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PLANKTON OF THE HOOGHLY ESTUARY WITH SPECIAL REFERENCE TO SALINITY AND TEMPERATURE*

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ABSTRACT

The results of investigations conducted on the plankton fluctuations in the Hooghly-Matlah estuarine system during the period January, 1959 to December, 1967 are presented. The upper zones of the rivers Hooghly and Matlah have been found to be rich in phytoplankton. Taking the entire estuarine system, generally two peaks of phytoplankton abundance, with yearly variations in their magnitude are observed, the diatoms playing the most important part in determining the pattern of seasonal variations. Among the zooplankters, copepods form the dominant group. Two annual peaks of abundance have been observed in the case of zooplankton abundance also.

The surface water temperature of the estuarine system varied beteen 19.0°C and 32.5°C, with the annual range of variation between 7.7°C and 12.08°C. The salinity varied from traces to 32.77‰ in different zones. Informations so far gathered on the plankton in this major estuarine system, in relation to salinity and temperature fluctuations, is reviewed and discussed, with special reference to the fisheries potential of the area.

INTRODUCTION

THE Hooghly-Matlah estuarine system in the State of West Bengal, India, occupies the foremost position among the estuaries on the east coast of the country as regards its fisheries resources and development potential. It has biological and physico-chemical characteristics of its own, presenting a complexity of environmental situations. Like other major estuaries in the country, this is also characterised by a predominant monsoon regime, with heavy freshwater discharges. The Hooghly river mouth (Fig. 1) is rather triangular in shape and is famous for the scouring action exhibited in the region. The tidal limit in the Hooghly is up to about 296 km from the mouth. The Central Inland Fisheries Research Institute, Barrackpore (India) has been carrying out investigations relating to the fisheries of this major estuarine system, for the past few years. Studies on the plankton and hydrology have been closely integrated in this research programme and significant contributions have been made in this direction. Initially, the hydrology and plankton of the stretch of the Hooghly between Palta and Diamond Harbour (Fig. 1) were studied (Dutta *et al.*, 1954). Next, observations on the hydrology of a 248 km stretch (Nabadwip to Kakdwip) were completed (Bose, 1956). Subsequently, the programme was expanded to cover the entire Hooghly-Matlah estuarine system, covering the Hooghly, the Rupnarain and the Matlah rivers. The observations made on the general trends concerning the distribution and fluctuations of plankton of the entire system, in relation to the hydrological factors and commercial fish landings, have already been published (Shetty, *et al.*, 1961). In the present account, results of the

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studies made since then have been presented to cover the data collected during 1959 to 1967, and the same are discussed in the context of earlier observations. The data have generally been considered in 2 sets, *viz.*, those for 1959 to 1962 and 1963 to 1967, as during the latter period, some curtailment of the work had to be effected due to administrative reasons.

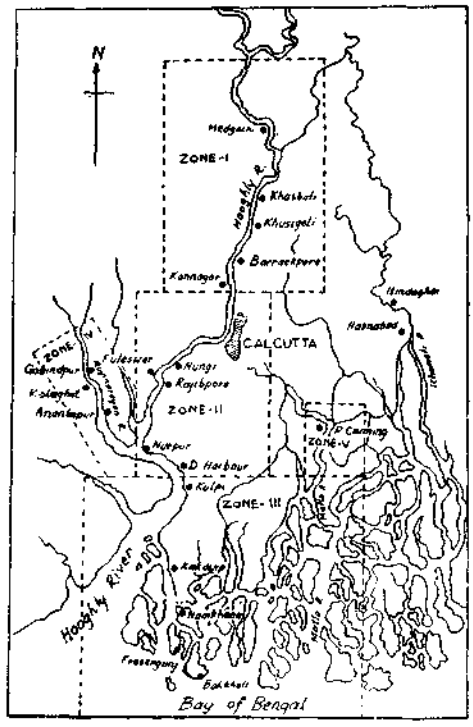

Fig. 1. Map of the Hooghly-Matlah estuarine system, showing collection centres and zones.

The centres of collection and the techniques followed were the same as described by Shetty *et al.* (*op. cit.*), being the continuation of a specific long-term programme of work. In Fig. 1 are shown the arbitrary zones into which the estuarine system has been divided for the purpose of these investigations.

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OBSERVATIONS ON PLANKTON COMMUNITIES

Phytoplankton

The results of investigations conducted since the inception of this programme have indicated that phytoplankton plays the dominant role in determining the quantitative distribution of total plankton in the Hooghly-Matlah Estuarine system (Shetty *et al.*, 1961). The present observations confirm this. The other significant

points brought out are that the upper zones of the rivers Hooghly and Matlah are generally rich in phytoplankton and that, while freshwater species predominate in the upper reaches of the Hooghly, the marine forms form the bulk in the lower zones of both the rivers. The zone-wise monthly averages and percentage composition of the major groups are given in Table 1. The fluctuation in total plankton is shown in Figs. 2 to 6.

