3. HYDROGRAPHY.

Assessment of environmental features and their changes is essential for understanding the ecology and inter-relations of the organisms inhabiting an area. Several studies mentioned earlier have contributed to the understanding of hydrobiological aspects of Indian estuaries. The State of Kerala gets the rainfall from both Southwest and Northeast monsoons and they have profound influence on the hydrography and biology of the estuaries. The seasons can broadly be divided (although this is somewhat arbitrary, since the onset of rainfall varies from year to year) into premonsoon (January to April), monsoon (May to October) and post-monsoon (November-December) periods. However, at the mouth regions of most of the estuaries saline conditions prevail at the beginning of the monsoon period also (May-June) although the salinity towards the interiors is brought down.

3.1. Cochin backwaters.

3.1.1. Salinity:

The most important factor controlling the biological processes in tropical estuaries is the monsoon and the associated changes in salinity. Wide variations were observed in the salinity structure of the water column in this estuary during the different seasons (Fig. 4 A).

Premonsoon:

A more or less vertically homogeneous pattern in salinity distribution was observed by the beginning of premonsoon. Salinity values were high (> 30‰) both at surface and bottom. It steadily increased through the season and registered the maximum value (34.8‰) in April. The influence of the saline water could be traced upto the head of the estuary (Fig. 4 B). The recovery after the monsoon was gradual and the values towards the head increased from 3.9‰ in January to 13.0‰ by April. Some amount of stratification occurred at the middle reaches during the early premonsoon. But the water column became well mixed during the peak premonsoon period.

Monsoon:

The onset of monsoon in May brought about a total change in the physical characteristics of the environment. Large quantities of fresh water were discharged into the backwaters through the rivers and land runoff during the monsoons. During the year of observation (1978) rains started from May and lasted upto October with intermittent breaks.

The surface salinity fell from 34.8‰ in April to 9.9‰ in May. Bottom salinity varied from 30‰ to 33.8‰ at mouth of the estuary. The water column became stratified showing a two-layered flow. In June an increase in salinity was observed both at the surface and botton due to a short break in the monsoon. Bottom salinity reached 35.5‰ which was the highest value recorded. The presence of this high saline water in the bottom layers was probably due to the intrusion of upwelled Arabian Sea water into the channel (see 3.1.2) during this period. Surface salinity reached near zero values in July when the monsoon was at its peak. It showed an increasing trend in August and September owing to an abatement of the force of the monsoons but decreased again in October when the rainfall increased. Towards the upper reaches the estuary remained fresh water dominated throughout the monsoon (Fig. 4 B).

Postmonsoon:

By November surface salinity started to show an increase. The water column continued to be stratified with high saline water (32.1‰) at the bottom. Sea water started to dominate by December, stratification being less apparent, the conditions leading into homogeneous situation of the premonsoon.

Salinity recovery was rapid at the mouth and gradual at the upper reaches. Even after the rain fall was decreased, the fresh water flow was still strong enough to restrict the incursion of marine water towards the head of the estuary during the postmonsoon period.

3.1.2. Temperature:

Fluctuations in temperature were not much and as pronounced as that of salinity but the seasonal changes were reflected in the temperature structure also.

Premonsoon:

Temperature was higher during the premonsoon season. In January the surface temperature was around 28°C. There was a gradual increase as the season progressed and by April the surface temperature reached 31.6°C. The water column was well mixed and homogenity prevailed with little difference in temperature between the upper and bottom layers (Fig. 4 A).

Monsoon:

The effect of monsoon was reflected in the temperature distribution also. Temperature suddenly dropped from 31.6°C in April to around 26.0°C in May at both surface and bottom. It increased to 29.8°C in June corresponding to a temporary break in monsoon and fluctuated between 28°C and 30°C during the monsoon season. Steep vertical gradient in temperature existed during this season. Lowest temperature (24.4°C) was recorded at the bottom in July. The difference between the surface and bottom temperature fell within the range of 1.6°C to 5.1°C from June to October.

Thus, during the monsoon period, especially in July-August, thermal stratification was very steep. The cold high saline water at the bottom layers is probably the upwelled Arabian Sea water entering the channel. Presence of cold dense waters upwelled from the sub-surface levels of Arabian Sea in the continental shelf and its incursion into the mouth area of Cochin backwaters has been reported during these months earlier (Banse, 1959; Ramamirtham and Jayaraman, 1960, 1963; Venugopal _et al_., 1979).

Postmonsoon:

During this season, temperature differences between the surface and bottom became less sharp and by December the water column became more or less homogeneous.

3.1.3. _Oxygen_:

The pattern of oxygen distribution was also similar to that of salinity and temperature. During premonsoon, the surface and bottom oxygen content did not show any significant variations and the values ranged between 2.0 ml/l to 3.0 ml/l.

