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HYDROGRAPHY OF THE CORINGA RIVER OF THE GAUTAMI-GODAVARI ESTUARINE SYSTEM

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ABSTRACT

The Coringa River is an important part of the Godavari estuarine system connecting the Gautami-Godavari and the Kakinada Bay. The river is flanked by extensive mangrove swamps which are traversed by a number of tidal creeks. The variations in the physical and chemical parameters such as transparency, temperature, salinity, dissolved oxygen, nitrite, inorganic phosphate and silicate were found to be primarily influenced by the tidal currents from the Gautami-Godavari and Kakinada Bay ends of the river. In addition, the drainage from the irrigation canals emptying into the middle portion of the river was also found to affect the hydrological conditions.

The Coringa River is characterised by low transparency of the water through a greater part of the year; prolonged period of freshwater inundation; salt-water incursion from both the ends beginning from November; steep horizontal and vertical gradients in salinity and temperature; high nutrient concentration during the summer season; and inflow and outflow of water during the flood and ebb phases of the tides respectively.

The possible role of mangrove swamps in the regeneration and replenishment of the nutrients is commented on.

INTRODUCTION

STUDIES on the hydrography and biology of the estuarine systems in India have not received as much attention as similar studies of the seas around the country.

Valuable contributions on the hydrography of some of the major estuaries on the east and west coast of India have been made by Sewell and Annandale (1922), Panikkar and Aiyar (1937), Dutta, Malhotra and Bose (1954), Seshaiya (1959), George (1956), Tampi (1959), Jacob and Rangarajan (1962), Ganapati and Rama Sarma (1965), Rama Sarma and Ganapati (1968), Ramamirtham and Jayaraman (1963), Ramanadham, Reddy and Murty (1964), Qasim *et al.* (1968) and Sankaranarayanan and Qasim (1969).

The Coringa and Gaderu rivers which are about 21 km and 11 km long respectively are the most prominent channels through which freshwater is drained into the Kakinada Bay from the Gautami-Godavari during the south-west monsoon period (Fig. 1). Dense mangrove vegetation is present on the banks of both the rivers and in the extensive swamps between the two rivers. The swampy area is also traversed by a net work of creeks and canals connecting the two rivers. The hydrographical conditions are affected considerably by the Gautami-Godavari to the south and the Kakinada Bay to the north, both of which in their turn are subject to tidal influence. In addition, the drainage from irrigational canal systems is directed into the Coringa principally at stations CII and CIV.

The Coringa is a shallow river and depths greater than 6 m were not encountered in its course. Usually the river is deeper in the middle than at the sides.

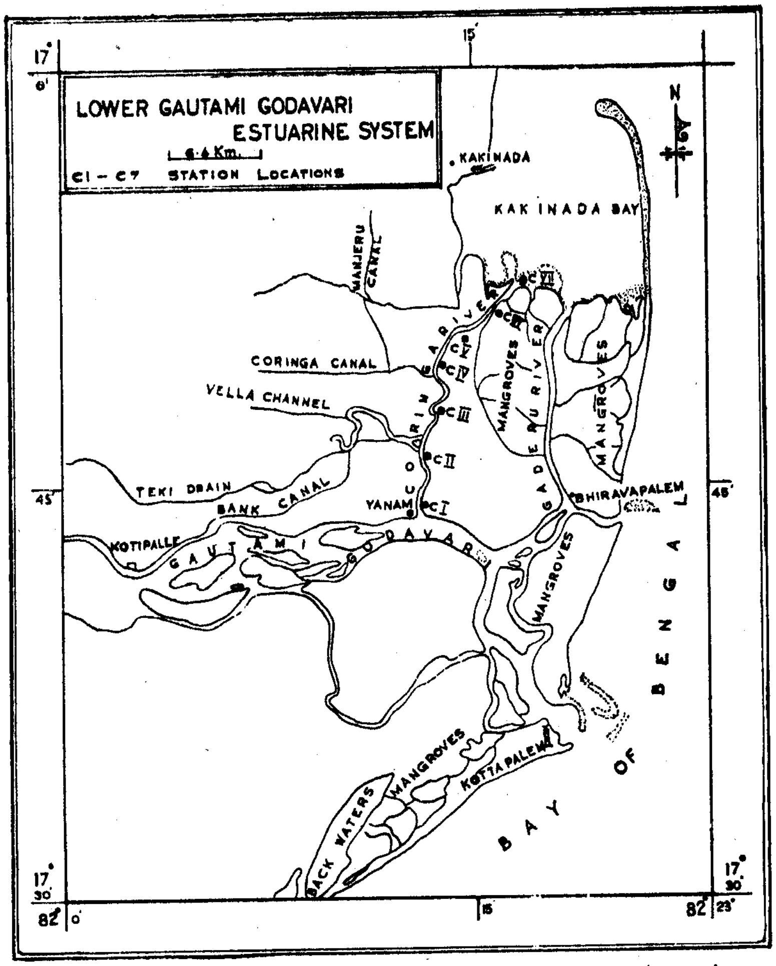

FIG. 1. Map showing the station positions (C I to C VII) in the Coringa River.

