HYDROLOGY OF THE INSHORE WATERS OF KARWAR BAY DURING 1964—1966

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ABSTRACT

Studies on the seasonal distribution of temperature, salinity, oxygen, phosphates, nitrites and silicates in the inshore waters of Karwar Bay at surface, middle and bottom levels were conducted from November 1964 to October 1966. The lowest values of temperature were recorded during the south-west monsoon period with a second minimum during winter months. The highest temperature records were observed in October-November and again during April-May when the salinity values were also higher. The lowest salinity in the surface layers was found in July during the first year and in August in the second. The oscillation of temperature and salinity during the year was a double one. But the oscillation of salinity in the middle and bottom layers during the second year was of a triple nature.

The distribution of dissolved oxygen in the bay showed that the surface waters were richer in oxygen content than the middle and bottom layers. During August-September the lowest oxygen content was found in the inner layers of the bay when the surface waters showed high oxygen content. It is striking to note that out of twenty four monthly averages, only three values recorded supersaturation in the surface waters of the inshore area.

The concentration of the dissolved salts showed their maximum during the south-west monsoon period. Phosphates and nitrities showed higher concentrations with increase in depth. As against these the silicate distribution showed an opposite trend, the surface layer being rich during the rainy season.

INTRODUCTION

The present paper embodies the observations on the distribution and seasonal variation in temperature, salinity, dissolved oxygen and nutrient salts in the surface, middle and bottom waters of the Karwar Bay for two years from November 1964 to October 1966. The bay is influenced by the influx of Kali river. Water samples were collected from the surface, middle (5 m) and bottom (6.5 m) regions for analysis, between 6 A.M. and 7 A.M. The depth of water at high tide off Karwar Head near the buoy is ten metres approximately. The collection point was located opposite the Karwar Head some distance away from the buoy as indicated in Fig. 1. All estimations were made as per standard methods adopted by the earlier workers.

TEMPERATURE

Monthly average values of temperature varied as follows: at surface from 25.65 to 30.13°C; at middle 25.26 to 29.83° C and at bottom 24.67 to 29.45°C during the first year, and at surface from 26.80 to 29.66°C, at middle from 25.37 to 29.46° C and at bottom from 24.97 to 29.42° C during the second year of observation.

The pattern of oscillation seen in the middle and bottom waters is a double one. A close examination of the fluctuation of temperature at different depths (see Fig.2) shows that the pattern of variation was almost the same, the bottom waters being invariably colder than the upper layers. The maximum values were seen invariably during April or May in the summer and again in October. As for the minima no significant variation was noticed in regard to surface temperature. The two minima for the middle and bottom waters differed, the monsoon values during July-August being much lower than those in the winter months.

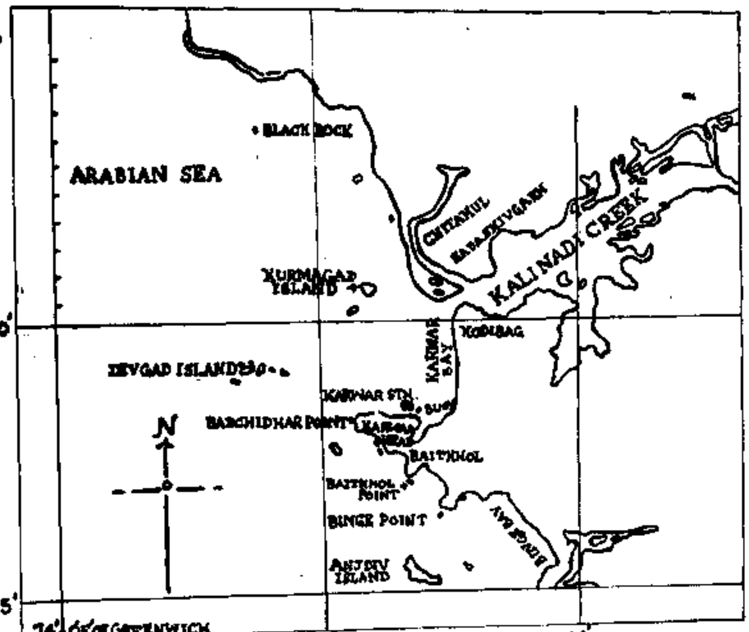

FIG. 1. Map of Karwar (adopted from Survey of India Map).

