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OBSERVATIONS ON THE HYDROLOGICAL CONDITIONS OF THE SURFACE WATERS OFF WALTAIR (BAY OF BENGAL) DURING 1964–'66

By P. MOJUMDER

Central Marine Fisheries Research Institute, Mandapam Camp

INTRODUCTION

HYDROLOGICAL studies at Waltair have been confined mainly to inshore areas up to 10 fathom line (18 metres), (Ganapati and Sarma 1958, Ganapati and Rao 1958, Rao and Rao 1962). Investigation beyond this region covered only part of the year (Ganapati *et al.* 1956, La Fond 1954, 1955). Variations of the surface salinity and the temperature of continental shelf waters and some stations beyond, were investigated from October 1952 to March 1953 by Ganapati and Murthy (1954). The upwelling and sinking phenomena were studied by La Fond (1954, '55), while Ganapati *et al.* (1956) observed the vertical chemical structure of water and the changes which occurred between October 1955 to May 1956. However, considerable work still remains to be done, especially with respect to the nutrient salts of the offshore region.

The present paper deals with the observations made from April 1964 to December 1966 on surface temperature, salinity, dissolved oxygen, phosphate and silicate content of waters off Waltair up to the depth-line of 55 metres (30 fathom) and a distance of about 20 miles from shore.

MATERIAL AND METHOD

I. *Area of operation :* The present work covers an area of 200 square miles off Waltair bounded by Latitude 17° 40′ N. to 17° 50′ N. and Longitude 83° 20′ E. to 83° 40′ E. The results given are for the statistical squares, each 100 square miles in extent, adopted by the Government of India fishing vessels for reporting their catches. The water samples were collected on board these vessels as an integral part of exploratory fishing programme. There are two statistical squares in the region referred to above :—

(i) One square bounded by Latitude 17° 40′ N. to 17° 50′ N. and Longitude 83° 20′ E. to 83° 30′ E. (which hereafter will be referred to as square No. 18) and

(ii) another square bounded by Latitude 17° 40′ N. to 17° 50′ N. and Longitude 83° 30′ E. to 83° 40′ E. (which will be referred to as square No. 19).

(For convenience of the skippers of the trawlers the statistical squares in the Visakhapatnam region are given serial numbers. Hence the numbers 18 & 19 referred to above.)

Square No. 18 : Adjoining the shore, depth varies between 11 metres and 55 metres. The distance from the mid-point to the shore is about 5 miles.

Square No. 19 : The depth in this square varies between 35 and 55 metres. The distance from the mid-point to the shore is about 15 miles.

II. *Collection of water samples :* The water samples for analysis were collected from April 1964 to June 1965 and from February to December 1966. Samples were collected on board the fishing vessels at different places depending on the fishing programme. Only surface samples could be collected. On each day of sampling, at least, one sample was collected from the area fished. The analyses were usually carried out on the following day. Air and surface water temperatures were noted correct to 0.1°C. on board the vessels. For chemical investigations collections were made in 300 ml. (approximate) capacity polythene bottles with 3-4 drops of chloroform added for preserving samples. For dissolved oxygen 125 ml. glass-stoppered bottles were used. The dissolved oxygen was fixed, on board, by adding Winkler's reagents.

III. *Analytical procedure*

(a) *Salinity* (‰) *:* Salinity was estimated by Mohr's method. Standard sea-water of Chlorinity 19.38‰ obtained from Copenhagen was used for standardisation of silver nitrate solution.

(b) *Dissolved oxygen (ml/L) :* The dissolved oxygen was estimated by Winkler's method.

(c) *Inorganic phosphate (μg at/L) :* Phosphate was estimated by Ceruleomolybdate method of Denige's modified by Robinson and Thompson (1948). Nessler's cylinders were used for comparison. The values were not corrected for salt errors.

(d) *Silicate (μg at/L) :* The silicate content was determined by the colorimetric method of Dienert and Waldenbuleke as modified by Robinson and Thompson (1948). Nessler's cylinders were used for comparison. Potassium chromate solution buffered with borax was used as standard.

The monthly means of observations are given in the Figures 1–6.

Results

Surface temperature

Square 18 : During the period of investigation the surface temperature showed two peaks, one in May and the other in September 1964 and October 1966, the May 1966 value being higher (Fig. 2). The minima are in August and in December, the December value being lower. The annual range in monthly mean temperature is 3.8°C.

The monthly mean surface temperatures vary between 25.7°C. and 29.5°C.