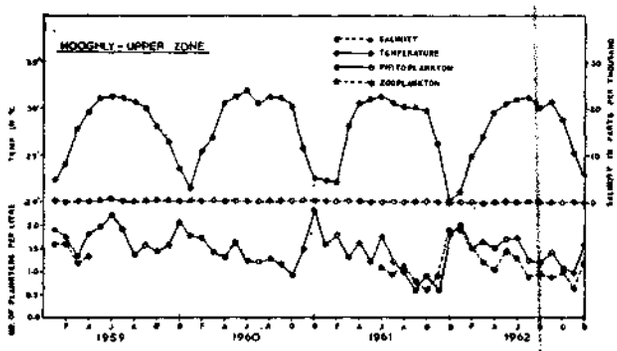

Fig. 2. The average monthly number of phytoplankton and zooplankton on a logarithmic scale, and the average monthly surface temperature and salinity in Zone I.

The present observations, along with the earlier ones (Shetty *et al.*, 1961) have shown that the diatoms determine the distribution of phytoplankton in all the regions of this estuarine system. The species responsible for the abundance in the different zones are given below:

Zone I:

Coscinodiscus granii
Coscinodiscus spp.
Melosira granulata
Synedra ulna

Zones II & IV:

C. granii
Synedra ulna
Skeletonema costatum
Hemidiscus hardmanianus
M. granulata
Triceratium sp.

Zones III & V:

Chaetceeros spp.
Biddulphia mobiliensis
S. costatum
Lithodesmium sp.
C. granii

Blue green algae, mainly species belonging to genera *Oscillatoria, Phormidium, Lyngbya, Nostoc, Microcystis* and *Trichodesmium* were collected from all the zones, but more from the regions of transient salinity.

The distribution of green algae was mainly in the freshwater zone only. The dominant forms encountered are: *Spirogyra* spp., *Mougeotia* spp., *Volvox* spp., *Pediastrum* spp., *Chlorella* spp. and *Seenedesmus* sp. The peak periods of their occurrence are generally observed in the winter seasons.

TABLE 1. *Zone-wise monthly averages (No./L) and percentage composition of the main phytoplankton groups*

Year	Group	Zone I		Zone II		Zone III		Zone IV		Zone V	
		Monthly average	% composition	Monthly average	% composition	Monthly average	% composition	Monthly average	% composition	Monthly average	% composition
1959	Diatoms	166.04	78.05	27.57	73.82	244.27	91.67	51.48	91.45	98.87	96.16
	Bluegreen algae	5.31	2.50	2.56	6.85	14.20	5.33	0.60	1.07	0.46	0.45
	Green algae	39.41	18.53	3.68	9.85	0.52	0.19	2.30	4.09	0.42	0.41
	Misc.	1.95	0.92	3.54	9.48	7.48	2.81	1.91	3.39	2.43	2.38
	Total	212.71		37.35		266.47		56.29		102.18	
1960	Diatoms	92.43	63.44	75.95	85.49	144.20	93.36	73.60	83.52	124.56	97.52
	Bluegreen algae	6.77	4.65	1.73	1.95	7.37	4.77	4.02	4.56	0.75	0.59
	Green algae	44.14	30.30	7.62	8.58	0.12	0.08	4.50	5.11	0.47	0.37
	Misc.	2.35	1.61	3.54	3.98	2.77	1.79	6.00	6.81	1.95	1.53
	Total	145.69		88.84		154.46		88.12		127.73	
1961	Diatoms	76.02	59.67	42.92	89.60	82.47	97.22	60.02	86.30	82.52	97.40
	Bluegreen algae	20.85	16.37	0.43	0.90	0.28	0.33	4.75	6.83	0.25	0.30
	Green algae	30.52	23.96	4.11	8.58	0.72	0.85	4.73	6.80	—	—
	Misc.	—	—	0.44	0.92	1.36	1.60	0.05	0.07	1.95	2.30
	Total	127.39		47.90		84.83		69.55		84.72	
1962	Diatoms	98.25	58.59	68.10	97.12	129.50	72.57	90.46	71.51	33.75	97.63
	Bluegreen algae	23.44	13.98	0.91	1.30	45.06	25.25	28.50	22.53	0.08	0.23
	Green algae	44.63	26.61	0.86	1.23	0.30	0.17	6.96	5.50	0.08	0.23
	Misc.	1.38	0.82	0.25	0.36	3.58	2.01	0.58	0.46	0.66	1.91
	Total	167.70		70.12		178.44		126.50		34.57	
1963	Diatoms	26.68	73.88	Samples	could	not	be	collected		45.00	98.99
	Bluegreen algae	5.05	13.98	,,	,,	,,	,,	1.35	4.81	0.08	0.18
	Green algae	4.38	12.13	,,	,,	,,	,,	1.20	4.28	—	—
	Misc.	—	—	,,	,,	,,	,,	0.25	0.89	0.38	0.84
	Total	36.11					,,	28.05		45.46	