It will be seen from Fig. 2 that the main peak of monthly average values was in May 1965 for surface waters and in April 1965 for middle and bottom waters; the secondary mode was observed in January 1965, in the first year. In the second year, the major peak was observed in April and a secondary one was noticed in November in all the three layers. It was also noticed that of the main peaks the highest value was at surface rather than in middle and bottom waters; whereas during the secondary peak the surface had lowest value. This may be due to the heating and cooling effect on the surface layer during summer and winter months. Thus a bimodal feature was observed in both the years in all the layers of the inshore waters, as observed also by the earlier workers (Bal *et al.*, 1946; Chidambaram, 1950; Prasad, 1957 and Subrahmanyan, 1959).

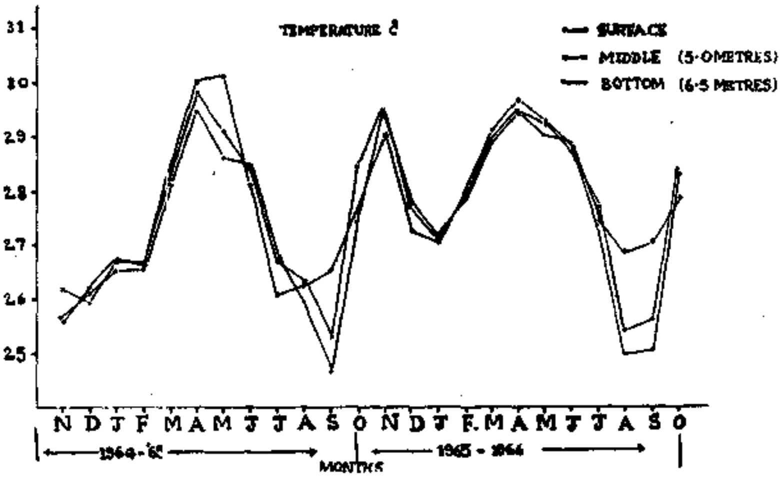

FIG. 2. Seasonal fluctuation in the temperature at different depths of the inshore waters of the Karwar Bay.

SALINITY

The minimum and maximum salinity recorded were: Surface 1.47-36.45‰ and 2.16-35.43‰, middle 17.92-36.56‰ and 5.77-35.43‰ and at bottom 22.52-37.15‰, and 3.98-36.02‰ during the first and second year respectively. It is evident that the minimum values at middle and bottom waters in the second year were lower than in the earlier year, which may be due to the influx of river water.

The variations in the monthly average values of salinity in the surface, middle and bottom layers were between 7.95-36.03‰, 23.90-36.03‰ and 26.73-36.12‰ in the first year and 12.98-34.61‰, 26.73-34.76‰ and 26.08-35.34‰ during the second year respectively (Fig.3).

It will be clear from Fig. 3 that the salinity values attained their minimum during July or August in the south-west monsoon. During the first year the lowest values in all the layers were observed in July; whereas in the second year they were noticed in August at the surface and in July in middle and bottom layers. From October onwards there was a gradual increase in the salinity values up to April or May with a slight fall in one or two months after December and this cycle was repeated in the following year in all the three layers. The salinity changes were more gradual in the middle and bottom layers in contrast to the abrupt fall in surface values noticed in July or August. This clearly indicates that the surface layers are more profoundly influenced by the Kali river discharge.

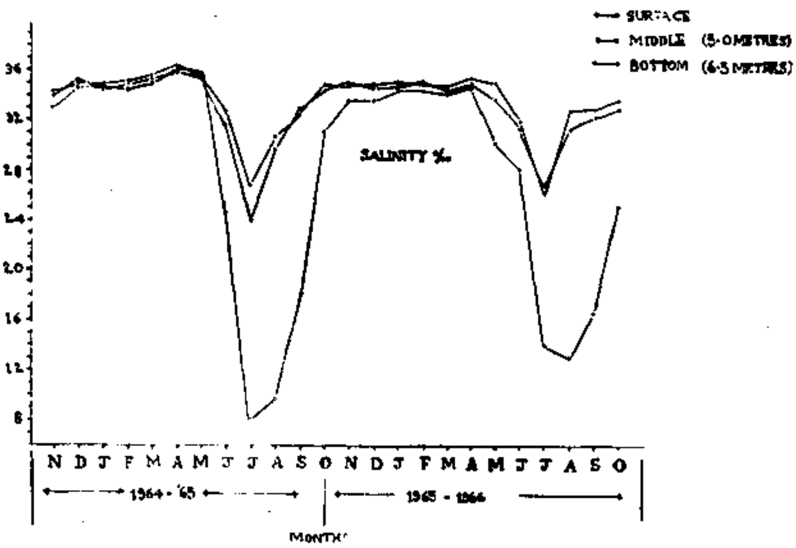

FIG. 3. Seasonal variation of salinity at different depths in the inshore waters of the Karwar Bay.