Square 19 : The general trend of seasonal fluctuations of surface temperature is more or less similar to that of square 18. The periods of high temperature values (May and September 1964 and October 1966) as well as the low value (December) coincide for both the squares (Fig. 2). The monthly mean surface temperature in square 19 varies between 25.8°C. and 29.8°C.

Air temperature

The fluctuations in air temperature in both the squares 18 and 19 are closely parallel to those of the surface temperatures. But from August to October 1966, an inverse relationship was found to exist between them (Figs. 1 and 2).

Salinity (‰)

Square 18: The average salinity of surface water is highest in April (34.05‰) and lowest in December (21.81‰) during 1964 and '65. Salinity increases rapidly from December onwards reaching fairly steady values during the period between March and August (Fig. 3). After August, salinity steeply decreases to reach the minimum value in December. Thus salinity fluctuation is unimodel.

Square 19: The trend is the same as that in square 18. Like square 18 this area is found to have one peak in April (34.40‰) and one minimum in December (23.15‰) for salinity. The values between May and August are found to remain more or less steady (Fig. 3).

It may be seen that the minimum for salinity for both the squares 18 and 19 was observed in December 1964 and in October 1966. This is probably related to the enormous discharge of the river systems into the Bay of Bengal and the North to South current bringing the low salinity water.

Dissolved oxygen

Square 18: The monthly mean values range between 2.96 ml/L and 5.59 ml/L. The oxygen content has two peaks, one in May and the other in January during 1964 & 1965, the January value being higher. The value in December 1966 was higher than that for May. The minima occurred in August 1964 and April 1965, the former value was lower (Fig. 4).

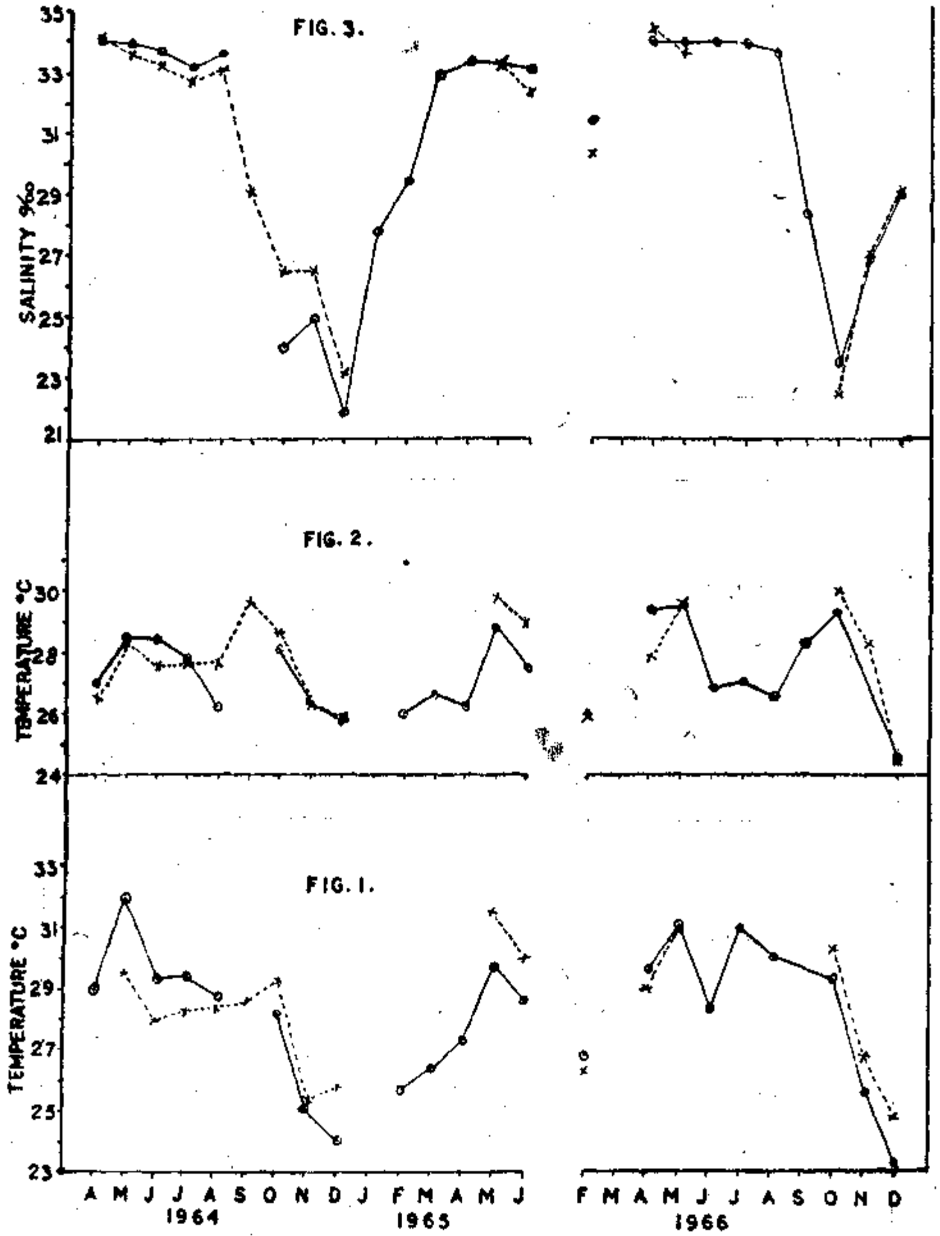
Square 19: The monthly mean values range between 3.0 and 5.3 ml/L. The general trend of fluctuations is similar to that of square 18 (Fig. 4).