However, at places where the river bends, the outer bank is steep presumably due to erosion by the swift flow of water, while the inner bank is shallow owing to deposition of sediments.

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Material and Methods

With a view to study the prevailing hydrographical conditions in the river, seven stations were located for sampling as detailed below :

Station No.	*Location*	*Approximate width of the river* (m)
CI	Yanam	60
CII	Georgepet	35
CIII	Tallarevu	50
CIV	Old Coringa Village	60
CV	Coringa bridge	75
CVI	Nali	100
CVII	Coringa mouth	146

Data on temperature, salinity, dissolved oxygen, nitrite, phosphate and silicate concentrations at different stations were collected in 11 surveys which cover the period November to June 1962-63. Water transparency was measured. From July to September sampling was not made as the river remained flooded with silt-laden freshwater at all levels. All the stations were sampled in a series continuously during each of the surveys. The depth of the water column was determined with the help of a subsig echosounder and also with a sounding lead.

The methods of estimation of inorganic phosphate, silicate and nitrite were according to the procedures described by Robinson and Thompson (1948a, 1948b, 1948c), while standard methods were used for the collection and processing of other data.

Hydrological Conditions

Transparency :

During the south-west monsoon season due to floodwaters in the river Gautami-Godavari, as well as silt-laden inflows from the irrigational canals, the Coringa River turns highly turbid. From November onwards, in spite of a considerable decrease in the inflows, very low Secchi disc readings were recorded. By January a slight increase in the transparency up to about 3/4 of a meter was noticed (K=2.267). During February the transparency gradually increased at stations CI and CIII while at stations CVI and CVII the value was about 0.5 m (K=3.399). During the summer months (March to June) there being no further inflow of silt-laden waters into the river the transparency was on the increase and comparatively high Secchi disc readings were obtained at station CI. At other stations in the river the Secchi disc values ranged from 0.25 to 0.75 m (K=6.8 to 2.267).

At stations CVI and CVII which are more open to the action of winds the waters turned turbid rather quickly when the prevailing winds were high.

Water movements :

The movements of water are primarily due to tides and freshwater inflows from the irrigational canals opening into the river. The tides are semidiurnal as in the Gautami-Godavari estuary to the south, and in the Kakinada Bay to the north.

The water movements are effected from both the ends of the river simultaneously due to the tides. During the period of study it was noticed that the effect of flood tide from the Gautami-end of the Coringa River was felt up to station CI from the point in the Gautami-Godavari where the Coringa River originates. The effect of the flood tide from the Kakinada Bay end was felt over a longer distance, i.e. up to station CII. During low tide the waters from stations CI and CII flow towards Gautami-Godavari, while at stations CIII to CVII the flow was towards the Kakinada Bay. It was noticed that the incidence of high tide occurs at station CVII some time earlier than at station CI. During the post-flood period there is a heavy freshwater inflow. The duration of ebb tide, during this period, is longer than that of the flood tide.

North-east monsoon season (December-February) :

During this period two surveys, one in January and the second in February were conducted. The ranges given below apply for the entire river.

Temperature : The surface temperatures ranged from 25.0°C to 29.5°C during this season (Figs. 2 and 3). The surface values were higher than the bottom values. The surface-bottom differences ranged from 0 to 1.8°C. These differences were minimum in the intermediate portion of the river.

Dissolved oxygen : The oxygen content ranged from 3.55 to 6.8 ml/L at the surface level and from 4.2 to 6.09 ml/L at the bottom level. The depth of the water column ranged from about 2 to 6 m in the river.

Salinity : The salinity ranged from near zero values to 24.14‰ at the surface and from 1.11 to 24.14‰ at the bottom levels. Markedly high surface-bottom differences, ranging from 1.11 to 13.38‰ were observed (Figs. 2 and 3). In general, these upward vertical gradients were conspicuous in the vicinity of stations CII, CIII and CV where waters of low salinity were drained into the river resulting also in the stratification of waters.

Nutrients : The nitrite concentrations ranged from 0 to 1.2 μg at/L with values at the surface levels being higher than at the bottom. The phosphate concentrations ranged from zero value to 0.34 μg at/L. The silicate concentrations were fairly high, being 25.0 to 150.0 μg at/L at the surface and bottom levels. As for other nutrients, higher concentrations were recorded in the intermediate portion of the river, especially at stations CII to CV.

Summer season (March-May) :

A total of six surveys, twice a month, were made during this season.

Temperature : A progressive increase in the water temperature was noticed. The surface temperatures which ranged from 30.0°C to 33.2°C were generally higher at most stations than the bottom temperatures which ranged from 30.0°C to 32.8°C. Such vertical temperature differences up to 2.3°C (Figs. 4 to 6) were observed at stations where comparable salinity differences prevailed.