DISSOLVED OXYGEN

The fluctuations in the concentration of dissolved oxygen at all the three levels is presented in Fig. 4 based on the monthly averages.

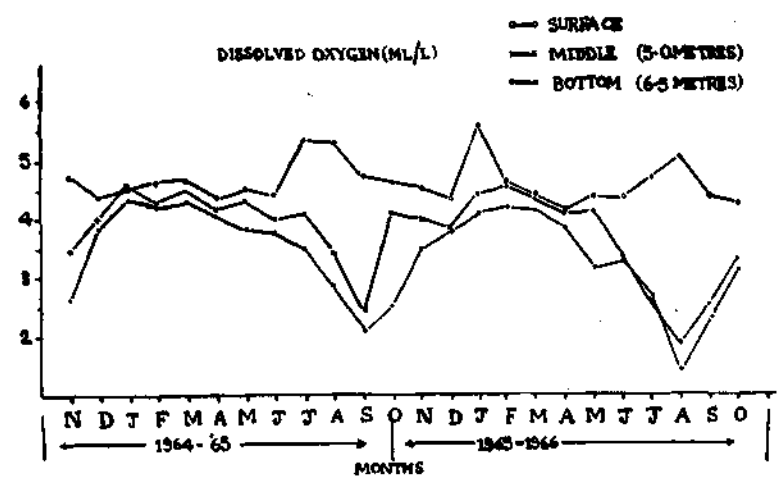

FIG. 4. Seasonal fluctuation in the oxygen concentration at different depths in the inshore waters of the Karwar Bay.

The variation in the monthly averages in surface, middle and bottom waters was from 4.10 to 5.55 ml/l, 1.89 to 4.56 ml/l and 1.43 to 4.36 ml/l indicating thereby that the surface layers always have a higher oxygen content. It is observed that more than 50% of the values lie between 4 and 4.5 ml/l. The highest oxygen concentrations in the surface layers were observed in July 1965, January and August 1966. Contrary to this the concentration of dissolved oxygen in middle and bottom waters showed an increase from November 1964 reaching the maximum in January 1965; thereafter it decreased gradually reaching the minimum in September 1965 in both the layers. The seasonal cycle of oxygen concentration repeated in the following year with slight deviation in the period of maxima and minima, these occurring in February 1966 and August 1966 respectively. Therefore, dissolved oxygen in the surface water exhibits a double maxima, once during the monsoon period and again in winter. As against this, a unimodal character with a single maximum either in January or February is exhibited in the middle and bottom layers of the bay.

Fig. 5 shows the dissolved oxygen and solubility of oxygen in ml/l, together with the percentage saturation, in surface, middle and bottom regions