In this square two peaks in the oxygen content were observed, one in May and the other in December/January; from June to October the values are low.

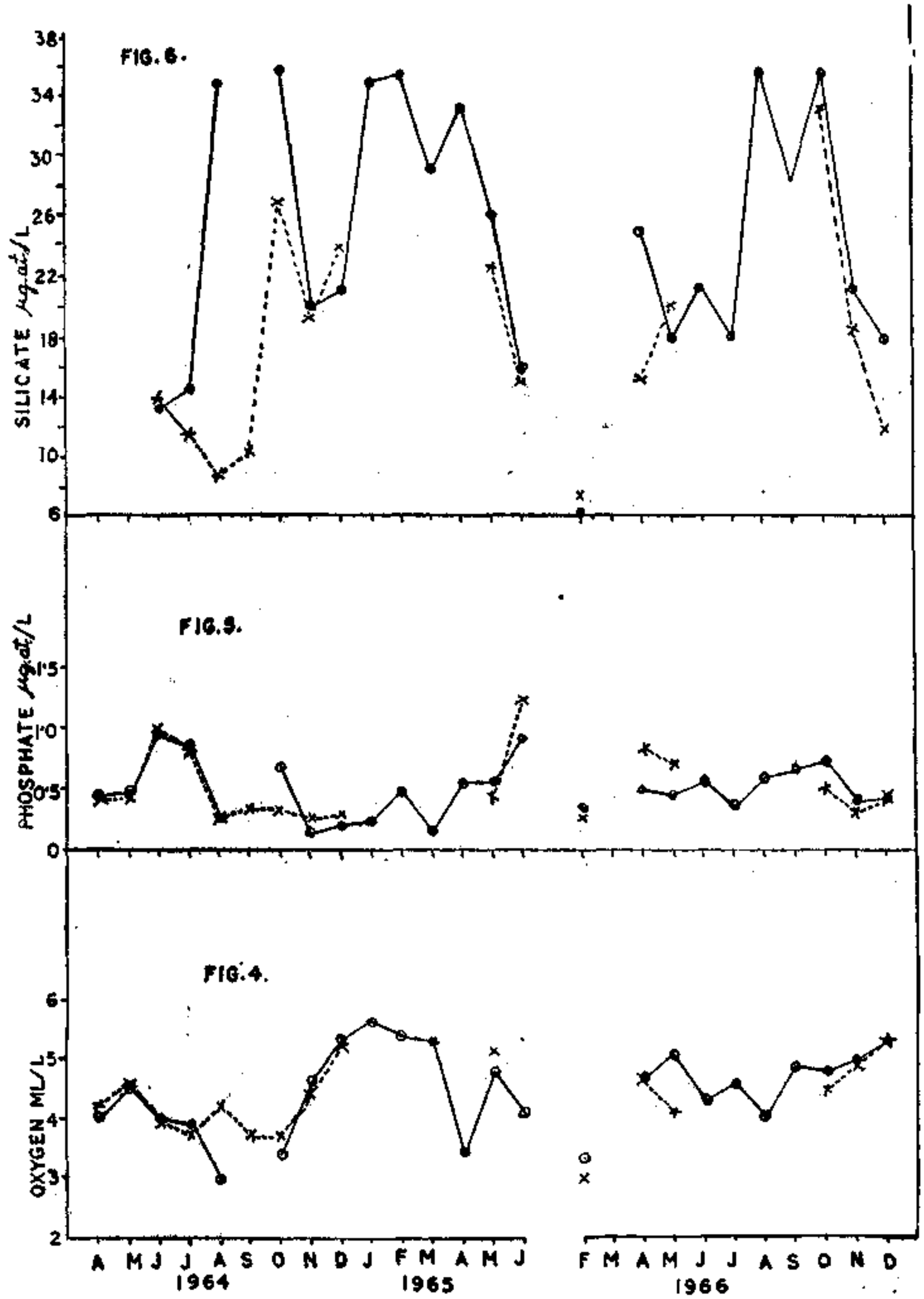
Phosphate

Square 18: The monthly mean phosphate values vary between 0.13 μg. at/L in November and 0.95μg at/L in June. The phosphate content is found to have three peaks, one in June, another in September/October and the third in February 1965. Of the three peaks, the June value in 1964 is the highest. In 1966, higher values obtained are from August to October. The three minima are in August, November and March, the November value being the lowest (Fig. 5).

Square 19: The general trend of fluctuations in phosphate content is, to a great extent similar to that in square 18. As in square 18 there are peak values in June and September/October 1966. The minimum of 0.25μg at/L is observed in November and the maximum of 1.24μg at/L in June. After June however the phosphate content declines steadily to reach a minimum in August, rising again to a secondary peak in October.



FIGS. 1-3, showing seasonal variations for air and water temperatures and salinity of surface waters, off Waltair during the years 1964-'66. FIG. 1—Air temperature; FIG. 2—Surface water temperature; FIG. 3—Salinity. o———o Square No. 18, x — — — — — x Square No. 19.



FIGS. 4-6, showing seasonal variations for dissolved oxygen, phosphate and silicate of surface waters off Waltair during the years 1964-'66. FIG. 4—Dissolved oxygen; FIG. 5—Phosphate; FIG. 6—Silicate. o———o Square No. 18, x— — — — —x Square No. 19.

Silicate

Square 18 : The silicate value gradually rises from June reaching the peak in August '64 (35.00 μg at/L) and declines from October, remaining more or less steady during November-December (20–21.1 μg at/L). From December the value again rises to a maximum in January 1965, from when on to April the silicate content remains more or less steady (Fig. 6).

Square 19 : During the major part of the period under investigation the silicate values are similar to those of square 18. But from June to August the silicate content declines in square 19, whereas it increases in square 18. From August however, silicate value gradually rises to a peak in October, after which the trends of fluctuations in both the squares seem to be more or less identical (Fig. 6).

Discussion

Results of the present study show that in regard to the characteristics of the surface waters of the area investigated, three distinct periods can be recognised in a year.

