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PLANKTON OF THE NARMADA ESTUARY AND ADJACENT CREEKS

S. N. GAJBHIYE, JIYALAL RAM, VIJAYALAKSHMI R. NAIR AND B. N. DESAI
National Institute of Oceanography, Regional Centre, Bombay-400 061

ABSTRACT

Phytoplankton pigments and abundance of zooplankton in the Narmada estuary, Bukki creek and Dahej creek were studied from March to September, 1979. The river sustained an appreciable quantity of phytoplankton pigments with relatively higher values towards the upstream stations. Mean chlorophyll was highest during the premonsoon period (31·48 mg/m^3) and lowest (7·8 mg/m^3) in the monsoon period. Average value of chlorophyll showed a rise in the postmonsoon period (19·3 mg/m^3). Zooplankton abundance in the river was not very high and mean biomass was maximum in September (2·72 m^3/100 m^3). The lowest biomass was in the monsoon period (0·41 ml/100 m^3). During the premonsoon period zooplankton biomass was moderate (1·68 ml/100 m^3). Copepods, decapod larvae, molluscan veligers, fish larvae and fish eggs were the most common groups in the collections. Incidence of cheatognaths in the river was in accordance with the prevailing salinity regime. Diversity of zooplankton was greater towards the mouth region. Biological characteristics of Dahej creek were comparable to that of the Narmada mouth while that of Bukki creek were similar to the upstream stations of the river.

INTRODUCTION

Although most of the rivers along the west coast of India are rich in plant and animal life, the increasing human activity has its impact on the environment imposing stress on the ecosystem. Therefore, to minimise pollution hazards to the Narmada river, the Gujarat Narmada Valley Fertilizers Company (GNFC) Limited, Bharuch, Gujarat, approached the National Institute of Oceanography, Bombay, for finding a suitable discharge point for the factory effluents in the river. Biological productivity of the area formed part of this investigation. Phytoplankton pigment concentration and zooplankton abundance in the entire estuarine system were studied for the period March-September 1979. The present investigation is the first report on the plankton of the Narmada river.

Narmada is one of the major river systems along the west coast of India. The river joins the sea close to Luwara (Fig. 1). The mouth of the estuary is approximately 20 km wide and is connected to the Gulf of Cambay. The extensive sand banks in the estuary are exposed during low tide and these keep shifting from season to season. The river also contains many sand banks with shallow channels in between them. Southwest monsoon has much influence on this river during July-August.

MATERIAL AND METHODS

During the period March-September 1979 samples were collected from 11 stations located along the 55 km stretch in the Narmada river (Fig. 1). In April no collection was taken. Due to navigational problems all the stations could not be covered each month. A few samples were collected from two adjacent locations–Bukki creek (St. 12), north west of Bharuch and Dahej creek (St. 13), north of the mouth of Narmada. For the estimation of phytoplankton pigments surface water samples were collected using a clean plastic bucket. In August from stations 6, 7, 8 and 10, samples were collected every 2–4 hours for a period of twelve hours to study the changes in chlorophyll and carotenoids concentrations. Analysis was done following the method of Strickland and Parsons (1968). Zooplankton samples were collected by surface hauls of 5 minutes duration using a Heron Tranter Net (mesh size 0·3 mm, mouth area 0·25 m^2) with a flow meter attached. Samples were preserved in 5% formalin and 25% of each sample was analysed for the enumeration of different groups of organisms. The period of study represents the premonsoon (March and May), monsoon (July and August) and postmonsoon (September) prevalent in the area.

RESULTS

Hydrographic conditions: The physical and chemical characteristic of this area were studied in detail (NIO Report, 1980) and some of the important features based on the above investigations are given below. Although tidal effect was noticed upto Station 1; the intrusion of saline water occurred only upto Station 6. Hence, the waterbody between station 1 and 6 was considered as fresh water zone and stations 7 and 11 as estuarine zone. The estuarine zone is well mixed without any significant vertical salinity gradient. Variations in the environmental parameters at these two

