Indian Journal of Marine Sciences
Vol. 2, December 1973, pp. 94-102

Salinity, Temperature, Oxygen & Zooplankton Biomass of the Backwaters from Cochin to Alleppey

P. HARIDAS, M. MADHU PRATAP & T. S. S. RAO
Regional Centre of National Institute of Oceanography, Cochin 18

Received 11 *July* 1973; *revised received* 15 *October* 1973

Variations in salinity, temperature, dissolved oxygen and zooplankton biomass in the backwaters from Cochin to Alleppey are discussed with reference to conditions prevailing respectively in premonsoon, monsoon and postmonsoon periods. 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 tidal influx and the fresh water efflux which differ with seasons. Higher temperature values observed in premonsoon fall with the advance of monsoon. High oxygen values recorded during monsoon suggest high primary production at surface during this season. Biomass values fluctuate with seasons and they can be correlated with the hydrographical conditions prevailing in the estuary.

THE backwaters from Cochin to Alleppey (09°30′-09°58′N; 76°15′-76°25′E) form a bar built estuary with two openings into the Arabian sea, one at Cochin and the second at Azhikode. During flood tide the sea water enters the estuary and the flow is reversed during ebb tide. The magnitude of influence of the tides progressively decreases with increase in the distance from the mouth. The spreading of the sea water to the upper reaches of the estuary is considerably dependent on the fresh water discharges.

Two major rivers, Periyar and Pamba, open into the estuary, the former north of Cochin and the latter at the southern extremity. The Muvattupuzha river and the Meenachil river join it around the middle. These rivers discharge large quantities of fresh water into the estuary during the south-west and the north-east monsoons. During the peak periods of the monsoons the efflux of fresh water into the sea through the harbour mouth at Cochin is such as to reduce the temperature and salinity of the surface waters of the coastal regions considerably[1]. The bottom of the estuary is muddy. The depth of the backwaters varies from 10 to 12 m around Cochin Harbour Channel to 1 m at Alleppey.

The hydrography of this estuary has been investigated by several workers[2-6]. Most of the work has been carried out in the area around Cochin Harbour. Nair and Tranter[7] were the first to extend their observations up to the head of the estuary in the south though their observations are limited to two cruises, one before and the other after the monsoons. The variations in the biomass in the Cochin backwaters have been studied by Menon *et al.*[8]. The present study covers the hydrographical changes and the biomass variations in this system over a larger area for a full year.

Materials and Methods

Monthly cruises were undertaken from January to December 1972 covering the area from Cochin to Alleppey. Seven stations were fixed (Fig. 1) representing various stages of sea water-fresh water interaction in the estuary. Observations were made during day time. The salinity and temperature were recorded for each meter depth using a salinity-temperature bridge (Type: M.C. 5 Electronic Switchgear Ltd., London). Water samples from the surface were analysed to estimate the dissolved oxygen content using Winkler's method. Zooplankton samples were collected using a HT net (mesh size: 300 μ). Each haul was of 5 min duration.

Results

The results are given in Figs. 2-4 and Tables 1 and 2. The data can be analysed with respect to the conditions prevailing in premonsoon (January to April), monsoon (May to October) and postmonsoon periods (November to December).

Salinity — The premonsoon period exhibited relatively stabler environment 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.

In January homogeneous conditions prevailed from top to bottom at most of the stations. Salinity in the Harbour Channel was high and gradually decreased towards the head. The bottom salinity was higher than the surface salinity (Fig. 2) showing the penetration of the high saline sea water along the bottom. There was a progressive increase in salinity at all stations with the advance of summer. By February the flow of high saline sea water at the subsurface level increased. The salinity at all stations exhibited considerable increase in March and April. The March-April period may be interpreted as the season of highest salinity when the influence of the sea water was at its maximum throughout the estuary.

In May, with the onset of south-west monsoon, the high salinity regime was almost completely wiped out even in subsurface layers around Cochin Harbour. At stations 1 and 2 the salinity fell from 31·5‰ to 6·5 and 3·3‰ respectively in the surface layer. Similar conditions could be observed throughout the estuary and the salinity fell to <1‰ towards