(1) May to August.

(2) September to December and

(3) January to April.

(1) *May to August* : This is a period of decline in air and surface water temperature, dissolved oxygen, and increase in silicates. Salinity, although high when compared to other periods, nevertheless shows a declining trend within this period. From a peak in June, phosphate content decreases steadily. The decline in dissolved oxygen along with the decline in temperature and increase in silicates is indicative of low level of phytoplankton production. That the phytoplankton crop is, in fact, low during this period has been shown by Ganapati and Sarma (1958). However what is more interesting is the direct relationship between oxygen and temperature, an observation that has been made by other workers also (Jayaraman 1951, Ganapati and Sarma 1958).

The declining trend in salinity values during May to July may be related to the clock-wise circulation of water in the Bay which, perhaps, brings in the waters of southern-rivers (Krishna and Godavari), but not in such large volume as to depress the salinity value markedly. It may be mentioned that the data of Ganapati and Sarma (1958) also show a lowering of salinity during this period, comparable to that observed here. The lowering of air and surface temperature is, perhaps, due to the prevalent south-west winds.

In this connection, the data of June-August period may be specially referred to. In July the surface temperature falls, reaching a minimum in August, the salinity remaining high. The low temperature of this period is perhaps associated with a seasonal flow in sea level, heavy rain and change in current direction. It seems also likely that the fall in temperature is due to sub-surface water coming to the surface (La Fond, 1954). That a minor upwelling during this period exists is observed by the fact that the surface current has an offshore direction.

Further evidence of possible near-shore upwelling is the shallow depth of the thermocline on the western side of the Bay of Bengal, observed by Prasad (1953).

The high value of phosphate, in June may be attributed to the secondary upwelling during the period and may also be associated with active dredging by the Port authorities (Ganapati and Rao, 1958). High values in June were observed also by Subramanyan and Sen Gupta (1965), in the Madras coastal waters.

