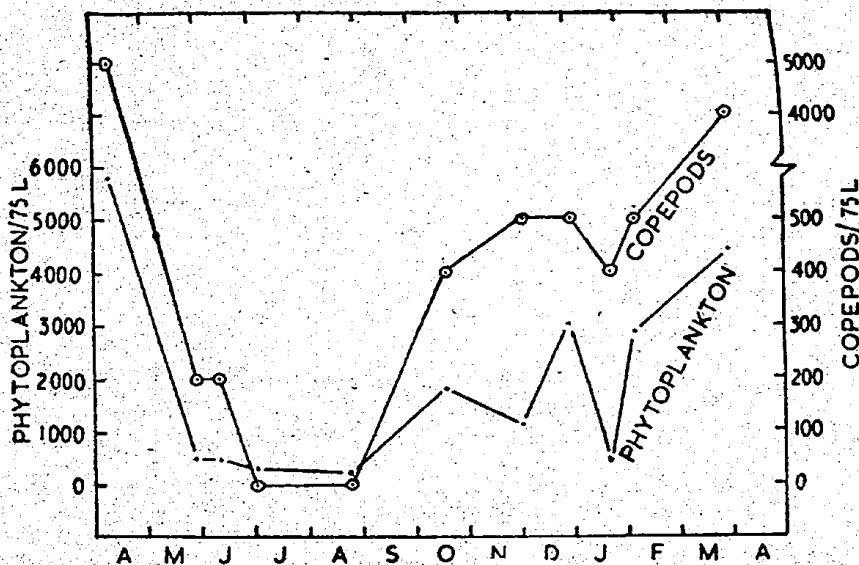


FIG. 5. Seasonal abundance of phytoplankton and copepods at Marmugao Bay from April 1968 to March 1969.

DIURNAL CHANGES

Temperature.—During pre-monsoon (May) the diurnal changes of temperature at the surface of water in Marmugao Bay were in the range of

29.5° C. and 30.5° C. (Fig. 6). The difference in day and night temperature was because of the warming of water caused by the solar radiation. During July the water temperature at the surface was cooler due to south-west monsoon effect. Diurnal changes in temperature occurred in the range of 26.5° C. and 27.2° C. during monsoon (Fig. 7).