Dissolved oxygen : The oxygen values ranged from 3.5 to 6.16 ml/L at the surface and from 3.1 to 5.32 ml/L at the bottom. The surface concentrations

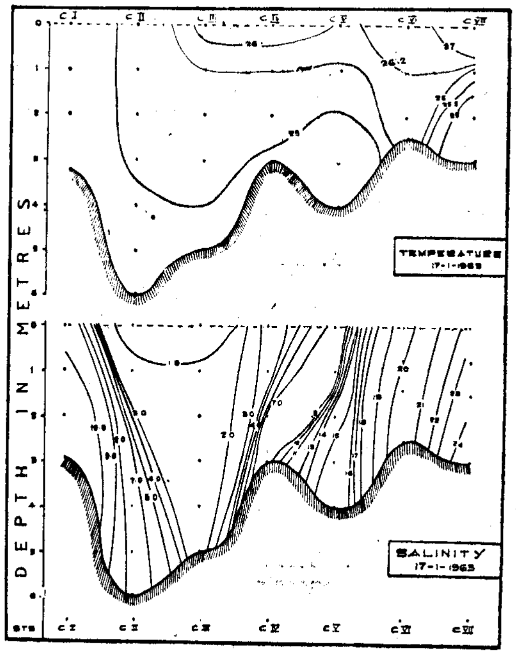

FIG. 2. Distribution of temperature and salinity in the Coringa River during January 1963.

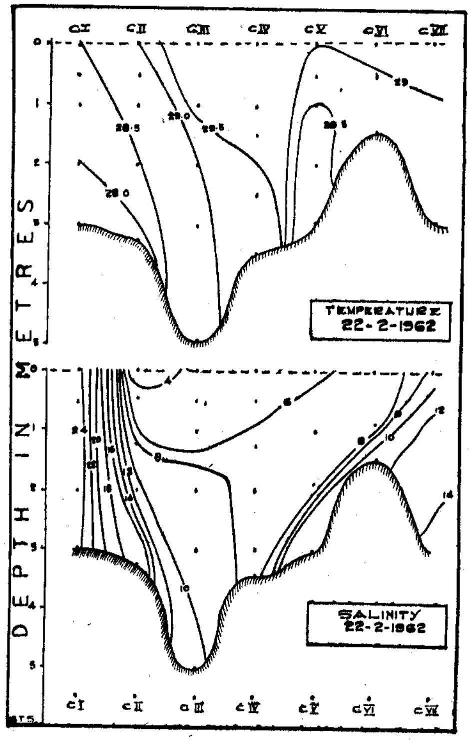

FIG. 3. Distribution of temperature and salinity in the Coringa River during February 1962.

were higher than the bottom concentrations. The levels of oxygen concentration were higher in March and May than in April.

Salinity : The salinity of waters at stations CVI and CVII was higher than at the Gautami-end because of the proximity of the former to the neritic zone. The surface and bottom salinity values ranged from 1.89 to 30.16‰ and from 4.83 to 32.27‰ respectively for the season (Figs. 4 to 6). The inflows from the irrigational channels at station CII were still brackish, while the waters entering the river from the two ends were comparatively more saline. Consequently vertical salinity gradients of varying magnitudes were observed. The vertical difference ranged from 0 to 18.05‰. As in the north-east monsoon season a downward tilting of the isohalines was noticed at station CII indicating continued dilution at the surface layers (Figs. 4 to 6).

Nutrients : The nitrite concentrations ranged from 0 to 6.0 μg at/L for the season both at the surface and bottom levels. Further, wherever surface-bottom differences prevailed the surface concentrations were higher than the bottom concentrations. The phosphate concentrations ranged from 0.06 to 3.4 μg at/L for the surface as well as bottom levels. Both nitrite and phosphate concentrations were higher, in the intermediate portion of the river than at the two ends, and maximum concentrations were noticed during April. In general, a progressively increasing trend was observed beginning from station CI in the direction of the Kakinada Bay.

The silicate concentrations ranged from 25.0 to 125.0 μg at/L for the surface as well as bottom levels. In general, the concentrations were higher in the intermediate portion of the river especially at the stations CII to CV than at the two ends of the river and an inverse relationship was noticed between the salinity values and the silicate concentration. Vertical differences prevailed at stations CI, CII and CIV in March, at station CII in April and at stations CI to CIV in May. Mostly these differences were noticed at stations, where comparable differences in the vertical distribution in salinity prevailed.

South-west monsoon season (June-September) :

During the season two surveys were made in June. From July owing to the incursion of silt-laden freshwaters from the Gautami-end as well as from the irrigational canals, sampling was not made during the period July to October.

