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DISTRIBUTION OF SALINITY AND MIXING PATTERNS IN THE VELLAR ESTUARY*

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ABSTRACT

During 1967, surveys of five tidal cycles (June, July, August, September and November) were conducted in the Vellar Estuary. The survey was so designed that it covered almost the whole summer and rainy seasons. Measurements of salinity and temperature were made in 17 fixed stations in the estuary which were visited in sequence. The data collected were analysed to know the distribution of salinity and also the mixing pattern in the estuary. From the results the following inference was made.

During June-July, when there was very little fresh water discharge in the river, the estuary remained predominantly marine, the mixing being nearly complete and without any marked vertical gradient in salinity. However during the flood tide there was an intrusion of a saline wedge along the bottom. The penetration of the saline wedge towards the head of the estuary extended to about 3.5 km along the bottom. Even during this period, there was a moderate horizontal and vertical salinity gradient in the upper part of the estuary.

During August, due to a small amount of river discharge, the pattern was changed slightly. The mixing of the two waters was rather incomplete, throughout the estuary, due to which, a moderate vertical salinity gradient was establised in the lower part of the estuary, while the same was more pronounced in the head of the estuary. The penetration of the saline wedge was much restricted and extended only to about 2 km from the mouth of the river. The more or less low salinity water in the surface extended down to a depth of about 0.5 to 0.7 metre, below which there was a halocline.

In September and November, the river discharge was considerably large and as a result, the vertical as well as horizontal halocline was well established, in the whole estuary. The low salinity surface water was further pushed downward to a level of about 1 metre in November and the saline wedge became less pronounced.

The isohalines were rather smooth and less steeply inclined during August, September and November than what they were during June-July.

INTRODUCTION

IN AN ESTUARINE system, the rhythmic ebb and flow of tides causes considerable complexity which is echoed in our understanding of its physico-chemical structure. Superimposed on the diurnal or semidiurnal tidal changes are the seasonal variations in rain fall and influx of freshwater through river discharge. Estuaries are therefore peculiar ever-oscillating environments deserving intensive investigation,

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particularly of its physico-chemical changes. Extensive observations on the physico-chemical and the seasonal changes have been made in UK, USA and Australia. The nature of circulation in river estuaries has been discussed in considerable detail by Rochford (1951), Redfield (1950), Ketchum (1951), Pritchard (1952, 1954) and Stommel (1953). An extensive review of the nature of circulation in different estuaries has been made by Stommel and Farmer (1952). However, such studies have been largely neglected in Indian estuaries and the need for a critical study of Indian estuaries has already been pointed out by Seshaiya (1959).

The hydrology of Vellar Estuary has been studied by Ramamoorthi (1954) Rangarajan (1958) and Jacob and Rangarajan (1959). Dyer and Ramamoorthi (1969) investigated salinity and water circulation in the Vellar Estuary for a period of about two months. The present communication is an extension of the work covering a period of 5 months, in order to understand the influences of tidal as well as seasonal changes on the distribution of salinity and the pattern of mixing in the Vellar Estuary.

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Methods

The plan of survey, the stations investigated and the method of investigation were the same as adopted by Dyer and Ramamoorthi (1969). The present investigation was carried out during June, July, August, September and November 1967 and comprises more than 2000 measurements each of salinity, temperature, current speed and direction. The pattern of distribution of salinity alone is considered in the present account to know the circulation in the estuary.

Results and Discussion

Classification of estuaries is mainly based on the physical character of circulation in the system under study (Stommel, 1953). The basic factor which determines the type of circulation is the part played by tidal flushing relative to that of river flow in the estuary in question. In the absence of other influences, the river water will tend to flow seawards as a layer of fresh water, separated by a distinct interface from the salt water below. En route the fresh water entrains sea water from below to form a halocline in which the salinity increases with depth seaward (Tully, 1958). The fresh-water transport system is superimposed on the tidal ebb and flood and thus becomes more complex in character.