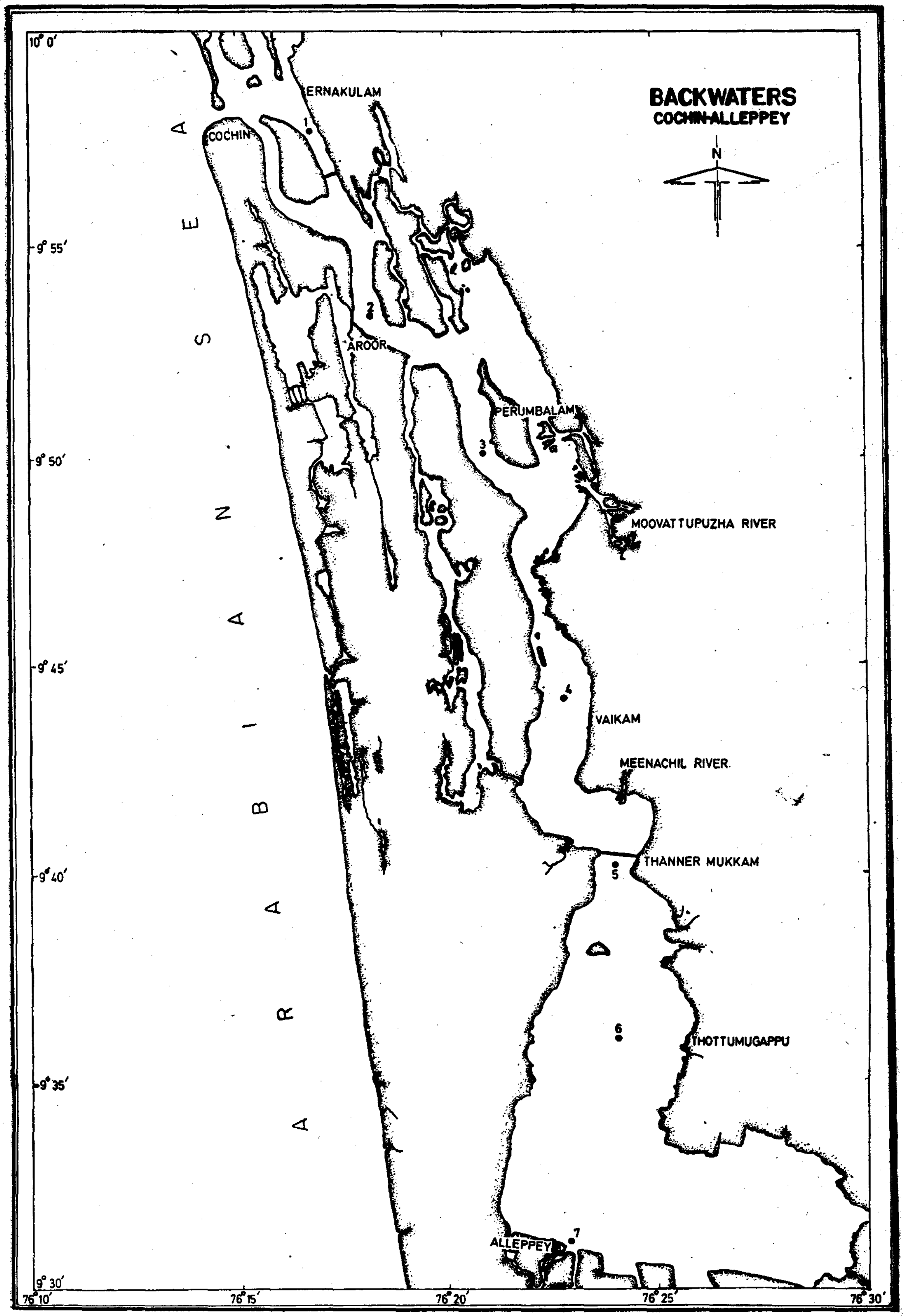

Fig. 1 — Station location map

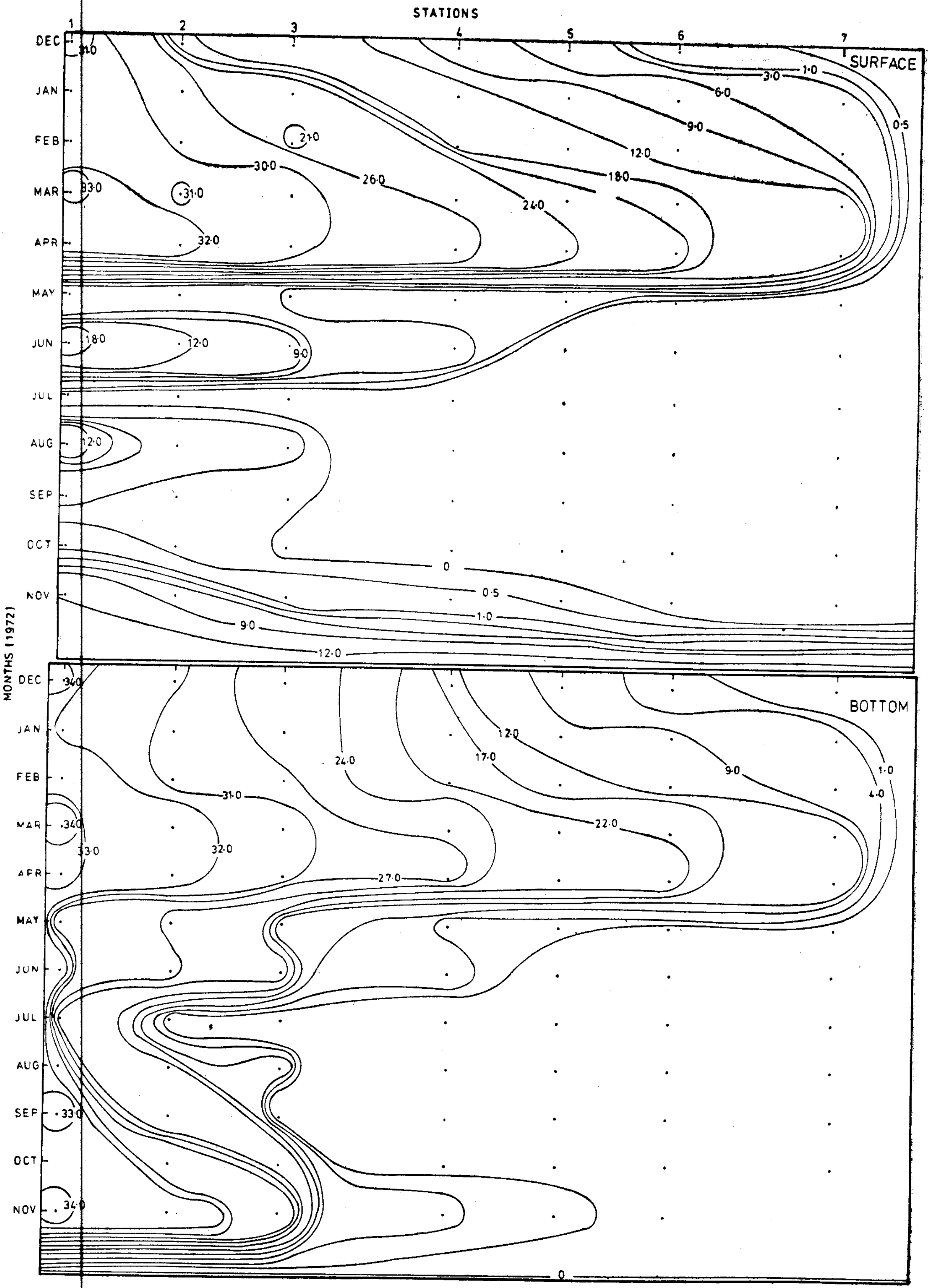

Fig. 2 — Distribution of salinity along the surface and bottom from Cochin to Alleppey during 1972

the head. However, the salinity at the bottom layers, though reduced, was still high at the stations nearer the mouth, thus establishing a distinct two-layered flow. This extension of high saline sea water at the mouth region into the backwater has also been noted by Ramamirtham and Jayaraman[2]. An increase in the salinity observed in June at stations towards the mouth was due to the irregular and discontinous rains whose intensity varied from time to time. In July when the south-west monsoon reached its peak, the salinity came down to <1‰ in the entire estuary. The influence of the sea water in the subsurface channel water was also much reduced where the salinity fell from 32·5‰ in June to ·5‰17 in July.