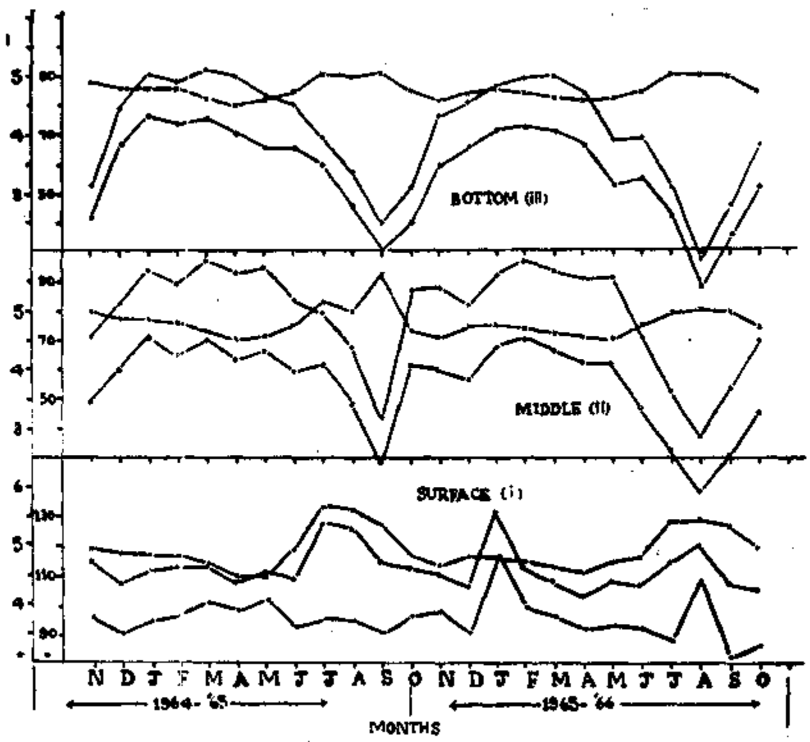

FIG. 5. Seasonal variation in the concentration of dissolved oxygen (ml/l) •—•, solubility of oxygen (ml/l) x—x and percentage saturation•—•at different depths in the inshore waters.

of inshore area. The monthly average values and dissolved oxygen, solubility and percentage saturation are plotted for each month.

The oxygen values at the surface layers hardly show two or three values at the supersaturation level, a few values near the saturation point (100%) and most of them distributed between 90 and 100% saturation points (see Fig. 5 i). The solubility and dissolved oxygen curves followed more or less similar patterns in their behaviour except for January 1966, when dissolved oxygen value exceeded the solubility value.

As regards the oxygen values in the middle and bottom regions, the saturation values never reached the 100% level. The dissolved oxygen content in both middle and bottom waters decreased from January 1965 until oxygen diminution occurred (2 or less than 2 m/l) in September 1965, and increased again gradually from October 1965 onwards to March 1966. But it is of interest to note that solubility values in this region showed a reverse trend from April or May 1965 to February or March 1966, contrary to the surface waters.

Nutrient Cycle

Phosphates— The values in the middle and bottom layers showed higher concentrations than the surface; but on a few occasions the middle values were lower than those at the surface. The bottom values always exceeded the middle and surface layers indicating the concentration of this salt at the bottom. The period June to November or December was marked by the presence of dissolved inorganic phosphates in higher concentration as against the period December or January to May when the values were low. The minimum and maximum range of monthly average values observed during this investigation varied from 0.2900 to 1.1591, 0.2712 to 1.0677 and 0.3828 to 1.5527 μg at/l in the surface, middle and bottom layers respectively.

It will be seen from Fig. 6 that there is a marked oscillation in the phosphate concentration at all levels of the inshore waters. The main mode was seen in October in the first year and in September during the second year. There was no total depletion of this salt at any time of the year.

Nitrites—The average values at surface, middle and bottom layers varied from 0.0344 to 2.0948 , 0.1269 to 2.7257 and 0.1913 to 3.5430 μg at/l respectively. It was also noticed that nitrite concentration always increased with the depth of the sample, the surface values being always the lowest. On certain occasions depletion of nitrites occurred.

The nitrite values showed two maxima during the first year, in January and September, at all the three levels and during the intervening period from April to August, higher values were obtained. Contrary to the nitrite cycle in the first year, two maxima were noticed in the second year, one in December-January and another in July-August and low values were recorded from February to April. The nitrite values were invariably higher in the bottom water, and the surface waters were generally poor just as for the phosphates. The characteristic rise and fall of nitrite values, similar to that observed by Subrahmanyan (1959) in the case of nitrites, can be easily seen from Fig. 6 from month to month. The abundance of nitrites in the pre- and post-monsoon months raises a doubt about the extent to which the river water is responsible for the enrichment of the waters. The presence of this salt in higher concentration in the bottom waters suggests that the nitrites are generally stored at the bottom in considerable quantities.