The mechanism of transport of fresh water in an estuary is the difference in salinity (or density) between the zones. It requires a continuous source of light water or fresh water, a continuous source of dense water or sea water and a sink for the mixed light and dense water. The light water is usually provided by the river run off and the dense water by the sea as a result of flood tide (Tully, 1958).

The Vellar Estuary, the river run off is not a constant feature and hence the input varies with the season of the year. During the drought period of the year, the main river discharge as well as influx from the feeding channels is very much limited. This condition prevails during May to July. Almost the entire estuary is occupied by the neretic waters. Consequently the tidal influences appear to be quite negligible in the estuary, which is obvious from the distribution of salinity (Figs. 1-5). The mixing is nearly complete and without any marked vertical gradient in salinity in

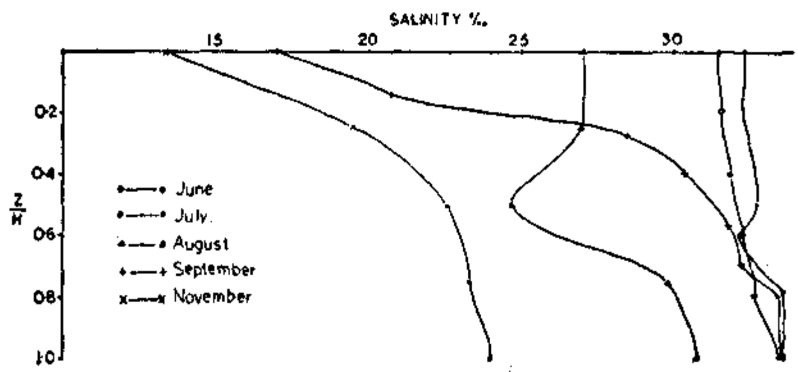

Fig. 1. Vertical distribution of tidal mean salinity at station 2.

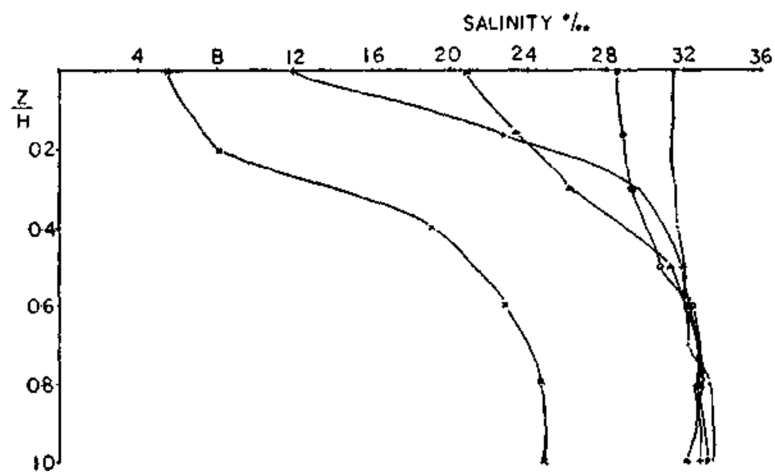

Fig. 2. Vertical distribution of tidal mean salinity at station 7.

the estuary except at the head (5 km from the mouth of the estuary), wherein a distinct halocline is seen below a depth of 1.0 m. However, the difference in surface-bottom salinity is only 2‰ as against 24‰ during the flood season and the mixing boundaries are still more or less horizontal. At depths greater than 4.0 m there is again a decrease in salinity. Even during this drought period a moderate horizontal salinity gradient persists in the upper part of the estuary. The absence of vertical salinity gradient in the lower part of the estuary during the drought period