	Diatoms	21.56	59.07	,	,,	,,	,,	21.75	66.23	91.20	99.42
	Bluegreen algae	3.80	10.41	,,	,,	,,	,,	9.34	28.44	0.12	0.13
1964	Green algae	11.14	30.52	,,	,,	,,	,,	1.75	5.33	0.05	0.05
	Misc.	—	—	,,	,,	,,	,,	—	—	0.36	0.39
	Total	36.50		,,	,,	,,		32.84		91.73	
	Diatoms	11.23	49.73	,,	,,	,,	,,	30.00	62.18	38.30	99.35
	Bluegreen algae	2.00	8.86	,,	,,	,,	,,	13.25	27.46	0.25	0.65
1965	Green algae	7.10	31.44	,,	,,	,,	,,	4.75	9.84	—	—
	Misc.	2.25	9.96	,,	,,	,,	,,	0.25	0.52	—	—
	Total	22.58	—	,,	,,	,,	,,	48.25		38.55	
	Diatoms	22.76	66.43	,,	,,	,,	,,	45.25	94.37	76.83	97.77
	Bluegreen algae	2.50	7.30	,,	,,	,,	,,	1.75	3.65	0.50	0.64
1966	Green algae	9.00	26.27	,,	,,	,,	,,	0.95	1.98	—	—
	Misc.	—	—	,,	,,	,,	,,	—	—	1.25	1.59
	Total	34.26		,,	,,	,,	,,	47.95		78.58	
	Diatoms	32.48	91.67	,,	,,	,,	,,	12.75	87.92	65.70	96.25
	Bluegreen algae	0.95	2.68	,,	,,	,,	,,	1.25	8.62	0.25	0.37
1967	Green algae	2.00	5.65	,,	,,	,,	,,	0.50	3.45	0.15	0.22
	Misc.	—	—	,,	,,	,,	,,	—	—	2.16	3.16
	Total	35.43		,,	,,	,,	,,	14.50		68.26	

As indicated in the earlier account given by Shetty *et al.* flagellates and euglenoids, mostly *Euglena* spp., *Phacus* sp. and *Trachelomonas* spp., are present in the freshwater and transient zones. The dinoflagellates like *Ceratium* spp; *Peridinium* spp. and *Noctiluca* sp., however, are present in appreciable numbers in the marine zones (III & V) only. The Chrysophycean alga *Dinobryon* sp. is present in the freshwater region only.

Zooplankton

The monthly zone-wise averages and percentage composition of the main zooplankton groups are given in Table 2. These observations confirm that the main trends are: (i) The copepods constitute the major groups in the zooplankton of the estuarine system, (ii) Rotifera and larval forms predominate in some of the regions, (iii) Rotifera, Protozoa and Cladocera are present in large numbers in the freshwater and transient zones and (iv) Larval forms, mainly those of crustaceans, occur in all the zones. A progressive increase in zooplankton production has been observed, except in Zone III.

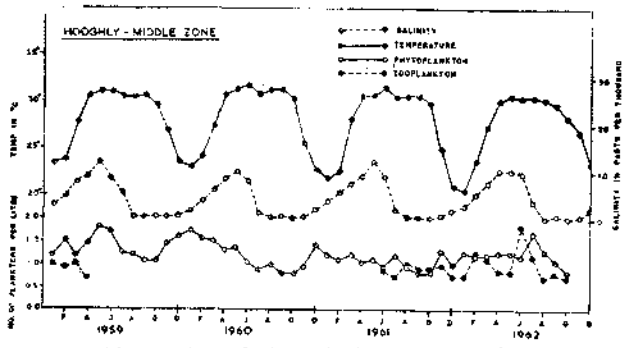

Fig. 3. The average monthly number of phytoplankton and zooplankton on a logarithmic scale, and the average monthly surface temperature and salinity in Zone II.