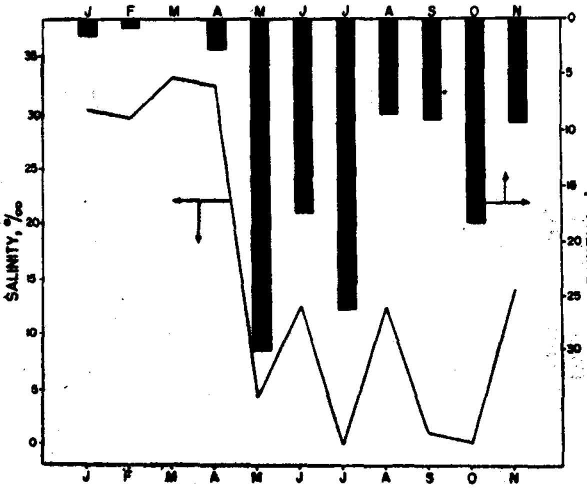

Fig. 3 — Correlation of the fluctuations in surface salinity and rainfall at station 1 during 1972

In August the salinity at stations nearer the mouth showed a tendency to recover although general conditions of low salinity continued to prevail. The salinity in the subsurface level in Cochin Harbour channel increased from 17·5‰ in July to 30·5‰ at station 1 and from 0 to 19·5‰ at station 2. But from station 4 onwards the salinity of the entire region remained <1‰. In September and October also a similar pattern continued. But the surface salinity in the Harbour channel fell about 10‰ whereas the rise in the salinity of the bottom layers indicated further penetration of the sea water.