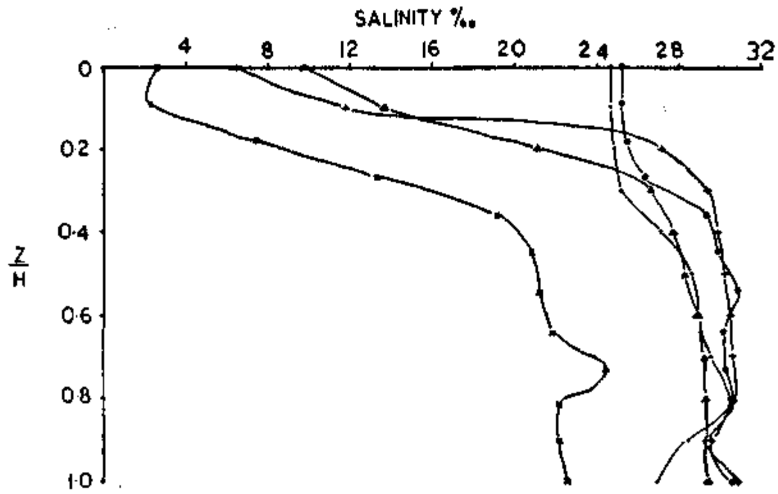

Fig. 3. Vertical distribution of tidal mean salinity at station 17.

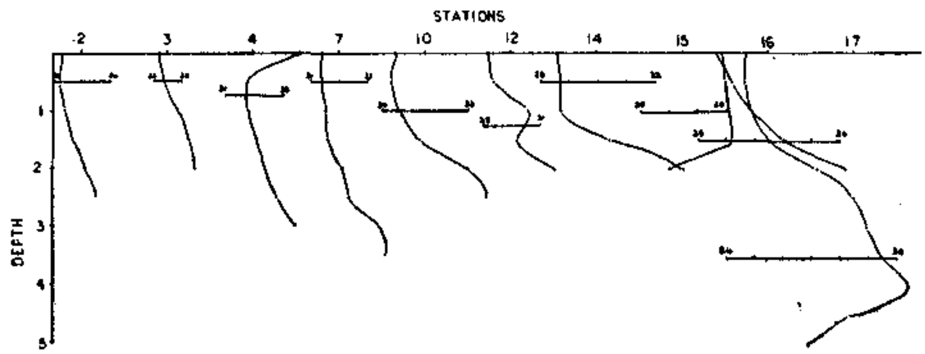

Fig. 4. Vertical distribution of tidal mean salinity during June.

indicates the operation of a cellular type of circulation as suggested by Rochford (1951) in the typical eastern Australian systems and by Ganapathi and Rama Sarma (1965) in Gautami-Godavari Estuary. Thus during the drought period, the estuary can be characterized as a vertically homogeneous with lateral homogeneity also.

The neretic dominance of the estuary continues to prevail till the end of July. During August, the distribution of salinity and the mixing pattern changes slightly due to a small amount of river discharge. The hydrological pattern which hitherto

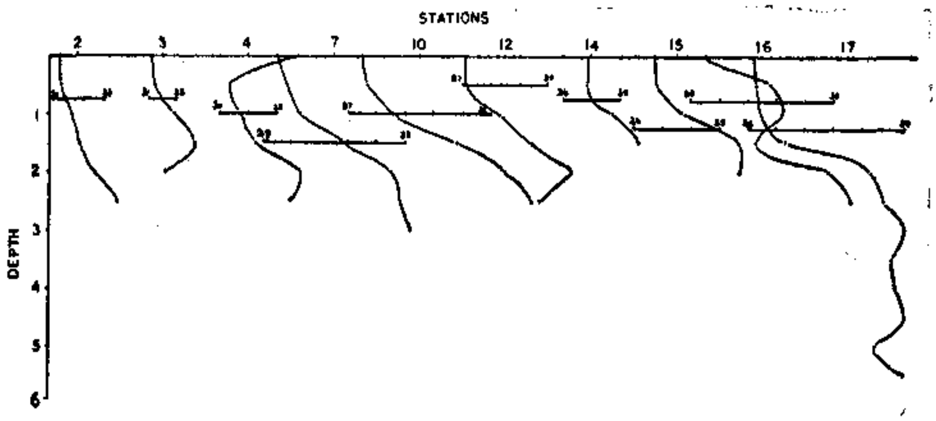

Fig. 5. Vertical distribution of tidal mean salinity during July.

