The hydrography of the Cochin Estuary has been investigated by Balakrishnan, 1957; Ramanathan and Jayaraman, 1963; George and Kartha, 1963; Cherian, 1967; Qasim et al., 1968; Qasim and Gopinath, 1969; Josanto, 1971a; Nair and Tranter, 1971; Haridas et al., 1973; Sreedharan and Salih, 1974; Joseph, 1974 and Unnithan et al., 1975. Most of these works have been based on a single sampling or restricted to a single season. A detailed investigation of the hydrography of the Cochin Estuary for all the seasons of the year was carried out to establish the proper correlation of the hydrography with the bottom fauna. In the present study, hydrographical parameters such as surface water and bottom sediment temperature, surface water and bottom water salinity and dissolved oxygen and rain-fall were studied during the period from March 1974 to March 1976.

Results and Discussion

Hydrographical conditions of the estuarine system depend on the interaction of the sea and the fresh water, the sea water dominating the system in summer and fresh water during monsoon months. A seasonal pattern is thus evident in the variation of the parameters. Based on the hydrographical parameters of the Cochin Estuary studied,
three definite seasons can be recognised, a pre-monsoon period (February to May) of high salinity, a monsoon period (June to September) of very low salinity, and a post-monsoon period (October to January) of progressively increasing and fluctuating salinity. Similar observations were also made by George and Kartha (1963) and Wair (1965).

4.1. Temperature

The details of surface water and sediment temperature are given in Fig.2.

Pre-monsoon (February to May):

In both the years there was a progressive increase in temperature as the summer advanced, from February to April. In January, the surface water temperature at station I near the mouth of the estuary was 27.2°C and the sediment temperature was 27.1°C. In February and March, the surface temperature increased to 29.8 and 31.0°C respectively. The sediment temperature also correspondingly increased to 29.4 and 30.9°C. The variation in sediment temperature in station I, at the mouth of the estuary was 29.5 to 31.3°C. At station III, in the middle region of the estuary, it ranged from 30.9 to 31.9°C and in station V, at the fresh water side of the estuary the range was from 30.3 to 32.1°C. For the region as a whole, the maximum temperature of surface water (32.5°C) and sediment
(32.2°C) was recorded in April at station IV.

Monsoon (June to September)

The period of South West Monsoon coincides with the period of minimum surface and sediment temperature. From June onwards, with the onset of South West Monsoon, the temperature began to fall and the lowest temperature for surface and sediment occurred in the month of August in the first year, and June in the second year. In May, the temperature at station I was 31.5°C at the surface and 31°C at bottom sediment. The lowest temperature of 25.1°C at the surface water and 25°C at the bottom sediment was recorded during the month of August at station I. The fall in temperature in this station was 6.4°C in the surface layers and upto 6°C in the bottom sediment. In the other stations, it ranged from 5.7 to 6.2°C at bottom sediment. Bottom sediment temperature varied from 25 to 26.4°C at station I near the mouth of the estuary, from 26.4 to 29.5°C at station III in the middle region and 26.1 to 29.5°C at station V in the fresh water end of the estuarine system.

Post-monsoon (October to January)

A steady increase in surface water and sediment temperature was observed during the post-monsoon period at all the stations. The variation in bottom sediment
The temperature in station I was 26.9 to 30.3°C. At Station III, in the middle region, it ranged from 27.9 to 30.6°C, and in station V, the range was from 27.3 to 29.5°C.

Temperature of the estuary is seldom constant and the variations are, to a large extent, due to changes in season, depth and physiography. The distribution of temperature in the Cochin Estuary is mainly affected by South West Monsoon. For the estuarine system as a whole, the pattern of variation of temperature is bimodal. A similar bimodal type of oscillation of temperature was noticed by other workers in the Cochin Estuary (Haridas et al., 1973). For all the stations put together, the lowest temperatures of surface and bottom sediment recorded were 25.1 and 25°C respectively at station I at the mouth of the estuary during August and the highest 32.5 and 32.2°C respectively at station IV, in the upper reaches of the estuarine system during April. The temperature usually decreased with depth. It was found during the present study, that in stations having shallow water, the temperature did not exhibit much difference between the surface water and bottom sediment.