Temperature (Figs. 7 and 8) : The surface and bottom temperatures ranged from 29.0°C to 32.2°C and 28.8°C to 31.2°C respectively. Vertical temperature differences appeared at different stations as the surface values were higher than the bottom values. The differences were mostly confined to the intermediate portion of the river.

Dissolved oxygen : The surface and bottom concentrations ranged from 3.5 to 5.93 ml/L and 4.39 to 5.51 ml/L respectively. In general the surface concentrations were slightly higher than the bottom concentrations.

Salinity (Figs. 7 and 8) : The salinity values were fairly high in the first fortnight of June. Owing to the influx of fresh and brackish waters into the river, a general fall in the salinity values was noticed towards the end of the month. The surface and bottom salinity values ranged from 2.23‰ to 23.96‰ and 5.54‰ to 30.46‰ respectively. Vertical differences ranging from 0 to 13.49‰ were noticed.

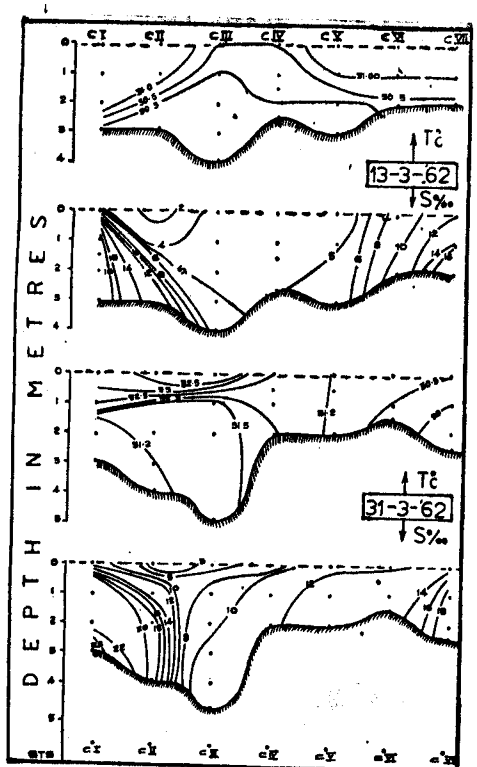

Fig. 4. Distribution of temperature and salinity in the Coringa River during March 1962.

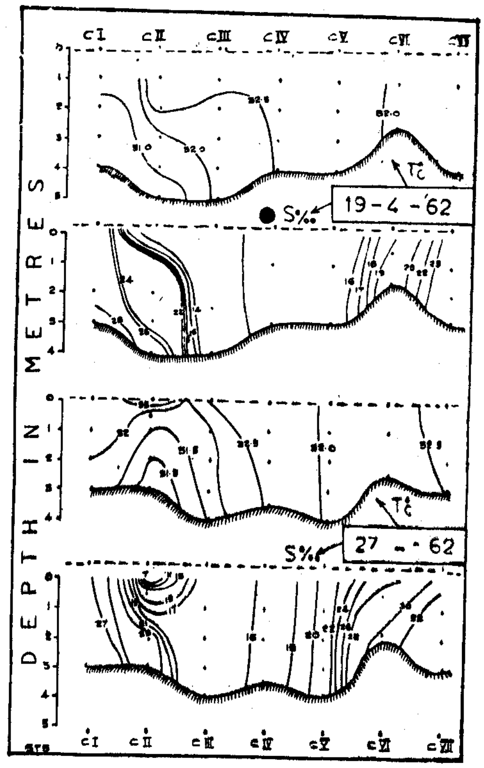

Fig. 5. Distribution of temperature and salinity in the Coringa River during April 1962.

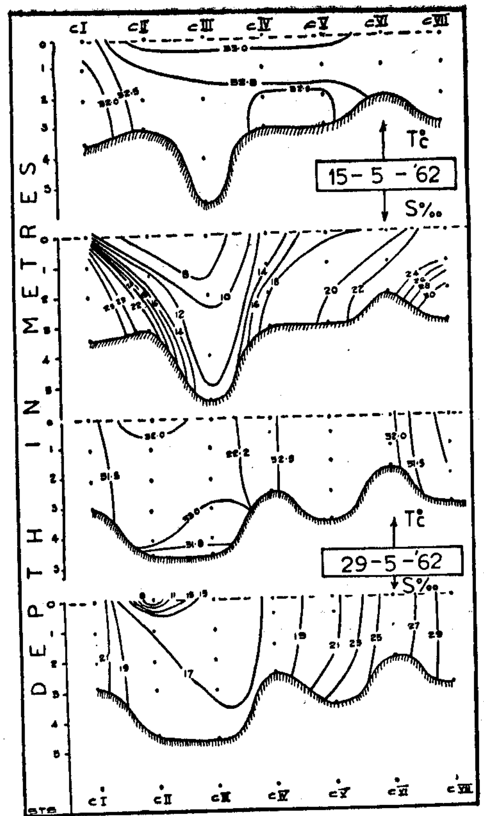

FIG. 6. Distribution of temperature and salinity in the Coringa River during May 1962.