characterized the drought period is slightly disrupted and the picture obtained during this month is more or less representative of the transitional stage of the estuary from drought to floods. The fresh water tends to displace the neretic water at almost all depths. The mixing of the fresh water with neretic water is rather incomplete throughout the estuary resulting in a moderate vertical salinity gradient in the lower part of the estuary, and this is more pronounced in the upper part of the estuary where a surface-bottom difference of 20‰ is seen at the head. Along the bottom, however, the neretic water is transported inwards, the penetration, being restricted to the lower most 0.5 m. This layer has a rather uniform salinity upto a

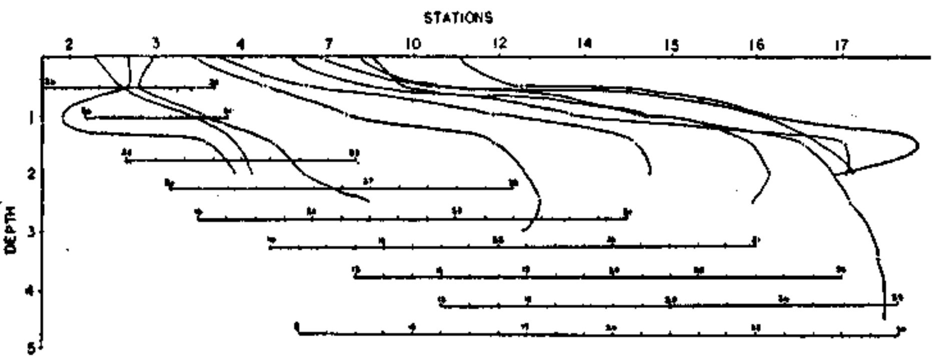

Fig. 6. Vertical distribution of tidal mean salinity during August.

distance of about 4.0 km from the mouth and forms the lower zone of constant salinity (Tully, 1958 ; Pritchard, 1952). The distribution of salinity both vertically and horizontally in the estuary during this month indicates (Fig. 6), that mixing is due to both entrainment and transfer of fresh-water downwards (Tully, 1958).

With the onset of north-east monsoon (September—Fig. 7) there is a large scale drainage of fresh water into the estuary and as a consequence, a freshwater isostatic head develops. This results in a gravity impelled flow of water with a rapid seaward displacement of surface water. With the seaward flow of fresh water or low salinity mixed water at the surface level and fairly high salinity water moving in an opposite direction along the bottom, a steep halocline develops which suppresses not only the tidal pressure but also the vertical mixing. In October, the inflow gains greater momentum, resulting in high floods and the prevailing structure is completely disrupted. This culminates—in a complete freshwater scouring of the estuary. The river water is drained into the sea, unimpeded, but the incoming

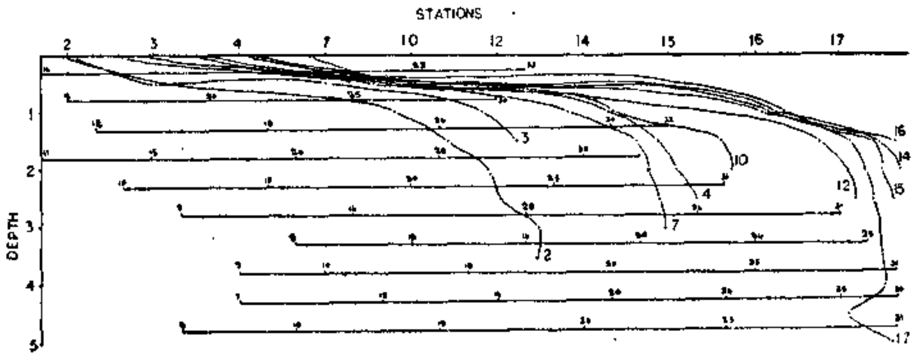

Fig. 7. Vertical distribution of tidal mean salinity during September.