(2) *September to December :* This is a period of cyclones in the Bay. The period is marked by a steep fall in salinity. Air and surface water temperatures have maxima in September/October and then drop to their minima in December. Phosphate and silicate have high values in September/October and then decline. On the other hand there is a steady increase in dissolved oxygen in September to December. Thus this is the period when the usual inverse relationship is seen between dissolved-oxygen and temperature. The increase in oxygen may be not only due to declining temperature (Rammurthy, 1953), but also to the increased phytoplankton production (Jayaraman 1951, Ganapati and Sarma 1958), facilitated by the increased availability of phosphates and silicates. Decline in salinity is, probably, due to the influx of river-water from the northern rivers (Mahanadi, Brahmaputra, Ganges, Debi), the surface current having roughly a counter-clockwise direction during the period. That there is an influx of river-water is also indicated by the increase in phosphates and silicates in September and October. The lower value in silicate during the months November and December is, perhaps, due to secondary peak in phytoplankton production during these months (Ganapati and Sarma 1958). During the period under consideration there exists an inverse relationship between silicate and salinity also. Similar observations were made in near-shore waters off Waltair by Ganapati and Sarma (1958), Ganapati and Rao (1958), off Madras city by Jayaraman (1951), Rammurthy (1953), Thirupad and Reddy (1959), Subrahmanyan and Sen Gupta (1965), off Mandapam by Jayaraman (1954).

A comparison of the local rainfall data (monthly climatic data for the world) with salinity values (as shown in the Table below) reveals that local rainfall alone is not responsible for the very low salinity observed during the period. Similar observations were made by other workers also along the east coast (Jayaraman 1951), (Subrahmanyan and Sen Gupta, 1965).

TABLE

Months		Visakhapatnam Total rain-fall (mm.)	Salinity (‰)	
			Square 18	Square 19
September 1964	..	331	—	29.04
October '64	..	90	23.95	26.51
November '64	..	140	24.88	26.50
December '64	..	7	21.81	23.15

The relatively high temperature (September-October), low salinity and high sea-level are indicative of the sinking phenomenon (La Fond 1954).

(3) *January to April :* This is the period of comparative calm in the Bay, when fishing schedules are least disturbed by weather. Temperature fluctuates during this period, although the general trend is one of increase. There is a rapid increase in salinity which attains high values by April and silicates are also high.

During one year (1965) when data were available for all the four months, dissolved oxygen, although very high, showed a declining trend. The peak in dissolved oxygen in January may be associated with the general cooling of the atmosphere due to the onset of north-east monsoon (Rammurthy 1953) and the high value during February-March may perhaps be accounted for by the phytoplankton bloom (Ganapati and Rao 1958, Ganapati and Sarma 1958). In April, however, of that year, it was seen that dissolved oxygen had a minimum value; surface temperature was lower than that in March. Similarly phosphate and silicate were higher than in March. Salinity, as stated before, increased. These features are indicative of upwelling (La Fond, 1954), having taken place during that year. But during next year i.e., 1966, these features were observed in June. Hence, it would appear that upwelling, if it takes place, may occur in different months in different years, as observed by La Fond (1955). Necessity for further studies on this phenomenon is indicated.

SUMMARY

Observations on the physico-chemical investigations viz., temperature, salinity, dissolved oxygen, phosphate and silicate content of surface waters up to the 30 fathom (55 metres) line and a distance of 20 miles from the coast off Waltair were made during the period April 1964 to December 1966.

The influence of the prevailing circulation of watermasses on the hydrographical conditions both in coastal and offshore waters off Waltair is outlined.

The temperature and salinity of the surface waters have been found to show a regular seasonal cycle corresponding to south-west and north-west monsoons.

The atmospheric and surface water temperatures show a close relationship.

Dissolved oxygen values are observed to be more or less steady during major part of the year. The relative influence of temperature and photosynthetic activities on dissolved oxygen during certain period of the year, is indicated.

Seasonal fluctuations of surface temperature, salinity, dissolved oxygen and other nutrient salts indicate the occurrence of upwelling (April-June) and sinking (September-October) during certain months of the year.

An inverse relationship between silicate and salinity was found to exist during September to December and a direct relationship between surface temperature and dissolved oxygen was found to exist during May to August.

Results of the present study show that in regard to the characteristics of shelf waters, three distinct periods can be recognised in a year.

(1) May to August (2) September to December and (3) January to April.

A comparison of the local rainfall data with salinity values reveals that local rainfall is not responsible for the very low salinity observed during certain months of the year.

It appears from the present data that upwelling may occur in different months between April and June, in different years.

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