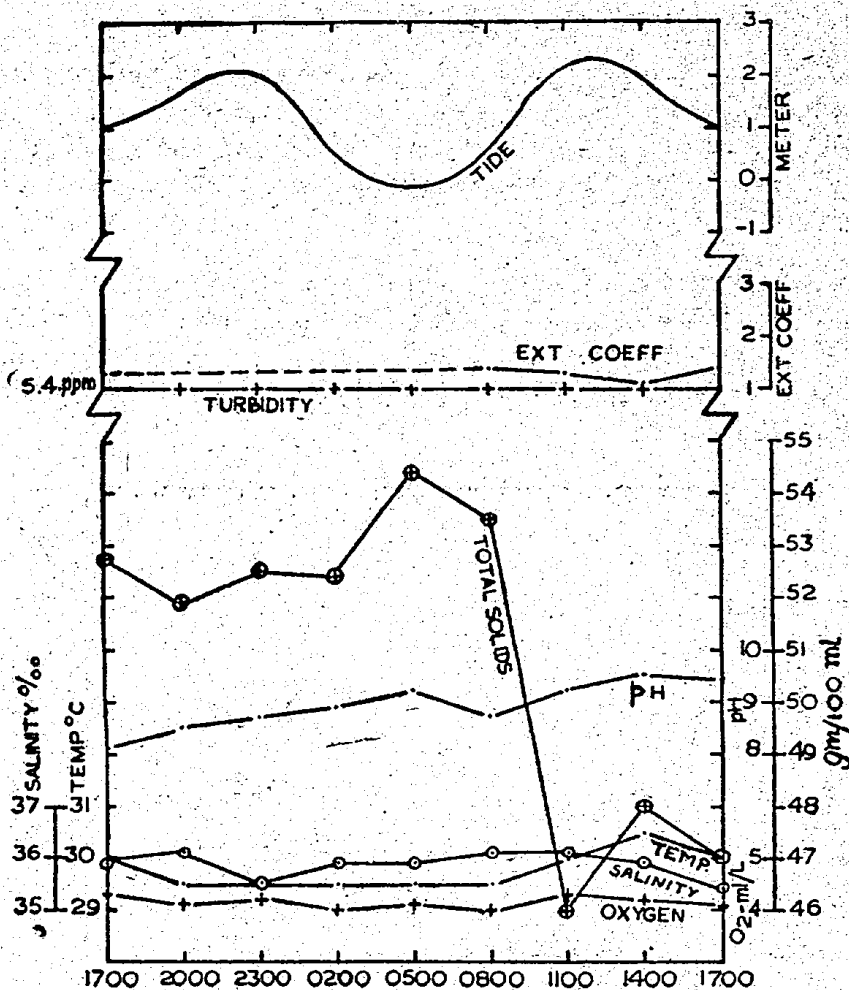


FIG. 6. Diurnal variations in various environmental factors at Marmugao Bay on May 12-13, 1968.

pH.—Observations during the pre-monsoon period on diurnal variations of pH (Fig. 6) as such in the higher range of 8 and 9.5 were much higher than the seasonal values of pH in the area. But during south-west monsoon (Fig. 7) the diurnal variations of pH ranged from 7 to 8 and corresponded with the respective seasonal values.

Salinity.—In May, observations on the diurnal variations of salinity which ranged between 35.4‰ and 36.1‰ (Fig. 6) showed that the fresh-water discharge by the river Zuari is little during the pre-monsoon months and the estuary is merely an extension of the neighbouring sea.

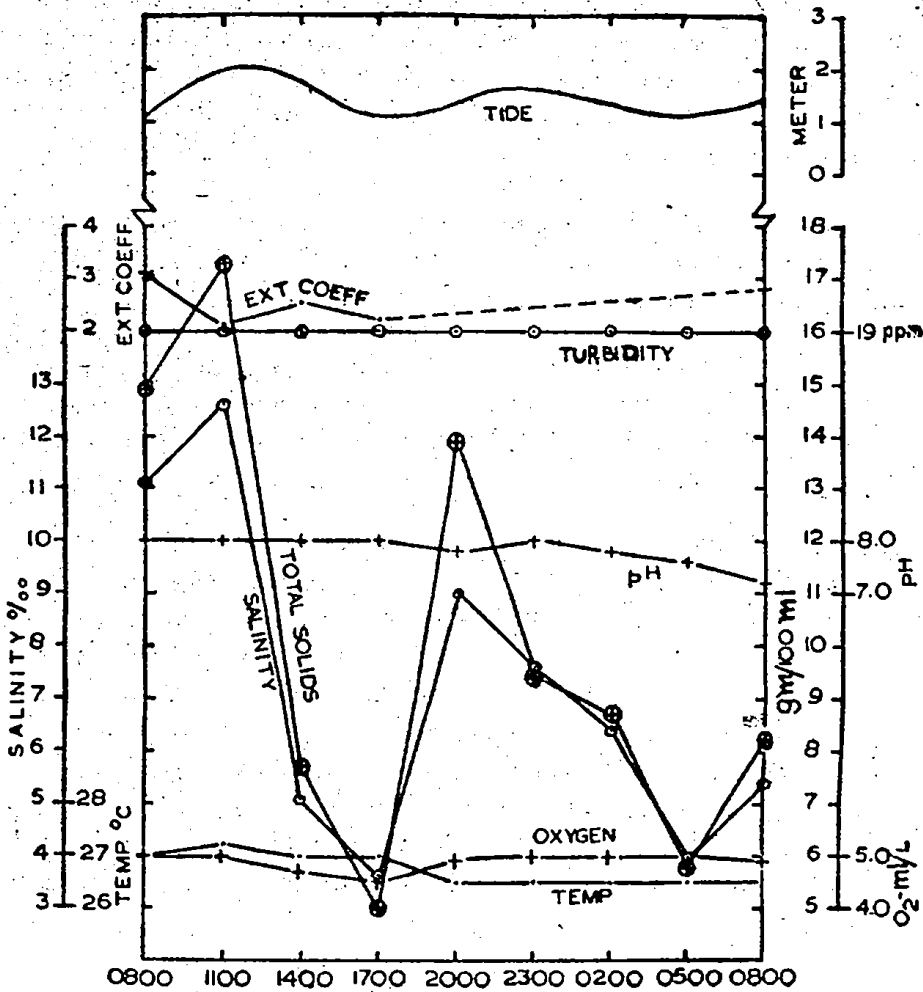


FIG. 7. Diurnal variations in various environmental factors at Marmugao Bay on July 25-26, 1969.