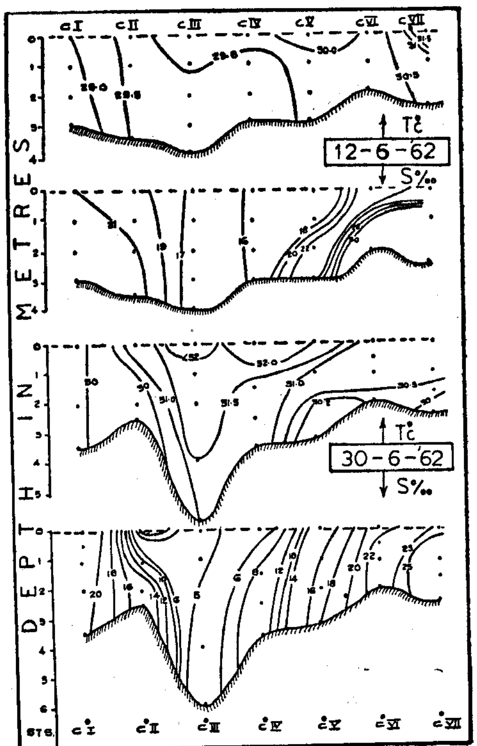

FIG. 7. Distribution of temperature and salinity in the Coringa River during June 1962.

During the latter part of June vertical differences prevailed near the bay-end of the river (stations CV to CVII). Later, when considerable inflows of fresh and brackish-

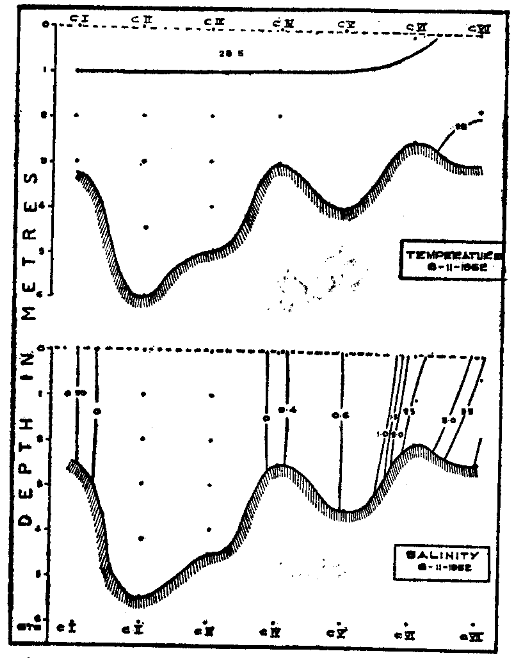

FIG. 8. Distribution of temperature and salinity in the Coringa River during November 1962.

waters into the river occurred surface-bottom differences of different magnitudes resulted at stations CII, CIV and CVII.

Nutrients : In general, there was a lowering in the level of nutrient concentrations during this season. A gradual fall in the nitrite concentration was noticed. The concentrations ranged from 0.05 to 0.3 μg at/L at the surface and from 0.1 to 3.0 μg at/L at the bottom levels. The bottom concentrations were usually higher than those at the surface and the waters at stations CV to CVII were relatively richer in nutrients.

The distribution of phosphate was more or less uniform both in the vertical and horizontal directions. The concentrations which ranged from 0.17 to 0.57 μg at/L were lower than in the preceding season.

The silicate concentration showed an increasing trend towards the end of June, the surface and bottom concentrations being 25.0 to 85.0 μg. at/L and 12.5 to 85.0 μg at/L respectively. The waters at stations CII to CVI were richer in silicates. Differences in the vertical ranging from 0 to 25.0 μg at/L prevailed during the month of June.

Post-monsoon season (October-November) :

During this season the river waters continued to remain fresh and loaded with silt and clay, as in the preceding season. By November, however, brackish water conditions prevail at the two ends of the river owing to their proximity to the sources of salt water. Only one survey was made during November for the season.

Temperature (Fig. 8) : The water temperature was moderately high, the values ranging from 28.0°C to 28.2°C. Vertical differences of low range (0.2°C to 0.5°C) were noticed, and mostly the surface waters were slightly warmer than the bottom waters.