The present data, as well as those published earlier, show that the zooplankton shows 2 peaks of abundance every year, during the winter season (November to January) and June to August. The fluctuation in total plankton is shown in Figs. 2 to 6. *Difflugia* spp.and other rhizopods are the most common protozoans in all the estuarine zones The other more common forms are *Arcella* sp., Foraminifera, Radiolaria, *Vorticella* sp., tintinnids and Actinopoda.

The more common rotifers encountered in this estuarine system are: *Brachionus* spp., *Keratella* spp., *Filinia* sp., *Trichocerea* sp., *Asplanchna* sp; and *Tetramastix* sp.

As regards copepods, 2 peaks of abundance (November to February and June to July) are significant. It has now been confirmed that the monsoon months are generally the poorest for copepod production. The important forms present are: *Pseudodiaptomus* spp., *Diaptomus* spp., *Cyclops* spp., *Acartiella* spp., *Microsetella* sp. and *Paracalanus* sp.

The Cladocera are generally found in the freshwater and upper transient zones, the maximum number collected being in the winter season. The dominant species

are: *Bosmina* sp., *Moina* sp., *Daphnia* sp., *Ceriodaphnia* sp., *Bosminopsis* sp., *Diaphanosoma* sp., and *Holopedium* sp.

Larval forms, mostly of invertebrates, have been collected from almost throughout the estuarine system, with some seasonal differences as was evident from the initial studies also (Shetty *et al.*, 1961). The crustacean larvae form the most important group, the others being megalopa, gastropod and lamellibranch veligers, annelid larvae and Cyphonautes. Larvae of sponges, Ophiopluteus, euphausids, mysids, insect larvae and fish larvae also occurred in the collections, though in lesser quantities.

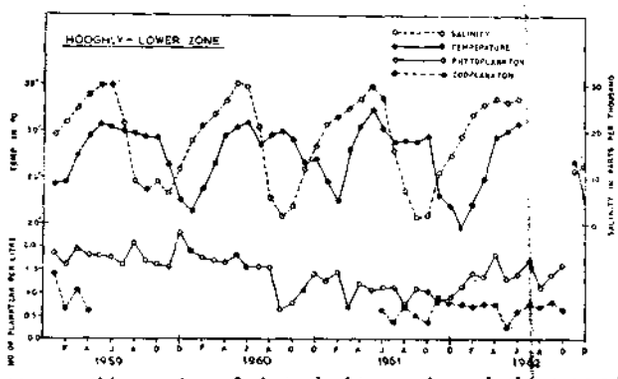

Fig. 4. The average monthly number of phytoplankton and zooplankton on a logarithmic scale, and the average monthly surface temperature and salinity in Zone III.

OBSERVATIONS ON HYDROLOGY

The data obtained on the salinity and temperature of surface waters are presented in Tables 3 to 6 and Figs. 2 to 6. From these as well as the earlier data it is possible to draw clear pictures of the temperature and salinity fluctuations in the entire estuarine system. The temperature varied between 19.33°C and 32.29° C during 1959 - 62 and 19.00°C to 32.50°C during 1963-67. The observations so far made clearly indicate that in this estuarine system there is no longitudinal temperature gradient from the freshwater to the marine zones, though seasonal fluctuations are present. The maximum and minimum temperatures are generally recorded in the pre-monsoon and post-monsoon months respectively, in all the zones, excepting Zone IV, where the maximum temperature is found during the monsoon season. However, the mean temperature during monsoons has been observed to be higher in all zones except Zone III. The yearly temperature distribution is bimodal, with peaks in May-June and Sept-Oct., the former peak being higher than the latter. The earlier observations had indicated that the September peak was higher than the May-June peak in Zone V (Shetty *et al.*, 1961). December-February has generally been found to be the low temperature period (19.00°C -25.64° C).

High salinity values are found to be common during May-June in the Hooghly and Matlah and during April-May in the Rupnarain. The data show the presence of 1 peak during pre-monsoon period (March-June), in all the zones. Almost freshwater conditions are observed in the upper reaches of the Hooghly and Rupnarain. As could be expected, the middle zone always presents wide salinity fluctuations.

TABLE 2. *Zonewise monthly averages (No./ L) and percentage composition of the main zooplankton groups*