The period from November to December connected the low saline monsoonal period with the high saline premonsoonal period. The salinity steadily re-established itself from the mouth towards the head and telescoped into the high saline period. By December the surface salinity increased from 1‰ in October to 31·5‰ at station 1, 18‰ at station 2 and 14·5‰ at station 3. A corresponding increase could be observed at other station also, especially along the bottom.

The fluctuations in the salinity of the surface layers are well correlated with the rainfall of the period (Fig. 3). Salinity changes in the Cochin Harbour channel are found to be closely related to the volume of fresh water discharged into the estuary (Rama

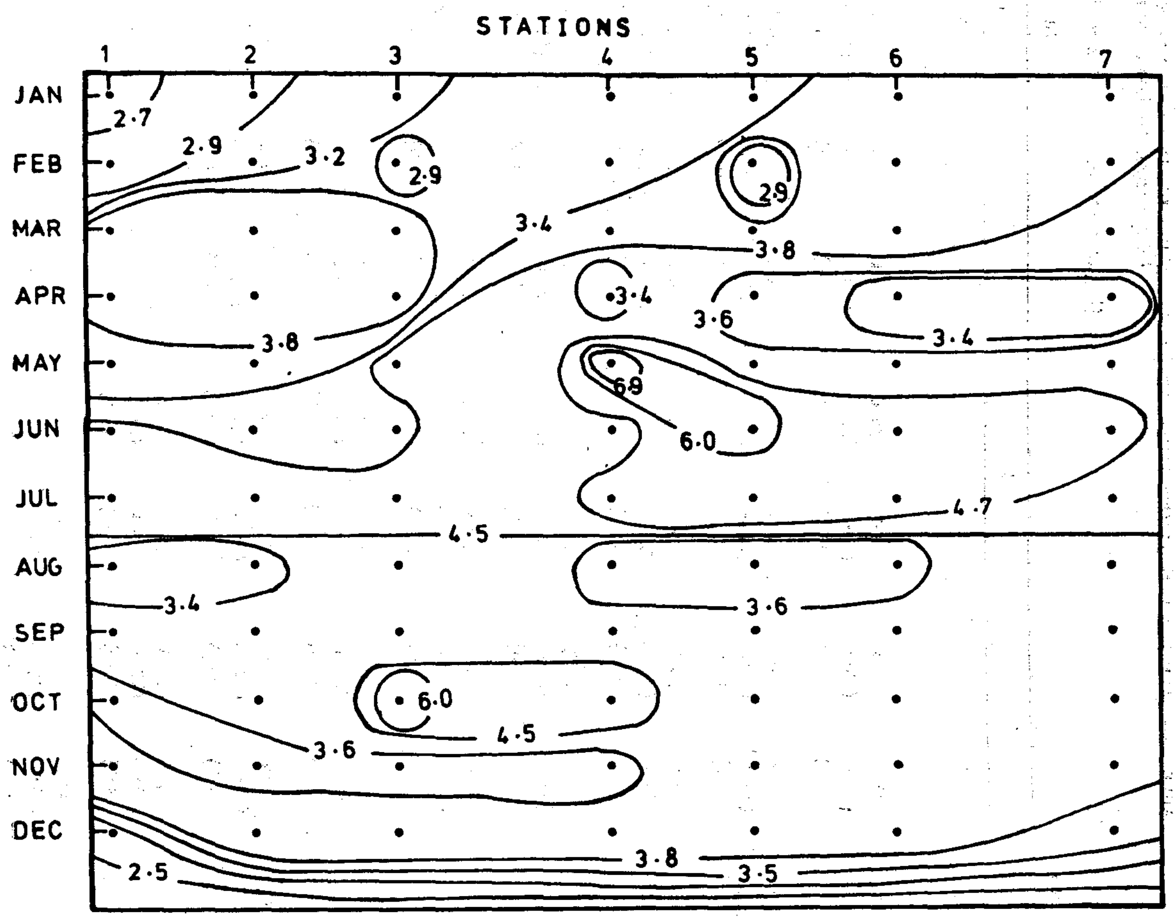

Fig. 4 — Distribution of dissolved oxygen (ml/litre) along the surface from Cochin to Alleppey during 1972

TABLE 1 — SALINITY AND TEMPERATURE AT EACH STATION DURING PREMONSOON (JANUARY TO APRIL), MONSOON (MAY TO OCTOBER) AND POSTMONSOON (NOVEMBER TO DECEMBER) SEASONS IN 1972

(Figures are mean values with range in parentheses)