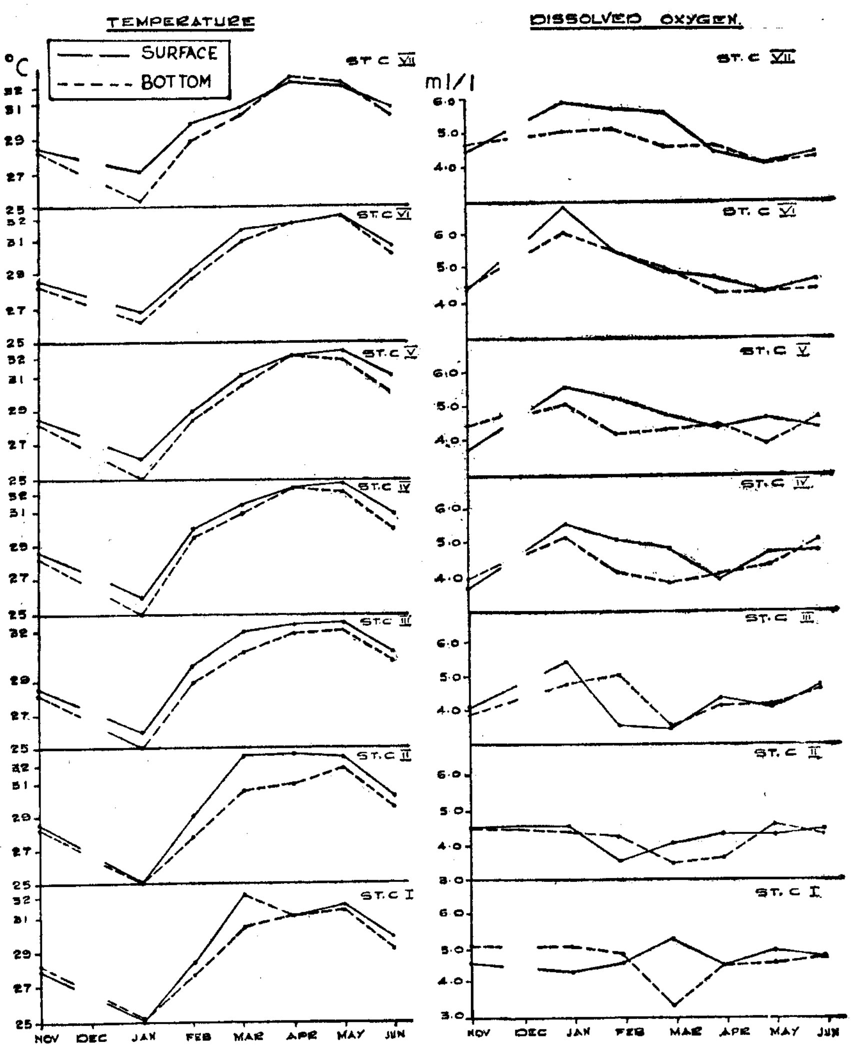

FIG. 9. Seasonal variations in Temperature and Dissolved Oxygen in the Coringa River at the surface and bottom levels: 1962-1963.

Dissolved oxygen : The waters were moderately rich in dissolved oxygen, the range being 3.68 to 4.64 ml/L and 3.95 to 5.05 ml/L for the surface and bottom levels respectively. Vertical differences of a low order prevailed at different stations.

Salinity (Fig. 8): Except at stations CVI and CVII where the waters became just brackish, the river water remained fresh. The surface salinity values ranged from 0 to 3.19‰ and the bottom salinity values from 0 to 3.91‰. Vertical differences of low magnitudes, ranging from 0 to 0.72‰ were observed.