Year	Group	Zone I Monthly average	Zone I % composition	Zone II Monthly average	Zone II % composition	Zone III Monthly average	Zone III % composition	Zone IV Monthly average	Zone IV % composition	Zone V Monthly average	Zone V % composition
1959	Copepods	3.25	10.75	7.25	32.97	22.50	72.35	3.68	73.75	2.60	29.28
	Cladocerans	0.25	0.83	—	—	0.12	0.39	—	—	0.56	6.31
	Rotifers	20.41	67.49	1.25	5.68	0.12	0.39	—	—	0.19	2.14
	Protozoans	0.75	2.48	—	—	2.12	6.82	—	—	0.25	2.81
	Larvae	5.25	17.36	12.55	57.07	5.55	17.84	1.31	26.25	5.22	58.78
	Misc.	0.33	1.09	0.94	4.28	0.60	2.22	—	—	0.06	0.68
	Total	30.24		21.99		31.10		4.99		8.88	
1960		Data for 1960 could not be collected.									
1961	Copepods	18.12	56.41	15.68	53.30	7.00	41.18	18.00	25.44	7.28	68.10
	Cladocerans	3.25	10.12	0.25	0.85	0.15	0.88	1.00	1.41	—	—
	Rotifers	2.50	7.78	1.25	4.25	0.40	2.35	21.25	30.03	0.53	4.96
	Protozoans	0.50	1.56	0.43	1.46	0.50	2.94	0.45	0.64	0.42	3.93
	Larvae	6.50	20.24	10.81	36.74	7.00	41.18	21.25	30.03	2.00	18.71
	Misc.	1.25	3.89	1.00	3.40	1.95	11.47	8.80	12.44	0.46	4.30
	Total	32.12		29.42		17.00		70.75		10.69	
1962	Copepods	22.85	29.75	14.02	38.79	12.80	46.13	9.17	14.90	6.58	62.79
	Cladocerans	6.47	8.42	0.20	0.55	—	—	0.90	1.46	—	—
	Rotifers	20.12	26.19	1.02	2.82	1.85	6.67	15.08	24.51	0.25	2.38
	Protozoans	0.85	1.11	0.32	0.89	1.50	3.40	0.50	0.81	0.25	2.38
	Larvae	25.25	32.87	20.16	55.78	10.55	38.02	31.43	51.08	2.90	27.67
	Misc.	1.27	1.65	0.42	1.16	1.05	3.78	4.45	7.23	0.50	4.77
	Total	76.81		36.14		27.75		61.53		10.48	
1963	Copepods	7.28	23.76	Samples could not be collected				8.25	48.53	7.50	64.65
	Cladocerans	4.20	13.71	,,	,,	,,	,,	0.75	4.41	—	—
	Rotifers	12.21	39.86	,,	,,	,,	,,	3.50	20.59	—	—
	Protozoans	1.26	4.11	,,	,,	,,	,,	0.25	1.47	0.35	3.02
	Larvae	5.68	18.54	,,	,,	,,	,,	3.50	20.59	3.25	28.02
	Misc.	—	—	,,	,,	,,	,,	0.75	4.41	0.50	4.31
	Total	30.63		,,	,,	,,	,,	17.00		11.60	

1964	Copepods	9.00	35.57	,,	,,	,,	,,	7.55	38.62	4.39	38.37
	Cladocerans	7.40	29.25	,,	,,	,,	,,	1.25	6.39	—	—
	Rotifers	3.00	11.86	,,	,,	,,	,,	4.50	23.02	—	—
	Protozoans	0.75	2.96	,,	,,	,,	,,	0.50	2.56	0.55	4.81
	Larvae	3.50	13.83	,,	,,	,,	,,	5.25	26.85	2.00	17.48
	Misc.	1.65	6.52	,,	,,	,,	,,	0.50	2.56	4.50	39.34
	Total	25.30		,,	,,	,,	,,	19.55		11.44	
1965	Copepods	2.90	21.06	,,	,,	,,	,,	12.60	43.90	3.00	38.96
	Cladocerans	2.47	17.94	,,	,,	,,	,,	0.95	3.31	—	—
	Rotifers	0.90	6.54	,,	,,	,,	,,	9.40	32.75	0.10	1.30
	Protozoans	0.50	3.63	,,	,,	,,	,,	0.50	1.74	0.65	8.44
	Larvae	5.50	39.94	,,	,,	,,	,,	3.25	11.32	3.25	42.21
	Misc.	1.50	10.89	,,	,,	,,	,,	2.00	6.97	0.70	9.09
	Total	13.77		,,	,,	,,	,,	28.70		7.70	
1966	Copepods	5.50	26.35	,,	,,	,,	,,	6.00	28.92	5.80	38.54
	Cladocerans	6.77	32.44	,,	,,	,,	,,	0.50	2.41	—	—
	Rotifers	5.00	23.96	,,	,,	,,	,,	7.25	34.94	0.25	1.66
	Protozoans	0.50	2.40	,,	,,	,,	,,	0.25	1.20	2.00	13.29
	Larvae	2.25	10.78	,,	,,	,,	,,	6.00	28.92	5.50	36.54
	Misc.	0.85	4.07	,,	,,	,,	,,	0.75	3.61	1.50	9.97
	Total	20.87		,,	,,	,,	,,	20.75		15.05	
1967	Copepods	2.00	16.33	,,	,,	,,	,,	3.50	51.47	3.50	31.82
	Cladocerans	2.50	20.41	,,	,,	,,	,,	0.25	3.68	—	—
	Rotifers	2.00	16.33	,,	,,	,,	,,	0.25	3.68	0.25	2.27
	Protozoans	1.25	10.20	,,	,,	,,	,,	0.05	0.74	2.50	22.73
	Larvae	3.75	30.61	,,	,,	,,	,,	2.50	36.76	4.25	38.64
	Misc.	0.75	6.12	,,	,,	,,	,,	0.25	3.68	0.50	4.55
	Total	12.25		,,	,,	,,	,,	6.80		11.00	