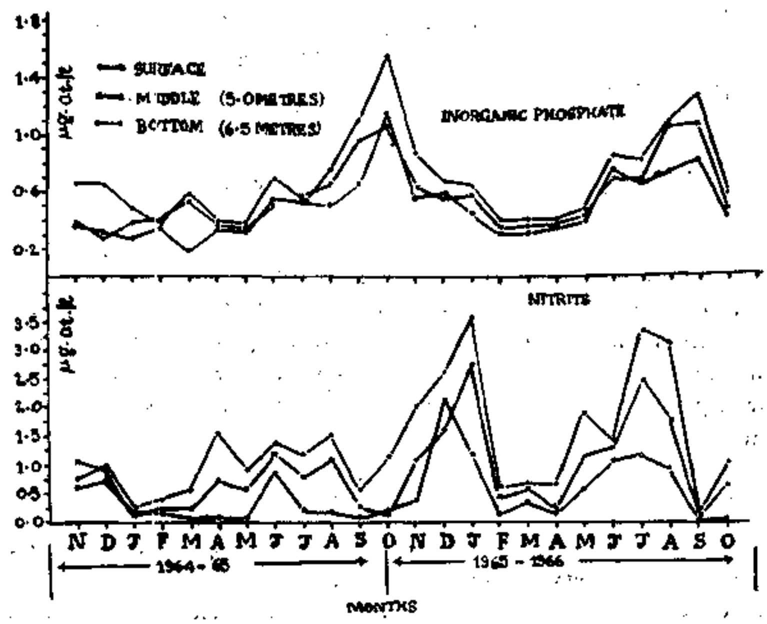

FIG. 6. Seasonal fluctuation in the phosphate and nitrite concentration at different depths of the inshore waters of Karwar Bay.

Silicates— The variation in the monthly average values of silicates observed in surface, middle and bottom waters was from 4.42 to 108.53, 4.84 to 44.02 and 5.50 to 50.31 µg at/l respectively. The lowest monthly average value was recorded from November to May and highest from July-September. The peaks for surface values during both the years were found to be in August. The peak values for middle and bottom waters in the first year were in August and July, whereas in the second year the peak occurred at both depths in July (Fig. 7).

The influence of the south-west monsoon is evident in the presence of high concentration of this salt at all levels. The range of monthly average values observed during the monsoon period in surface, middle and bottom waters in the first year was 30.29 to 108.53, 20.28 to 33.63 and 23.20 to 30.31 µg at/l and during

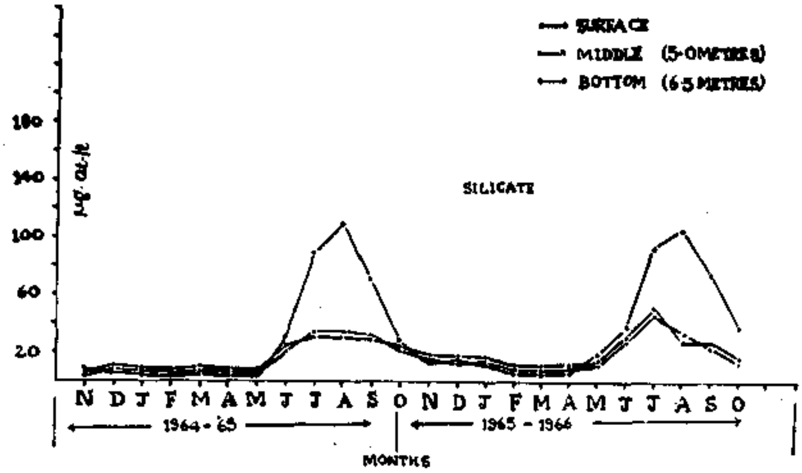

FIG. 7. Seasonal cycle of the silicate content at different depths of the inshore waters of Karwar Bay.

the second year for the same period 36.68 to 105.39, 23.68 to 44.03 and 23.86 to 50.32 μg at/l respectively. Contrary to the concentration of phosphates and nitrites in the bottom waters, the silicates were invariably seen in higher concentrations in the surface waters, the values for bottom waters being always low. The Kali river discharging into the Karwar Bay may be primarily responsible in enriching the surface layers with silicates in addition to the normal sources.

DISCUSSION

The present study shows that even in a shallow water area distinct characteristic differences exist between surface, middle and bottom waters in respect of temperature, salinity, dissolved oxygen and nutrient salts. The monthly average values at surface levels were subjected to wider fluctuations than at the bottom levels in regard to the above hydrological factors.

The oscillation of surface temperature at Karwar was a double one as observed by Subrahmanyan (1959) and Sewell (1929). A similar trend was also noticed in middle and bottom waters, during the year. The temperature gradually increased up to May 1965. Thereafter, the fall in temperature to the lowest levels in July 1965 was seen in the surface layers. The lowest values ot temperature for middle and bottom waters were observed in September 1965. The temperature values during winter months ot the first year were lower than the corresponding period of the second year.