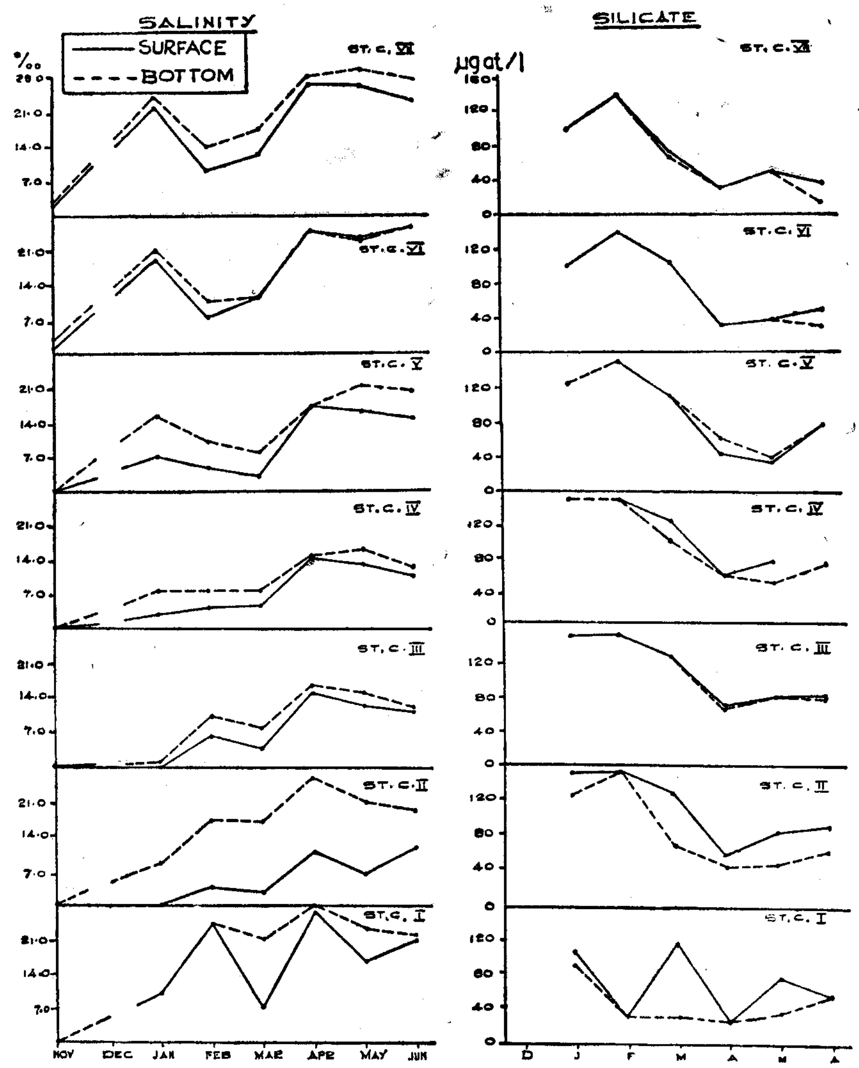

FIG. 10. Seasonal variations in Salinity and Silicate in the Coringa River at surface and bottom levels: 1962-1963.

Nutrients: During this season there is a decline in the levels of concentration of nitrite and phosphate. The former ranged from 0 to 0.4 μg at/L both at the surface and bottom levels, while the latter ranged from 0.12 to 0.42 μg at/L at the surface and from 0.12 to 0.23 μg at/L at the bottom levels.

The silicate concentration was exceptionally high. Accurate determination could not be made as the samples were turbid.

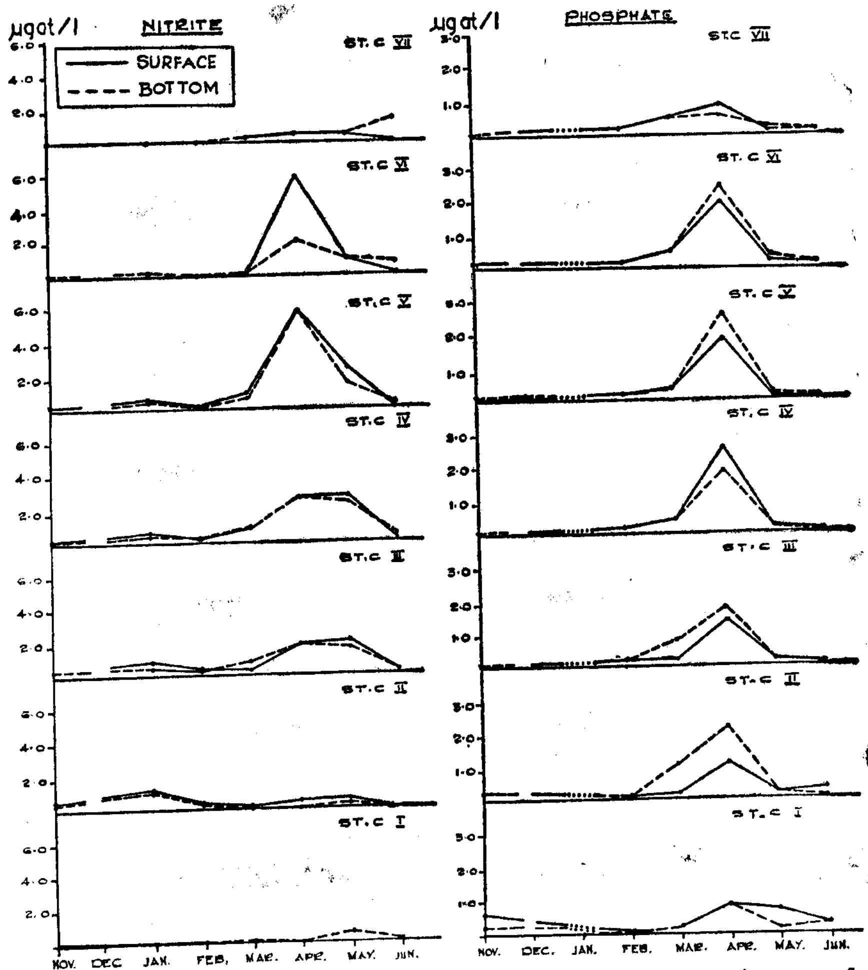

FIG. 11. Seasonal variations in Nitrite and Phosphate in the Coringa River at surface and bottom levels : 1962-1963.