During March-April, the atmospheric temperature is high and there is practically no rainfall. This results in high surface water and sediment temperature during this period. From June onwards, with the onset of the monsoon, changes in the water temperature become apparent. The
months of June, July, and August can be considered as the active period of South West Monsoon in the area under investigation. These are accompanied by a gradual fall at the surface water temperature and bottom sediment temperature. As is evident from the data, from the beginning of the monsoon, temperature shows a decrease. The decline in surface water and bottom sediment temperature during the monsoon were highly significant. Sankaranarsayanan and Oasim (1969) stated that the influx of fresh water into the estuarine system is not the sole factor in bringing down the bottom water temperature in the estuary, but the intrusion of a tongue of cold water from the sea may also be a significant factor. It has also been reported that cold water from the upwelled area entering on the shelf may contribute to the decrease in temperature at the mouth of the estuarine system (Ramanritham and Jayaraman, 1963).

4.2. Salinity

Salinity distribution in the estuary is a result of the combined action of water movement induced by fresh water discharge, tidal variation and mixing process. Depending upon the degree of mixing between the fresh water and salt water, the estuary may vary from well mixed type to a stratified type.

The distribution of surface and bottom salinity values are given in Figs. 3 and 4.
Fig. 3. Rainfall (mm) and salinity (%) values of surface and bottom waters at station I.
Fig. 4. Mean salinity (‰) values of the surface and bottom waters at stations II to V.
Pre-monsoon (February to May)

The pre-monsoon period exhibited relatively stable salinity in the estuary. The influence of the sea water was very much pronounced as the intrusion of saline water was traceable up to the head of the estuary (Haridas et al., 1973). At the mouth of the estuary (station I), the bottom salinity varied from 32.0 to 33.13%. In the middle region (station III), the bottom salinity varied from 26.22 to 29.96% and from 24.88 to 28.89% at the upper reaches (station V). The pre-monsoon period is dry with minimum rainfall, and the maximum salinity was observed during this period at all the stations. For the region as a whole, the maximum bottom salinity of 33.13% was recorded during March at station I, located closer to the barmouth.

Monsoon (June to September)

Drastic changes in salinity structure were observed with the onset of the South West Monsoon. There is a considerable lowering of salinity both in the surface and bottom waters at all the stations during the commencement of the South West Monsoon. Salinity began to fall with the onset of the South West Monsoon and for the region as a whole, the lowest salinity values both for the surface and bottom waters were recorded during the month.
of August in the first year and June in the second year. During the years of observation, very low saline conditions at bottom water (0.13 to 2.81°/o) prevailed at all the stations during June to August, when the South West Monsoon reached its peak.

Post-monsoon (October to January)

A steady and gradual increase in salinity at all stations was observed during the post-monsoon period. The salinity steadily re-established from the mouth towards the head of the estuarine system. By November, the bottom salinity increased from 16.38°/o in October to 31.55°/o at the mouth of the estuary. A corresponding increase could also be observed at all the other stations, both in the surface and along the bottom. The variation in salinity in station I at the mouth of the estuary was from 14.89 to 32.31°/o. At station III, in the middle region it ranged from 1.26 to 31.02°/o and in station V, at the fresh water side of the estuary, the range was from 0.42 to 28.62°/o.

Among all the hydrographical parameters studied, salinity was found to be the most fluctuating factor. The salinity, in general, decreases from the mouth of the estuary towards the head. The extent of intrusion of saline water depends on the strength of the tidal influx and fresh
water discharge which differ with seasons. A higher bottom salinity was always observed, which showed the penetration of high saline sea water along the bottom and indicating a two-layered flow. This extension of high saline sea water into the estuary has also been noted by Ramamirtham and Jayaraman (1963). The pre-monsoon period exhibited relatively stable saline environment and the influence of the sea water was very much pronounced as the intrusion of saline water can be traced upto the head of the estuary. There was a progressive increase in salinity at all the stations with the advancement of summer. Kendall's rank correlation coefficient matrix (Sokal and Rohlf, 1969) shows that the salinity of the estuary was found to be significantly positively correlated with the temperature (Tables 1 to 10). The salinity at all the stations exhibited considerable increase in March and April and this period may be interpreted as the season of the highest salinity, when the influence of sea water and rate of evaporation was at its maximum throughout the estuary.