TABLE 3. *Annual surface water temperature (°C) of different zones during 1959-1967*

Year	Zone I			Zone II			Zone III			Zone IV			Zone V		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1959	31.25	22.33	27.98	31.07	23.37	28.24	30.63	22.59	27.83	30.77	21.63	27.59	30.77	21.93	27.39
1960	32.08	21.43	28.20	31.68	22.66	28.29	30.93	21.58	27.74	30.38	20.83	27.77	31.20	20.72	27.34
1961	31.20	20.11	27.66	31.33	20.90	27.77	32.29	21.90	27.44	31.37	19.75	27.31	29.60	21.45	26.95
1962	31.35	20.89	27.83	30.63	20.55	27.58	30.90	19.62	—	31.33	19.33	27.41	30.50	20.50	27.11
1963	31.01	20.95	28.00	31.17	21.59	28.16	30.73	20.46	27.88	31.08	19.00	27.29	30.95	20.32	27.48
1964	32.50	21.78	—	31.57	23.12	28.44	31.98	22.96	28.27	31.12	21.04	27.79	30.45	22.25	27.42
1965	—	—	—	30.90	21.73	27.84	30.85	21.57	27.77	31.92	21.84	28.22	30.40	21.30	26.91
1966	—	—	—	31.25	20.21	28.04	31.09	20.68	27.85	31.21	21.75	28.10	31.25	20.55	27.08
1967	—	—	—	31.93	21.37	28.78	32.09	21.75	27.90	32.21	22.91	–	30.85	20.15	27.80

TABLE 4 a. *Zonewise seasonal variations of surface water temperature (°C) during 1959-1962*

Zone	Pre-monsoon (March-June)			Monsoon (July- October)			Post-monsoon (November-February)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minium	Mean
I	30.94–32.08	26.81–28.12	29.45–30.44	30.58–31.35	28.06–30.28	29.93–30.76	25.62–26.43	20.11–21.99	23.01–24.17
II	30.63–31.68	27.31–28.26	29.67–30.25	30.46–31.27	28.36–30.26	29.71–30.84	24.48–26.84	20.55–22.93	22.42–24.32
III	30.63–32.29	26.57–27.91	29.31–30.23	29.50–29.93	28.51–29.27	29.09–29.54	23.20–26.98	19.62–22.50	21.72–25.11
IV	30.38–31.37	26.77–28.99	29.20–30.18	30.12–31.42	27.97–29.92	29.56–30.95	24.87–25.70	19.00–21.67	21.70–23.15
V	29.55–31.20	25.65–26.85	27.77–29.66	29.60–31.17	28.27–29.30	29.21–30.10	25.35–27.42	20.32–21.45	23.01–25.66

TABLE 4 b. *Zonewise seasonal variations of surface water temperature (°C) during 1963-1967*

Zone	Pre-monsoon (March - June)			Monsoon (July - October)			Post-monsoon (November-February)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
I	31.01–31.51	26.82–28.66	29.24–30.30	31.00–32.50	30.12–30.54	30.79–31.17	—	—	—
II	30.78–31.57	27.05–29.50	29.55–30.55	30.34–31.37	29.24–30.52	29.85–30.91	26.01–27.22	20.21–23.12	24.15–24.76
III	30.73–32.09	26.62–29.31	29.26–30.67	30.13–31.12	28.49–29.93	29.78–30.25	25.55–27.76	20.68–22.96	22.93–24.66
IV	31.08–32.21	26.45–29.20	28.63–30.66	29.69–31.00	27.68–30.25	28.79–30.56	24.90–28.14	21.04–22.83	22.97–25.11
V	30.40–31.25	26.02–28.10	28.64–29.61	29.22–30.62	28.47–29.62	28.94–30.06	25.82–26.55	20.15–22.25	22.94–23.91

The lower zone of the Hooghly and Matlah show salinities between 1.56 - 32.77 ppt and 4.49 - 31.60 ppt respectively (Table 5).