DISCUSSION

The Coringa River forms part of the Godavari estuarine systems opening into the Bay of Bengal. The Coringa River arises from the Gautami branch of the main Godavari River and is characterised by (1) Presence of several channels of fresh-water inflows, (2) Low transparency of the water almost throughout the year, (3) Prolonged period of freshwater domination, (4) Influence of salt water from the ends of the river, beginning from November, (5) Markedly high gradients, horizontal and vertical, in salinity and temperature, (6) High nutrient content of the waters and (7) the inward flow of waters from the two ends of the river during flood phase and the outward flow during the ebb phases of the tide.

In general, the waters are less transparent and during the south-west monsoon and post-monsoon seasons they are highly turbid, but comparatively clearer in summer months. The great abundance of organic detritus drained into the river from the surrounding mangrove swamps leading to the Coringa, carry turbid waters during low tide. The river being shallow, the tidal currents from the two ends are strong enough to agitate the bottom water and also bring the bottom sediments into the overlying waters. When the winds are high, the turbid waters of the Kakinada Bay are swept in during the high tide, thereby decreasing the transparency at stations CV to CVII.

A wide annual temperature range of about 7°C was encountered in the river at the surface level, largely due to the changes in the atmospheric temperature, with the minimum in January, increasing gradually to maximum values in April and May, followed by a decline in June. The relatively lower temperatures at the two ends of the river are due to their proximity to the colder neritic waters. The waters in the intermediate portion of the river are warmer because of insolation. The outflow of warm waters at the surface over the relatively cold waters below at the two ends of the river brought about vertical differences in temperature of different magnitudes. These differences were negligible in November (Fig. 8), but more pronounced from February to May.

The seasonal changes in the oxygen concentration (Fig. 9) indicate that the range of fluctuations is moderate. The trend of variation indicates that the oxygen concentration bears an inverse relationship with temperature. Instances where surface-bottom differences prevail owing to excess of surface concentrations over the bottom concentrations are more frequent than those where the bottom concentrations exceed the surface concentrations. The slightly lower oxygen content at the bottom level may be due to the utilisation of oxygen in the oxidation of organic matter which is derived largely from the extensive mangrove swamps.

In the early stages of the system's recovery from the annual flooding, vertical gradients in salinity of different magnitudes become established first at the two ends of the river (Figs. 2 and 3). The extension in the establishment of vertical gradient in salinity to the intermediate stations occurs from February onwards. In addition to the gradual diminution in the freshwater drainage from the irrigational channels at stations CII and CIV, indirectly assisting increased tidal flow during the successive high tides, there may also be an upward transfer of salt from the lower more saline zone to the upper less saline zone, a process referred to as entrainment by Tully (1958).

In Coringa River, the halocline formation is frequently noticed at different stations because of the persistence of the inflows of either fresh or brackish water into the river almost throughout the year. To some extent mixing occurs due to tidal currents. The action of the winds on the mixing of fresh and salt waters, so high in the adjoining Kakinada Bay, seems to be negligible as the waters are shielded from the wind action by the dense highly grown vegetation on the banks.

The disposition of isohalines during the months of January to June (Figs. 2 to 7) clearly indicate that the isohalines between the stations CI and CII at the Gautami end and between the stations CVI and CVII at the Kakinada Bay end are closely packed compared to the isohalines in the intermediate portion of the river. This may be the result of the pressure imposed on the high saline waters entering the river from the two ends by the outflow of the low saline waters from the middle of the river. The effect of drainage at station CIV, though significant in the early stages of the system's recovery from the floods is not so apparent later, owing to the reduced drainage capacity of the irrigational channel. However, the drainage of freshwater from the irrigational channel opening at station CII continues to have its effect throughout the year.

The Coringa River plays a significant role in the water movements and hydrographical conditions of the Kakinada Bay (Rama Sarma and Ganapati, 1968).

The high level of silicate concentration encountered in the river may be attributed to the persistence of freshwater influx into the river. The seasonal trends of distribution indicate that the waters are rich in silicate during the post-monsoon months and a decline is noticed during the hot summer months (Fig. 10). In general the intermediate portion of the river is richer than the two ends of the river. The lower concentration during the months, April to June may be attributed to the diminished inflow of freshwater into the river. As observed in the Gautami-Godavari estuary an inverse relationship exists between salinity and silicate content. At stations where salinity stratification prevailed there were comparable differences in the silicate content between the surface and bottom levels. This is because vertical mixing is not possible owing to the prevailing vertical density differences.

The seasonal trends of variation in the nitrite concentration are marked in the intermediate portion of the river. Maximum concentration is noticed in the summer months of March to May. The high concentration in the intermediate portion of the river may be attributed to local agencies such as regeneration from the marshy mangrove swamps which are rich in organic content and also due to the seepage from the adjoining lands. The mangrove swamps play an important role in the nutrient supplies to the Coringa River and Kakinada Bay. The seasonal trends in phosphate concentration followed closely the nitrite concentration (Fig. 11). The simultaneous increase in the nitrite and phosphate concentrations in the intermediate portion of the river indicates that they are derived from the mangrove swamps as noticed by Daiber (1959) in the Delaware estuary.

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