The behaviour of salinity in the surface water coincided with the ups and downs of the temperature conditions at the surface layers. The lowest salinity was recorded in the surface layer in July. The decline in the temperature values during winter months from November apparently did not influence the salinity as it went on increasing from November to April 1966, decreasing again with the commencement of the rainy season.

The oscillation of salinity in the three layers during the first year was a double one, and in the second year a double one at the surface and triple ones at the middle and bottom (Fig. 3). Subrahmanyan (*op. cit.*) observed triple oscillation in a year and stated that only two are clearly marked. It is to be seen in future, whether the triple oscillation phase in the layers mentioned above continues or not, or it is so significant when the salinity values reach below 25‰ during certain months in the middle and bottom layers. The oscillation phase in the inshore waters was always positive, i.e. the surface water of low salinity resulted from the influx of river or rain water gets slowly mixed up with the water of higher salinity of the bottom which is brought to the upper layers by wave and wind action. The positive phase throughout the year may be due to the proximity to the shore as indicated by Subrahmanyan (*op. cit.*). Sewell (1929) observed transition of a positive phase to a negative one. In the negative phase higher salinity resulted at the surface water due to evaporation by heat during summer and mixing with the bottom layers due to wind and wave action. Subrahmanyan (*op. cit.*) did not notice in the area he investigated such changes as observed by Sewell.

The distribution of dissolved oxygen in the surface waters for most of the period showed the average values between 4.0 and 4.7 ml/l. According to Subrahmanyan (1959 pp. 221-26) dissolved oxygen usually fluctuates between 3.5 and 5.0 ml/l. He observed more instances of supersaturation in 1950 when the salinity and temperature were favourable for solubility of oxygen. It is interesting to note that out of twenty four monthly average values only three showed supersaturation for oxygen, but none in the middle and bottom waters, although all the samples were collected within the euphotic zone. The middle and bottom samples taken at a depth not exceeding 7 meters and positively within the euphotic zone showed traces of oxygen content sometimes reaching a bare minimum in some months. This appears to be in conformity with the observations made by Subrahmanyan (*loc. cit.*).

Orr (1933) and Ellis *et al.* (1946) state that the respiratory activity of the animals dwelling in the area and the decay of dead organic substances are the chief causes for undersaturation and depletion of dissolved oxygen in tropical waters. It is stated by the earlier workers that the abundance of zooplankton is marked by the total absence of diatoms due to the grazing effect of the former forms. It is observed by Subrahmanyan (1959) that during the appearance of intense bloom of phytoplankton during June-July, the zooplankters including their reproductive stages are also on the increase requiring the greater demand for oxygen. Therefore, it is quite probable that the respiratory activity of the fauna, accumulation of organic substances and their putrefaction may collectively be responsible for the lower values of the dissolved oxygen in the Bay. Thompson and Gilson

(1937), Riley (1941) and Smith *et al.* (1950) are of the opinion that the supersaturation is not a common feature in tropical waters. According to them the zone of maximum photosynthesis is below the surface waters.

The monsoons play an important role in enriching the waters with nutrient salts due to the upwelling caused. The period June to November or December showed high content of dissolved inorganic phosphate. The bottom layers registered higher phosphate content than the surface.

The nitrite distribution like phosphates showed higher concentration in the bottom and middle waters than the surface. High concentrations were seen in April, June and August. On certain occasions complete depletion of this salt was noticed. There was wide variation in the distribution of nitrites from surface to bottom, the bottom layers always showing higher concentrations. The bottom sediments may be storing considerable quantities of nitrogenous compounds and the nitrites may be liberated to the overlying layers due to agitation during the monsoon period or brought to the surface layers due to upwelling as suggested by Moore (1931) and Gilson (1937).

The maximum silicate content observed at Karwar Bay in surface waters was 185.20 μg at/l in July 1966. During winter and summer months the values for surface and bottom fluctuated within narrow limits.

Prasad (1958) has stated that the monsoons play an important role in the water movements. In consequence of changes that are set up in the surface circulation by the south-west monsoon currents, and of the increase in the strength of the Somali Current, water of high fertility is swept around the northern part of the Arabian Sea and down the west coast of India. This statement holds good for the Karwar region, as seen from the salient hydrological conditions noticed in the bay and adjacent waters.

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