neretic water due to the tidal effect, is completely blocked. This condition persists the whole of October. The salinity of the water in the estuary is 1.0‰ at all depths and in all stations. (Therefore tidal cycles were not conducted during this month and hence no data is presented.) This is due to (a) almost a continuous and heavy inflow of freshwater from the river and (b) the narrow mouth compared to the great width of the estuary.

With the subsidence of the monsoon rain in late November (Fig. 8) river discharge becomes considerably decreased. The recovery cycle leading to the establishment of estuarine conditions is rather rapid and disrupts the fresh water dominance

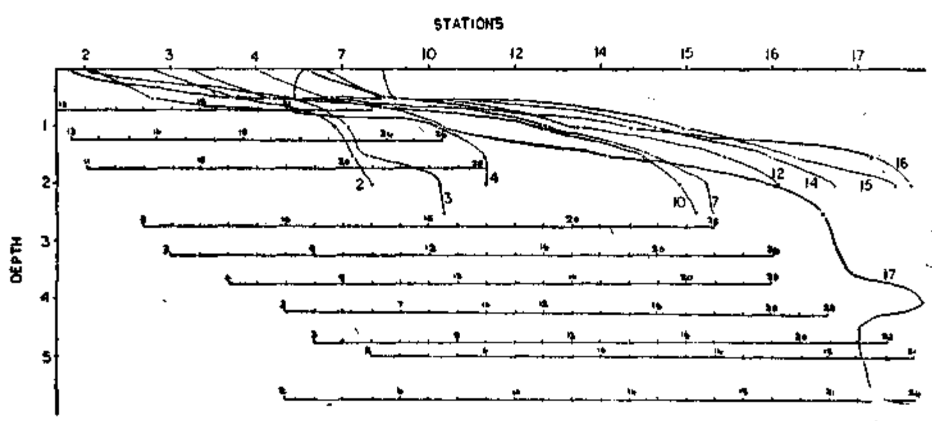

Fig. 8. Vertical distribution of tidal mean salinity during November.

in the estuary. Consequent on the diminution in the pressure exerted by freshwater, neretic penetration gains prominence and this is obvious from the establishment of brackishwater conditions in the estuary as a whole. A steep vertical salinity gradient becomes established once again commencing from the region of confluence of freshwater and neretic water. This is followed by a progressive increase in the zone of vertical salinity gradient in the direction of the head of the estuary, as observed by Ganapati and Rama Sarma (1965) in Gautami-Godavari Estuary. During the beginning of this post-flood recovery period, the mixing boundaries are oriented horizontally and the isohalines are rather smooth and less steeply inclined. The penetrating neretic water pushes up the low salinity surface water to a level of 0.5 m from surface in the aft estuary. But in the fore-estuary there is already considerable neretic domination. Thus, as pointed out by Dyer and Ramamoorthi (1969), the Vellar Estuary is a typical salt wedge estuary at a time when the river flow completely dominates circulation and appears to be well stratified during low river discharge. This feature is particularly evident during pre-and post monsoon period. During the drought period, and also during the monsoon period, the estuary exhibits vertical and lateral homogeneity. This condition is due to (a) the predominating influence of tidal currents during drought period and (b) the predominating influence of fresh water during monsoon period. Thus, with regard to mixing exchange, circulation and distribution of salinity structure during different periods the Vellar Estuary shows resemblances to various other estuaries like the Australian estuaries and Tees (Alexander *et al.*, 1935), and Tamar Estuaries (Milne, 1939).

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