DISCUSSION

The results from earlier investigations conducted under this programme of work (Dutta *et al.*, 1954; Bose, 1956; Shetty *et al.*, 1961) have indicated the relationship between hydrological factors and plankton production in the Hooghly-Matlah estuarine system. Other studies like those of Roy (1955) have also dealt with the factors determining the fluctuations and distribution of plankton communities in the Hooghly sector. On the basis of such background knowledge, the observations described in this paper, particularly the role played by the more important parameters *viz.*, salinity and temperature in the production of plankton in the different regions of the estuarine system is highlighted. There is practically no longitudinal temperature gradient and vertical thermal stratification in the entire system, the homothermy being, probably, attributable to the combined effects of the characteristic morphology of the rivers and the violent tidal mixing (Pantulu and Bhimachar, 1964). The presence of 2 peaks in the abundance of plankton has been confirmed

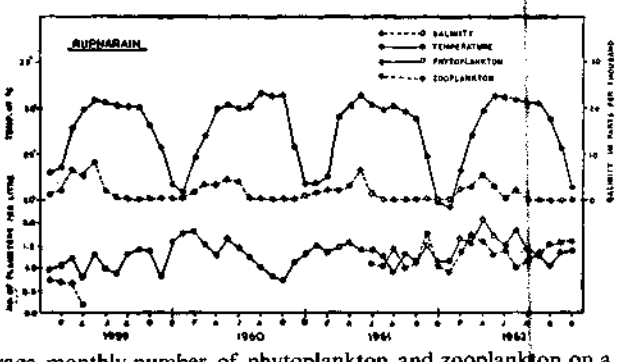

Fig. 5. The average monthly number of phytoplankton and zooplankton on a logarithmic scale, and the average monthly surface temperature and salinity in Zone IV.

by the present data. This indicates that, in addition to the abundance of some forms during the winter season, when the temperature is low, there are some species which predominate at higher temperature regimes also. Shetty *et al.* have enumerated the species which prefer high and low temperatures. The present observations indicate that the diatoms which tolerate higher temperatures are mainly *Synedra ulna, Ditylum brightwelli, Coscinodiscus granii* and *Chaetoceros* spp., while those thriving well at lower temperatures are certain species of *Coscinodiscus, Melosira* sp., *Chaetoceros* sp. and *Biddulphia* sp. However, different species of *Chaetoceros* and *Biddulphia* have been found to be less sensitive to temperature changes and occur in substantive numbers during both high and low temperature regimes, as has been indicated earlier by Shetty *et al.* Low temperatures have been found to be more congenial for the growth of green algae and certain genera of blue green algae.

Data on the distribution of zooplankton have indicated that while many of the rotifers and cladocerans show an inverse relationship with the water temperature, some species of *Brachionus* and *Keratella* appear to have wide powers of temperature tolerance. *Bosminopsis* may thrive well in higher temperatures, while the copepods prefer lower levels, although they may be available throughout the year.

TABLE 5. *Annual salinity (ppt.) at different zones during 1959-1967*

Year	Zone I			Zone II			Zone III			Zone IV			Zone V		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1959	0.60	Tr.	Tr.	11.82	Tr.	4.19	29.89	6.32	18.14	8.23	Tr.	2.14	27.52	4.49	16.60
1960	Tr.	Tr.	Tr.	9.90	Tr.	3.42	30.09	1.67	17.39	4.90	Tr.	1.46	28.85	11.80	18.01
1961	Tr.	Tr.	Tr.	12.08	Tr.	4.28	29.92	1.56	17.21	6.52	Tr.	1.37	28.04	10.55	20.00
1962	Tr.	Tr.	Tr.	10.04	Tr.	4.36	27.13	–	–	5.51	Tr.	1.30	27.64	10.12	19.82
1963	Tr.	Tr.	Tr.	17.76	Tr.	6.62	29.25	7.60	18.27	11.36	Tr.	3.49	25.56	9.27	18.85
1964	Tr.	Tr.	Tr.	17.77	Tr.	5.59	32.52	5.96	18.64	5.94	Tr.	3.11	31.60	11.12	19.66
1965	Tr.	Tr.	Tr.	18.87	Tr.	6.31	31.49	6.70	19.85	5.86	Tr.	1.08	29.60	7.98	18.08
1966	–	–	–	20.81	Tr.	8.02	32.28	10.36	21.29	14.63	Tr.	3.21	29.27	13.02	21.75
1967	–	–	–	22.19	Tr.	8.10	32.77	4.97	21.97	15.58	Tr.	–	28.68	7.21	18.47