The South West Monsoon is characterized by heavy rainfall and there is a decrease in salinity values both in the surface and bottom waters at all the stations during this season. This is because of the strong fresh water flow pushing back the high saline sea water and the penetration of sea water was restricted. During the peak of the South West Monsoon (June to August), the estuary
becomes completely filled with fresh water. The quantity of fresh water discharged in the backwater through the rivers and land run off is greater, so that the tidal influence becomes almost negligible.

A steady increase in surface water and bottom water salinity was observed at all the stations during the post-monsoon period. With the termination of the monsoon season (in October) and the decrease in fresh water flow, a high saline condition begins to develop all over the estuarine system. During the post-monsoon period, the salinity distribution is unstable, which is probably due to the continued vertical mixing process.

The salinity variations clearly indicate a bimodal fluctuation in the region of study. The fluctuations in the salinity of the surface layers are well correlated with the rainfall of the period of investigation (Fig.3).

4.3. Dissolved oxygen

The values for dissolved oxygen in the surface and bottom waters are given in Fig.5.

Pre-monsoon (February to May)

In general, the higher oxygen values were observed in the late pre-monsoon period and the lower values were
Fig. 5. Mean dissolved oxygen (ml/L) values of the surface and bottom waters at stations I to V.
FIG. 5

DISS. OXYGEN (Surface)

DISS. OXYGEN (Bottom)

Station No. 5

Station No. 4

Station No. 3

Station No. 2

Station No. 1

DISSOLVED OXYGEN

mL/l

Station

1974 1975 1976
found during the early pre-monsoon periods, when the salinity and temperature are high. Dissolved oxygen values of bottom water varied from 4.2 to 4.6 ml/L at the mouth of the estuary, from 4.0 to 5.4 ml/L at the middle region and 4.1 to 4.8 ml/L at the upper reaches.

Monsoon (June to September)

The influence of South West Monsoon could be felt in the distribution of oxygen values also. During the South West Monsoon, high dissolved oxygen values were obtained for the surface water throughout the estuarine system. At the bottom water, for the region as a whole, the maximum value of 5.4 ml/L was recorded at station IV in the month of July. However, at the mouth of the estuary at station I, dissolved oxygen content of bottom water showed a decrease during South West Monsoon and the minimum value of 2.42 ml/L was recorded in June 1974. Dissolved oxygen values at bottom water varied from 2.42 to 4.7 ml/L at station I near the mouth of the estuary, 4.4 to 5.23 ml/L at station III in the middle region, and 4.4 to 5.12 ml/L in station V at the upper reaches.

Post-monsoon (October to January)

Just after the monsoon period, a slight decrease in the dissolved oxygen values was observed throughout the estuarine system. The decrease in dissolved oxygen at
bottom water in station I at the mouth of the estuary was from 5.21 to 3.76 ml/L. At station III, in the middle region, it ranged from 5.67 to 4.98 ml/L and in station V, at the fresh water side the range was from 5.25 to 4.21 ml/L.

Like salinity and temperature, dissolved oxygen values also show seasonal variations. Dissolved oxygen, both in the surface layers and bottom waters, showed a distinct pattern of seasonal fluctuations in the entire area of study. The higher values of dissolved oxygen were found at surface and bottom waters during the South West Monsoon periods in all the stations except station I. The precipitation, the increase in fresh water influx, and decrease in temperature were favourable for an increase in the dissolved oxygen values during this period. Qasim et al., (1969) stated that the higher oxygen concentration during this period could be due to the higher primary production occurring in the surface layers during the monsoon period. Nutrient concentrations are also higher during the South West Monsoon in the Cochin Estuary (Sankaranaray and Qasim, 1969). The bottom water at station I showed a decline in dissolved oxygen values between June and August. This could be due to the decomposition of organic matter and the influx of cold sea water from the upwelled areas. The dissolved oxygen content at the mouth of the estuary
is relatively lower. A similar situation has also been reported by Sankaranarayanan and Jayaraman (1972) at the Mandovi and Zuari estuaries at Goa. After the peak of the South-West Monsoon, there was a decrease in dissolved oxygen values in September and December. Then onwards, a stable condition is observed which continued throughout the post-monsoon period.