Depth	Stations													
	1		2		3		4		5		6		7	
	S	T	S	T	S	T	S	T	S	T	S	T	S	T
							PREMONSOON							
0	31·5 (29·7-33·1)	29·4 (28·3-30·0)	28·8 (25·6-32·5)	29·4 (27·9-30·3)	26·4 (20·5-30·9)	29·6 (28·5-30·3)	19·7 (12·5-26·4)	30·1 (29·2-30·5)	16·6 (9·0-24·1)	30·3 (30·2-30·3)	13·9 (6·6-22·4)	30·3 (30·1-30·4)	8·0 (2·5-13·0)	30·2 (30·0-30·3)
1	31·6 (30·0-33·2)	29·5 (28·2-30·6)	28·8 (25·6-32·5)	29·3 (27·9-30·2)	26·6 (21·0-31·2)	29·7 (28·6-30·3)	20·4 (15·0-26·4)	29·9 (28·7-30·4)	16·9 (10·2-24·1)	30·1 (29·4-30·4)	14·6 (8·5-22·4)	29·9 (29·2-30·3)	8·2 (3·9-13·0)	29·8 (29·0-30·3)
2	32·1 (30·6-33·5)	29·5 (28·0-30·6)	29·0 (26·0-32·5)	29·3 (28·0-30·1)	26·7 (21·0-31·3)	29·5 (28·6-30·0)	29·2 (16·3-26·5)	29·7 (29·0-30·4)	17·1 (10·5-24·1)	30·2 (29·4-30·3)	14·8 (8·6-22·4)	29·8 (29·0-30·1)	8·5 (3·9-13·0)	30·1 (30·0-30·2)
3	32·2 (30·7-33·7)	29·2 (28·0-30·6)	29·2 (26·2-31·6)	29·3 (28·1-30·2)	26·7 (21·0-31·3)	29·6 (28·5-30·0)	21·6 (17·0-26·6)	29·7 (29·0-30·0)	17·3 (10·5-24·1)	30·1 (29·8-30·3)	— —	— —	— —	— —
4	32·4 (30·8-33·8)	29·2 (27·9-30·4)	29·4 (26·0-32·5)	29·2 (28·1-30·2)	27·0 (22·2-31·5)	29·7 (28·5-29·9)	23·3 (18·2-26·7)	29·6 (29·0-30·0)	— —	— —	— —	— —	— —	— —
5	32·5 (30·9-33·9)	29·0 (27·6-30·0)	29·8 (26·0-32·5)	29·2 (28·0-30·1)	27·9 (23·7-31·5)	27·5 (28·5-30·1)	— —	— —	— —	— —	— —	— —	— —	— —
6	32·6 (31·0-34·1)	29·0 (27·6-30·0)	30·2 (26·4-32·5)	29·2 (28·1-30·0)	28·0 (23·8-31·5)	29·4 (28·5-29·7)	— —	— —	— —	— —	— —	— —	— —	— —
7	32·7 (31·0-34·1)	29·0 (27·6-30·0)	30·2 (26·4-32·5)	29·3 (28·0-30·4)	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —
8	32·7 (31·0-34·2)	29·0 (27·5-30·0)	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —

TABLE 1 — SALINITY AND TEMPERATURE AT EACH STATION DURING PREMONSOON (JANUARY TO APRIL), MONSOON (MAY TO OCTOBER) AND POSTMONSOON (NOVEMBER TO DECEMBER) SEASONS IN 1972 — *Contd*