TABLE 6 a. *Seasonal variations in salinity (ppt.) at the different zones during 1959-1962*

Zone	Pre-monsoon (March - June)			Monsoon (July - October)			Post-monsoon (November - February)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
I	Tr. – 0.60	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
II	9.90–12.08	6.05– 7.82	8.09– 9.40	1.17– 5.18	Tr.	0.29– 1.29	3.58– 9.99	Tr. – 0.58	1.40– 4.60
III	27.13–30.09	23.51–25.98	26.65–28.05	15.95–21.57	1.56– 7.15	6.69–11.65	20.72–23.74	6.32–11.99	14.19–18.52
IV	4.40– 8.23	0.28– 3.15	2.86– 5.49	Tr. – 1.81	Tr.	Tr. – 0.45	1.71– 5.00	Tr.	0.52– 1.47
V	27.52–28.85	20.92–22.80	25.47–26.02	17.89–26.89	4.49–13.51	12.99–19.85	17.31–19.22	4.81–12.34	10.93–15.21

TABLE 6 b. *Seasonal variations in salinity (ppt.) at the different zones during 1963-1967*

I	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
II	17.77–22.19	7.93–12.11	13.34–17.61	0.39– 9.62	Tr.	Tr. – 2.66	4.45– 8.58	0.24– 2.20	2.59– 4.67
III	29.25–32.52	22.72–26.44	26.97–30.34	13.22–32.77	4.97–10.36	8.47–15.94	21.30–22.70	11.53–14.77	16.72–18.69
IV	5.86–15.58	0.60– 9.35	2.47–11.72	Tr. – 1.55	Tr.	Tr. – 0.38	0.44– 6.01	Tr.–0.95	0.20– 2.33
V	25.56–31.60	21.28–22.95	24.12–28.04	18.77–28.68	7.21–17.71	15.33–23.80	15.69–17.58	9.27–13.02	13.05–14.27

The salinity of the Hooghly-Matlah Estuarine System is known to exhibit intensive variations. No vertical stratification of salinity has been observed in any of the components of the system, which is attributable to the combined action of the uneven nature of the substratum, violent tides, 'bores', morphology of the mouth region and silting pattern (Pantulu and Bhimachar, 1964). Generally in estuarine waters of this kind, the biota are composed of marine species which move into its different zones, resident species which normally prefer the transient zones and freshwater forms which generally inhabit the upper zones. The zooplankton distribution observed in the present studies tend to follow this general pattern. The presence of copepods as the dominant element in all the zones of the estuarine system is significant, but it would be worthwhile if copeopod distribution is studied species-wise, which was beyond the scope of the present programme. The presence of rotifers, cladocerans and protozoans in large numbers in the freshwater and upper region of the transient zones is another phenomenon related to the overall salinity pattern.

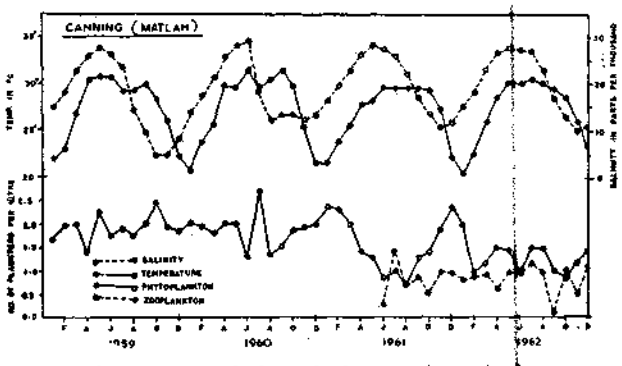

Fig. 6. The average monthly number of phytoplankton and zooplankton on a logarithmic scale and the average monthly surface temperature and salinity in Zone V.

Shetty *et al.* were able to find an indirect relation between plankton production and rainfall in the Matlah only. The phosphate (PO_4) content of the system is normally high during the hot months and maximum in the lower freshwater and upper transient zones (Bose, 1956). High turbidity values have been recorded during the monsoon seasons. No regular trend in the fluctuations of dissolved oxygen from surface to bottom, has been observed.

The increased plankton production during the winter months, especially in the lower zone of the estuarine system, is known to induce immigration of several marine and freshwater fishes into the area. The spawning seasons of many species of commercially important fishes also coincide with this period (Pantulu and Bhimachar, 1964; Gopalakrishnan, 1968). The secondary plankton peak in the warmer waters is probably due to the availability of large quantities of nutrients in the water, caused by violent tidal turbulence. More remains to be known on the interrelationship between the distribution of nutrients in this estuarine environment, especially with reference to fish populations and further studies in this direction would be desirable.

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