Surface oxygen content showed a general increase during the monsoon period. It increased to 4.0 to 5.0 ml/l in July and August. But the bottom values decreased during this period, the minimum observed being 0.5 ml/l in August (Fig. 4 D). The very low oxygen content at the bottom layers during July-August was further evidence to the presence of upwelled water. The low oxygen content generally found in the bottom during monsoon period is probably owing to the high turbidity and low light penetration (Qasim _et al._, 1968; Venugopal _et al._, 1979) limiting primary production in these layers.

During the postmonsoon period, the surface and bottom oxygen values were more or less same and the water column fairly homogeneous. However the surface values were still less, compared to the monsoonal period.

3.2. Comparison with other estuaries.

The hydrographical characteristics of Cochin backwaters is typical of other estuarine systems of Kerala coast. In all these estuaries monsoon is the key factor bringing about the annual cyclic changes in the hydrobiology of the environment. As mentioned earlier, the most important parameter controlling the biological processes in tropical estuaries is salinity. The large quantities of fresh water which inundate the estuaries during the monsoon often abruptly alters the salinity structure and causes total transformation in the faunal composition.

The basic difference in the physical characteristics of Cochin backwaters with other estuaries studied is that the Cochin backwaters form a large basin of brackish water into which several rivers empty. The other estuaries apart from Veli and Thottappilly (which are primarily fresh water lakes having limited periodic connection with the sea) are river mouths where estuarine conditions develop. More over the channel area of Cochin backwater system is constantly dredged and deepened to accommodate port traffic while the mouth of other estuaries are comparatively shallower (some dredging operations are conducted periodically at Beypore and Neendakara also). However, the general hydrography at the mouth regions of Neendakara, Kallai, Beypore, and Mahe estuaries is more or less similar to Cochin Backwater system and hence only the salient features are discussed.

3.2.1. Comparison of Neendakara, Kallai, Beypore, Korapuzha and Mahe estuaries.

Salinity:

Salinity distribution in these estuaries was similar during the premonsoon period. At Neendakara the surface salinity ranged between 31.4‰ to 34.2‰ while at the bottom it varied between 32.1‰ to 34.4‰ (Fig. 5). At Kallai maximum salinity of 35.7‰ was recorded in April (Fig. 6). At Beypore, the salinity after registering a maximum (33.3‰) in February fell during the subsequent months of the season and at the peak of premonsoon, in April, it was only 29.2‰ at bottom (Fig. 7). The conditions were similar at Korapuzha and Mahe estuaries also. The water column was well mixed and the values ranged between 30‰ to 35‰ during the premonsoons (Figs. 8 and 9).

Salinity fell with the onset of monsoon in May. At Neendakara it was reduced from 34.2‰ in April to 16.9‰ at the surface and 18.6‰ at the bottom (Fig. 5). Similar decrease was noticed at Korapuzha, Kallai, and Mahe but the salinity remained high at Beypore. A slight reduction in the force of monsoon on the southern parts of Kerala in June resulted in a temporary rise in salinity in the estuaries at Cochin, Neendakara, Veli and Thottappilly. But again it fell to near zero values both at surface and bottom in all the estuaries with the heavy rains in July. But at Neendakara the surface and bottom salinities were reduced only to 6.6 and 14.4‰ respectively in July probably because of the lesser rainfall in this area.

Vertical stratification during monsoon was less pronounced in these estuaries as compared to that in Cochin backwaters. However, a lesser gradient was observed at Kallai, Beypore and Korapuzha during the later part of the monsoon period (Figs. 6, 7 & 8). Virtually no stratification occurred at Neendakara and Mahe estuaries (Figs. 5 & 9). The probable reason for the less marked stratification compared to Cochin backwaters is that the sand bar at the mouth of the latter is deepened periodically allowing free incursion of sea water along the bottom as a typical salt wedge.

Because of the same reason, the salinity recovery in some of these estuaries was slower in the early premonsoon period (November) compared to Cochin backwaters. The regional variations in the rainfall also influenced this to some extent. By December the salinity started increasing in all the estuaries.

Temperature:

Temperature also fell in tune with the pattern of salinity distribution (Figs. 5-9). In general, it fell by 7.0 to 8.0°C in monsoon compared to the pre-monsoon values. But a shart gradient in the vertical thermal structure was not apparent in these estuaries unlike Cochin backwaters except at Kallai (Fig. 6). The differences between surface and bottom in general were only about 1.0 to 1.5°C. At Kallai the highest gradient observed was 3.5°C in August.