Depth	Stations													
	1		2		3		4		5		6		7	
	S	T	S	T	S	T	S	T	S	T	S	T	S	T
							MONSOON							
0	6·5 (0·5-17·9)	29·4 (28·0-30·0)	3·3 (0·3-12·7)	28·6 (28·0-30·5)	2·3 (0·0-10·0)	29·7 (28·0-30·7)	0·8 (0·0-3·4)	29·9 (29·0-30·7)	0·2 (0·0-1·1)	29·8 (29·1-30·4)	0	29·7 (29·1-30·1)	0	29·6 (29·1-30·0)
1	8·2 (0·5-18·7)	29·3 (27·9-30·0)	3·7 (0·5-12·7)	29·3 (27·8-30·5)	2·5 (0·0-10·5)	29·5 (27·9-30·7)	0·8 (0·0-3·5)	29·8 (29·0-30·5)	0·2 (0·0-1·0)	29·7 (28·6-30·4)	0	29·6 (28·7-30·0)	0	29·5 (28·7-30·0)
2	12·7 (0·5-26·2)	29·1 (27·7-30·1)	5·4 (0·0-16·5)	29·2 (27·4-30·4)	3·9 (0·0-14·3)	29·4 (27·9-30·3)	0·8 (0·0-3·7)	29·4 (28·1-30·5)	0·2 (0·0-1·0)	29·5 (28·2-30·5)	0	29·4 (28·5-30·0)	—	—
3	19·1 (3·0-28·5)	28·8 (27·7-29·8)	7·5 (0·0-18·1)	28·9 (27·2-30·1)	4·9 (0·0-19·7)	29·1 (27·8-30·5)	0·9 (0·0-4·1)	29·3 (28·0-30·5)	0·2 (0·0-1·1)	29·3 (28·2-30·0)	0	29·4 (28·5-30·0)	—	—
4	22·2 (3·5-29·5)	28·7 (27·5-29·2)	10·8 (0·0-21·0)	28·9 (27·0-30·0)	5·3 (0·0-21·0)	29·0 (27·5-30·4)	1·2 (0·0-5·8)	29·3 (28·0-30·5)	0·3 (0·0-1·1)	29·4 (28·0-30·0)	—	—	—	—
5	26·8 (17·5-31·6)	28·3 (26·5-29·5)	12·6 (0·0-25·7)	28·8 (27·0-30·0)	6·4 (0·0-22·3)	28·9 (27·5-30·4)	1·3 (0·0-1·3)	29·3 (28·0-30·0)	0·6 (0·0-1·1)	29·0 (28·0-30·0)	—	—	—	—
6	28·8 (20·0-32·5)	28·2 (26·9-29·0)	18·7 (0·0-26·5)	28·6 (27·0-30·0)	7·1 (0·0-19·0)	28·5 (27·4-30·2)	—	—	—	—	—	—	—	—
7	28·8 (17·5-32·8)	28·0 (26·9-28·9)	20·2 (0·0-21·5)	28·6 (27·0-30·0)	11·3 (0·0-14·1)	29·2 (27·6-30·2)	—	—	—	—	—	—	—	—
8	31·2 (28·5-33·0)	28·2 (27·0-29·0)	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 1 — SALINITY AND TEMPERATURE AT EACH STATION DURING PREMONSOON (JANUARY TO APRIL), MONSOON (MAY TO OCTOBER) AND POSTMONSOON (NOVEMBER TO DECEMBER) SEASONS IN 1972 — *Contd*

Depth	Stations													
	1		2		3		4		5		6		7	
	S	T	S	T	S	T	S	T	S	T	S	T	S	T
	POSTMONSOON													
0	23·5 (14·5-31·6)	28·7 (28·4-29·0)	13·9 (9·5-18·3)	29·6 (29·2-30·0)	10·8 (7·0-14·5)	30·3 (30·0-30·6)	3·6 (1·6-5·5)	30·4 (30·0-30·8)	1·5 (0·5-2·5)	30·3 (30·0-30·5)	0·3 (0·0-0·5)	29·9 (29·4-30·3)	0	29·8 (29·5-30·0)
1	27·9 (23·0-32·7)	29·0 (28·9-29·0)	18·0 (15·3-20·7)	29·6 (29·2-29·9)	11·3 (7·5-15·0)	30·0 (29·9-30·0)	4·7 (1·8-7·5)	30·0 (30·0-30·0)	1·5 (0·5-2·5)	30·2 (30·0-30·3)	0·5 (0·0-0·9)	29·8 (29·4-30·1)	0	29·7 (29·3-30·0)
2	31·7 (30·8-32·6)	29·9 (28·7-29·0)	20·9 (19·3-22·5)	29·4 (29·2-29·6)	17·3 (15·5-19·0)	29·9 (29·7-30·2)	5·6 (2·5-8·7)	30·0 (29·9-30·0)	1·7 (0·5-2·9)	30·0 (29·9-30·0)	1·0 (0·0-2·0)	29·3 (28·6-29·9)	0	29·3 (28·6-29·9)
3	33·0 (32·7-33·3)	28·9 (28·6-29·2)	26·7 (25·5-27·8)	29·4 (29·4-29·4)	22·0 (21·5-22·5)	29·9 (29·5-30·2)	6·0 (3·0-9·0)	29·8 (29·8-29·8)	2·0 (0·5-3·5)	29·7 (29·4-29·9)	0	29·9 (29·9-(29·9)	— — —	— — —
4	34·3 (33·8-34·7)	28·9 (28·5-29·2)	28·7 (27·2-30·2)	29·3 (29·1-29·4)	23·5 (23·5-23·5)	29·8 (29·4-30·0)	6·7 (3·0-3·3)	29·8 (10·0-29·8)	2·0 (0·5-3·5)	29·6 (29·2-29·9)	— —	— —	— —	— —
5	34·3 (33·9-34·7)	29·0 (28·5-29·4)	30·1 (29·5-30·7)	29·2 (29·0-29·3)	24·8 (24·6-24·9)	29·6 (29·2-30·0)	8·0 (4·0-12·0)	29·7 (29·6-29·8)	— —	— —	— —	— —	— —	— —
6	34·4 (34·0-34·7)	29·0 (28·5-29·4)	31·4 (30·5-32·2)	29·1 (28·9-29·2)	25·3 (24·9-26·0)	29·5 (29·0-30·0)	— —	— —	— —	— —	— —	— —	— —	— —
7	34·4 (34·0-34·7)	28·9 (28·4-29·4)	31·6 (31·0-32·2)	29·2 (28·9-29·4)	25·5 (24·9-26·0)	29·5 (29·0-30·0)	— —	— —	— —	— —	— —	— —	— —	— —
8	34·4 (34·0-34·7)	28·9 (28·4-29·4)	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —

S = salinity (‰); T = temperature (°C); — = absence of depth.