On the contrary in July, the diurnal variations in surface salinity showed a wide range of fluctuations from the highest 12.6‰ during the flood and lowest 3.6‰ during the ebb (Fig. 7). Direct relation of the salinity values with the tidal changes indicated a heavy freshwater discharge by the river Zuari in the Bay during the south-west monsoon.

Dissolved oxygen.—In May, the diurnal variations in dissolved oxygen were in the range of 4 ml/L and 4.3 ml/L. The values were somewhat higher during flood as well as ebb tide periods but lower during the intertidal phases (Fig. 6).

In July, the diurnal range of dissolved oxygen was from 4.5 ml/L to 5.0 ml/L (Fig. 7) which corresponded with higher oxygen values during south-west monsoon season. Diurnal variations of dissolved oxygen showed inverse relation with water temperature which varied with day and night difference in the solar radiation.

Turbidity.—Turbidity during pre-monsoon was 5.4 ppm (Fig. 6) and during south-west monsoon 19 ppm (Fig. 7). No diurnal changes occurred in turbidity values and thus no effect of tide was observed.

Total solids.—The high range of total solids during pre-monsoon from 46 gm/100 ml to 55 gm/100 ml indicated the contribution of total salts from the highly saline waters. The low range of total solids during monsoon from 5 gm/100 ml to 18 gm/100 ml was due to low salinity.

Diurnal variations of the total solids content in water during the pre-monsoon period showed no relation with the surface salinity (Fig. 6), probably because of the stirring up of sediments by the wind action of the waves at the observation point. However, during the south-west monsoon, the diurnal variations in the total solids showed a clear relation with the surface salinity in the area (Fig. 7) probably because of consistently high amount of suspended matter brought down by the river and land run-off as well as due to excessive turbulence. Similar relation of high and low values of the suspended matter with the flood and ebb tides in Cochin Backwater have been reported by Qasim *et al.* (1968) and Qasim and Gopinathan (1969).

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REFERENCES

- George, P. C. ... "The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions," *J. zool. Soc. India*, 1953, 5, 76-107.
- George, M. J. and Kartha, K. N. K. "Surface salinity of Cochin Backwater with reference to tide," *J. mar. biol. Ass. India*, 1963, 5(2), 178-84.
- Gonzalves, E. A. .. "Variation in the seasonal composition of the phytoplankton of Bombay Harbour," *Curr. Sci.*, 1947, 16 (10), 304-05.
- Poole, H. H. and Atkins, W. R. G. "Photo-electric measurements of submarine illumination throughout the year," *J. mar. biol. Ass. U.K.*, 1929, 16, 297-324.
- Qasim, S. Z., Wellershaus, S., Bhattathiri, P. M. A. and Abidi, S. A. H. "Organic production in a tropical estuary," *Proc. Ind. Acad. Sci.*, 1969, 69, 51-94.
- , Bhattathiri, P. M. A. and Abidi, S. A. H. "Solar radiation and its penetration in a tropical estuary," *J. Exp. mar. Biol. Ecol.*, 1968, 2, 87-103.
- and Gopinathan, C. K. "Tidal cycle and the environmental features of Cochin Backwater (a tropical estuary)," *Proc. Ind. Acad. Sci.*, 1969, 69, 336-48.
- Riley, G. A. and Bumpus, D. F. "Phytoplankton-Zooplankton populations on Georges Bank," *J. Mar. Res.*, 1946, 6 (1), 54-71.
- Sankaranarayanan, V. N. and Qasim, S. Z. "Nutrients of the Cochin Backwater in relation to environmental characteristics," *Mar. Biol.*, 1969, 2 (3), 236-47.
- Strickland, J. D. H. and Parsons, T. R. *A Manual of Sea-water Analysis, Bull. Fish. Res. Bd. Canada*, 1965, 125.
- Subrahmanyam, R. and Sarma, A. V. H. "Studies on the phytoplankton of the west coast of India. Part III. Seasonal variation of phytoplankton and environmental factors," *Indian J. Fish.*, 1960, 7, 307-36.