Oxygen:

Oxygen content at the surface layer in these estuaries was generally higher compared to Cochin back-waters. At Neendakara it fluctuated between 3.3 ml/l to 3.8 ml/l during the premonsoon. It further increased to 4.9 and 5.3 ml/l in August and November (Fig. 5). The bottom values did not vary much from the surface values during early monsoon period. But from August a difference of about 1.5 ml/l was observed between them. The distribution of surface oxygen at Kallai was different. From 2.3 ml/l in April it increased to 4.7 ml/l in June. Values then decreased steadily during the monsoon season and registered the minimum in October (Fig. 6). The bottom values showed similar trend of distribution as that of surface without much difference except in April and May. A steady increase in the surface oxygen content was noted at Beypore estuary from the premonsoon to monsoon period (Fig. 7). The maximum value 5.5 ml/l was observed in August. Here also the bottom oxygen did not show any significant variation from that of the surface. The oxygen distribution did not exhibit any definite trend which could be correlated to seasons at Korapuzha and Mahe where high and low values occurred in all seasons (Figs. 8 & 9).

One notable aspect emerging in the comparison of the hydrographic parameters is the absence of upwelled Arabian Sea water in any of these estuaries during the July-August period unlike the Cochin backwaters probably owing to the shallower nature of their mouths.

3.2.2. <u>Comparison of Veli and Thottappilly lakes</u>.

These two lakes on the southern part of the Kerala coast differ from the other estuarine systems in their hydrobiological aspects. The Veli lake has a sand bar across its mouth which permits exchange of fresh and marine waters only for a short span of time. At Thottappilly a man-made barrage obstructs free inflow of water from the sea (see 2.1).

Salinity:

At Veli the surface salinity was low throughout the year. Maximum value recorded was 4.5‰ in November. During the premonsoon the values ranged from 0.7‰ to 3.2‰. Bottom salinity was higher during this period, registering the maximum in March (23.8‰) (Fig. 10). It fell to near zero values during monsoon and the water column became practically fresh. During the post-monsoon the bottom salinity increased to 23.4‰ while the surface values remained low. Murugan et al. (1980) have also observed low salinities in this lake but maximum value they recorded was only 4.8‰.

The Thottappilly lake was dominated by fresh water throughout the year. The salinity was very low, always less than 3‰ during all the seasons except in January when the bottom salinity was 7.9‰ (Fig. 11).

Temperature:

High temperature prevailed during the premonsoon at Veli. From 31.2°C in January it increased to the maximum of 34°C in March (Fig. 10). During the monsoon the values fell and fluctuated between 25°C and 30°C. The minimum was observed in October. During post-monsoon the surface temperature was around 30°C. The bottom values did not show any variation from those of the surface during all seasons since it is a shallow area (2.5 m).

The temperature distribution was almost similar at Thottappilly also with maximum temperature (33.0°C) being recorded in March and April at the surface and minimum (26.5°C) in July at the bottom (Fig. 11). The bottom temperature was only slightly less compared to the surface except in July and October.

Oxygen:

The surface water at Veli had high oxygen concentrations throughout the year ranging between 4.0 ml/l to 5.9 ml/l except during early premonsoon period (January and February). Oxygen in the bottom layer was lower in most of the months, maximum difference being recorded in August (Fig. 10).

Oxygen distribution at surface at Thottappilly was more or less similar to the Veli lake (Fig. 11).

The major difference of Thottappilly and Veli lakes from the other estuaries is the presence of low saline water at the surface throughout the year. While at Thottappilly the bottom salinity also remains low more or less throughout, salinity goes quite high at Veli lake in post and premonsoon seasons. The origin of this high saline bottom water at Veli although there is no free connection with the sea is subject to some speculation.

It is perhaps best explained in terms of the dynamics of a coastal aquifer (Glover, 1959; Cooper, 1959). It involves ocean tides, the rise and fall of the ground water table and the bed of the sand bar acting as a permeable medium. A zone of diffusion is formed in the bed and sea water and fresh water become intimately mixed in this zone. To quote Cooper "it appears to be reasonably certain that wherever a zone of diffusion exists in a coastal aquifer a flow of sea water from the floor of the sea into the zone of diffusion will occur. The flow may be interrupted or reversed during low stages of tide or high stages of the water table but on the average it will persist in a land ward direction".

Thus the salinity increase in the bottom layer of Veli lake may be through this diffusion, occurring along the bed. (However, the presence of some typically coastal species in the Veli lake in some months - see Chapter 4 - makes it impossible to arrive at a firm conclusion. There could also be a possibility of some water spilling over during intense wave action and sinking to the bottom of the lake).

At Thottappilly the configuration of the terrain where collections were made is different. The barrage is built about 0.5 km away from the sand bar and the collections were made from inside the spillway. The distance from the sea to the place of collection may account for the lower salinity at the botton encountered at this station.

.....