TABLE 2 — TOTAL BIOMASS OF ZOOPLANKTON AT EACH STATION DURING DIFFERENT MONTHS OF THE YEAR (1972)

[Biomass values are expressed in displacement volume (ml)]

Months	Stations 1*	2	3*	4	5	6	7
January	4	6	40	16	9	7	5
February	2	8	22	19	19	1	0·5
March	2	16	16	11	7	9	1
April	8	28	72	28	12	24	6
May	0·5	1·5	0·2	1·5	0·2	1·5	1
June	110	30	20	0·5	10	8	5
July	0·4	0·4	0·3	0·3	0·2	—	—
August	2·5	0·6	0·4	0·3	—	—	—
September	0·3	0·3	0·2	—	—	—	—
October	0·2	—	0·1	—	—	—	—
November	2	2	—	—	—	—	—
December	2	3	2·5	1·5	—	—	—

— = values less than 0·1 ml.

*High values encountered at station 3 in April and station 1 in June are due to the presence of large numbers of hydromedusae and ctenophores.

Raju, V. S., Anto, A. F. & Abraham, P., unpublished data).

An analysis of the distribution along the longitudinal axis showed that the salinity values always fell sharply after station 3 in the surface as well as the bottom layers during summer. This suggests a more pronounced influence of sea water up to this station, and conversely that of the fresh water beyond this station. During monsoons the area of fluctuation oscillated more towards the mouth of the estuary. This is because the strong fresh water flow pushed back the high saline sea water and the penetration of sea water was restricted to the bottom layers.

The nature of stratification of the estuary varied with seasons. During summer distinct stratified layers were not present. In January the difference between the surface and the bottom layers was only 0·5‰ at stations 1 to 3. At station 4 an increase of 2·5‰ was observed from 0 to 1 m depth and then a subsequent increase of 3·5‰ up to 5 m depth. In March and April the salinity profile at any of the stations did not show notable increase at any depth.

The salinity pattern exhibited marked stratification during the nonsoon period. The sharp increase in the salinity was as much as 17‰ within 1 m depth. The depth where fluctuation occurred in a particular month tended to be the same at all the stations, but it varied with months.

Thus based on the salinity changes the entire year can be broadly classified into three seasons, viz. January to April, May to October and November-December. January-February is the " season of increasing salinity " while March-April is the " season of peak salinity ". The second season, May to October is the " season of low salinity " with July as the " season of fresh water ". The period from November to December is the " season of salinity recovery ".

Temperature — The seasonal variations were well reflected in the temperature pattern also. There was a progressive increase in temperature as the summer advanced. In January the temperature at station 1 was 28·3°C at the surface and 27·5°C at the bottom. In February and March the surface temperature increased to 29·2° and 29·9°C respectively. The bottom temperature, however, after rising to 29·7°C in February fell to 28·7°C in March. April presented a uniform condition, the temperature being high throughout the estuary around 30°C.

By May the temperature showed trends of falling down with the onset of south-west monsoon. The surface temperature at station 1 was 29·9°C and the bottom temperature 28·9°C. A decrease in the rainfall in June corresponded with a small rise in general temperature pattern especially along the surface. July presented the lowest temperature conditions in sharp contrast to that of April. The fall in temperature varied from 1·2°C in the surface layers and up to 3·5°C in the bottom waters at station 1. In the other stations it ranged from 1° to 2·3°C. This was well in conjunction with the peak of the south-west monsoon and the low salinity conditions prevailing throughout the estuary. The lowest temperature, 26·5°C was recorded during this month at 5 m depth at station 1.

A similar pattern of low temperature was present in October after a small rise in August and September. The trends of further increase in temperature in November and December showed the fitting of the postmonsoonal period into the premonsoonal period.

The temperature usually decreased with depth. But at stations having shallow water the temperature did not exhibit much difference between surface and bottom layers. Sometimes cells of higher temperature were found to occur in the bottom layers at stations near the mouth. But these occurred only in the premonsoonal period in December.

Oxygen — The influence of the monsoon could be seen in the oxygen values also. An analysis of the surface oxygen values at all the stations for the whole year (Fig. 4) showed that the higher oxygen values are found during the monsoonal period. The lower values were found during the postmonsoonal and early premonsoonal periods, the lowest being 2·5 ml/litre in December at station 1. The oxygen values were low in the Harbour channel in January and February also. But they increased up to 3·9 ml/litre towards the head of the estuary. The oxygen content around the Harbour channel is relatively lower. A similar situation has been reported at the Mandovi and Zuari estuaries at Goa[9]. The higher oxygen values were observed in the late premonsoonal period and during the monsoons. The oxygen saturation appears to be uniformly high and this can be attributed to the higher primary production occurring in the surface layers during this period[10]. The maximum value 6·9 ml/litre was encountered at station 4 in the month of May. The presence of cells of high oxygen content around this station during the monsoons may be due to the discharge of oxygen rich waters from the rivers of this area.

Biomass — The effect of the changes of the hydrographical conditions were reflected on the total biomass of the zooplankton also (Table 2). During the months from January to April the biomass values were always higher at stations 2 and 3 than at the mouth and gradually decreased towards the head of the estuary. Comparatively higher values were observed throughout the estuary in April along with the peak of the summer.

With the onset of heavy rains in May, the biomass values went down to 1·5 ml and below in the entire estuary. A substantial re-establishment of plankton population could be recognized in June especially at stations nearer the mouth. This corresponds to an increase in salinity during this month. Low biomass values were observed during the rest of the monsoon period. During postmonsoon period also the biomass values were low although a slight increase could be observed at stations nearer the mouth.

Discussion

Hydrographical conditions of this estuarine system depend on the interaction of the sea and the fresh water, the sea water dominating in the summer and fresh water during the monsoon months. There is thus a seasonal pattern in the variations of the parameters.

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 the fresh water efflux which differ with seasons. The salinity always increases towards the bottom indicating a two-layered flow. During summer distinct stratified layers are absent. This well-mixed condition is probably enhanced by strong tidal currents[11].

As monsoon progresses the sea water is pushed back into the sea. Well stratified layers are present during most of the monsoon and the postmonsoon periods. During the peak period of the south-west monsoon, i.e. in July, most of the estuary becomes completely fresh water. The quantity of fresh water discharged into the backwater through the rivers and land run off is so much that the tidal influences become almost negligible.

The distribution of temperature is also affected by the monsoons. The higher temperature values of the premonsoon period fell with the advance of monsoons.

The higher oxygen values during the monsoons suggest higher primary production at the surface during this season. Qasim *et al.*[10] have found that maximum primary production occurs at the surface during the premonsoon and monsoon periods in the Cochin backwaters. Nutrient concentrations are also high during the monsoons in the backwaters[5].

The biomass values fluctuate seasonally in correlation with the hydrographical conditions prevailing in the estuary. The zooplankton populations reached their abundance along with the peak of the summer. The higher biomass values, always encountered at the areas in proximity to the month after the establishment of high salinity regime; suggest a more stable environment in this area unlike the mouth which is affected more by the mixing of the tides and turbulence. The linear decrease in the biomass towards the head of the estuary is correlated with that of salinity.

Acknowledgement

The authors wish to express their thanks to Dr N. K. Panikkar, Director, for the facilities and encouragement.

References

1. DARBYSHIRE, M., *Deep Sea Res.*, **14** (1967), 295.
2. RAMAMIRTHAM, C. P. & JAYARAMAN, R., *J. mar. biol. Ass. India*, **5** (1963), 170.
3. GEORGE, M. J. & KRISHNA KARTHA, K. N., *J. mar. biol. Ass. India*, **5** (1963), 178.
4. QASIM, S. Z., BHATTATHIRI, P. M. A. & ABIDI, S. A. H., *J. exp. mar. Biol. Ecol.*, **2** (1968), 87.
5. SANKARANARAYANAN, V. N. & QASIM, S. Z., *Mar. Biol.*, **2** (1969), 236.
6. QASIM, S. Z. & GOPINATHAN, C. K., *Proc. Indian Acad. Sci.*, **69** (6) (1969), 336.
7. NAIR, K. K. C. & TRANTER, D. J., *J. mar. biol. Ass. India*, **2** (1971), 203.
8. MENON, N. R., VENUGOPAL, P. & GOSWAMI, S. C., *J. mar. biol. Ass. India*, **13** (1971), 220.
9. SANKARANARAYANAN, V. N. & JAYARAMAN, R., *Curr. Sci.*, **41** (1971), 204.
10. QASIM, S. Z., WELLERSHAUS, S., BHATTATHIRI, P. M. A. & ABIDI, S. A. H., *Proc. Indian Acad. Sci.*, **69** (1969), **51**.
11. BOWDEN, K. F., *Estuaries* (American Association for the Advancement of Science, Washington DC), 1967, 15.