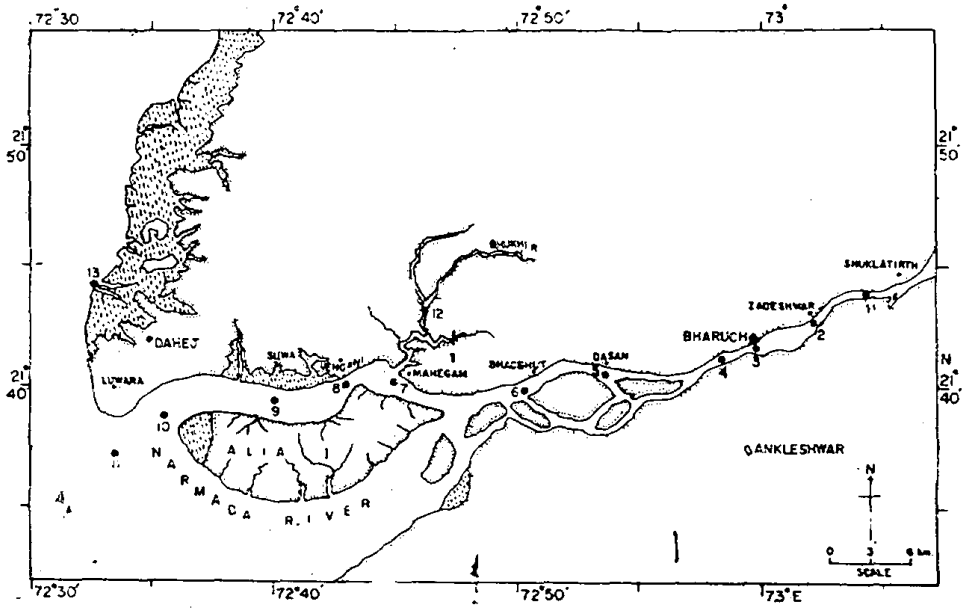

Fig. 1. Location of stations in the Narmada estuary and adjacent creeks.

zones are given in Table I. Temperature varied between 25.5 and 31.2°C with relatively high values in June. Dissolved oxygen ranged between 6.6 and 9.2 ml/l suggesting a very good water quality for aquatic life. Phosphate and nitrate concentrations were relatively higher towards the downstream stations. The levels of phosphate and nitrate in March varied between 0.5–5.29 and 3.57–13.71 µg-at/l respectively. The concentration of phosphate was fairly high (0.39–12.16 µg-at/l) during the monsoon period while the nitrate values (0.07–81.0 µg-at/l) increased appreciably. At St. 12 the recorded salinity was 0.9‰. The range of salinity at St. 13 was 18.08–24.56‰ during July and August.

Pigment concentration: Fig. 2 and Table II give the values of phytoplankton pigments in the surface waters of Narmada river. Values of total chlorophyll and carotenoids varied between 4.3–242.3 mg/m^3 and 1.2–126.78 m-SPU/m^3 respectively (Fig. 2). In March fairly uniform values of total chlorophyll were observed with high values at St. 11 and St. 1. Carotenoid concentration was more at the estuarine stations 9 and 11. In May the trend was almost similar to that of March. The maximum value for total chlorophyll was recorded in June. During the monsoon period of July–August noticeable reduction in pigment concentration at most of the stations was observed. In September the pigment values showed an increasing trend with relatively high values towards the mouth region.

In August phytoplankton pigment values at stations 6, 7, 8 and 10 over a 12 hr period (0800 – 2000 hrs) showed significant variation. Towards the middle part of the surveyed region (Stations 6 and 7) chlorophyll and carotenoids varied between 1.06–28.02 mg/m^3 and 1.98–19.8 m-SPU/m^3 respectively. At stations located towards the mouth (Stations 8 and 10) chlorophyll (2.09–11.23 mg/m^3) and carotenoids (1.07–6.58m-SPU/m^3) ranges were relatively low. These variations in phytoplankton pigments had no correlation to time of collection. Whenever high value of phyto-

Table I. Monthly variations in the range of temperature, salinity, dissolved oxygen and nutrients in the Narmada estuary. Chl. *a* and zooplankton biomass values are mean for the particular month.

Month	Temperature (°C)	Salinity (‰)	Oxygen (ml/l)	Phosphate (µg-at/l)	Nitrate (µg-at/l)	Chl. *a* (mg/m^3)	Zooplankton biomass (ml/100 m^3)
			Freshwater Zone (St. 1–6)				
Mar.	25.5–30.0	<.1	7.7–9.2	0.5– 1.68	5.64–13.71	2.03	1.85
May	28.9–29.5	<.1	7.3–7.6	0.97– 1.03	0.21– 0.29	2.78	—
June	30.5–31.2	<.1	7.5–7.8	6.45– 5.26	0.07– 0.57	36.19	1.20
July	28.0–29.6	<.1	6.6–8.13	0.39–11.84	0.07– 0.57	1.80	0.53
Aug.	26.5–29.0	<.1	6.6–8.8	9.35–12.16	3.07–29.0	1.61	0.28
Sept.	—	—	6.8	.32– .39	54.57–60.0	3.74	2.40
			Estuarine Zone (St. 7–11)				
Mar.	27.0–27.8	12.0–31.63	6.65–7.83	1.22–5.29	3.57–12.21	1.8	1.71
Aug.	27.0–29.7	0.20–3.70	6.55–8.3	1.52–2.32	55.25–81.0	1.25	0.41
Sept.	—	4.5–14.5	7.5	0.54–1.16	49.43–57.0	6.76	2.87

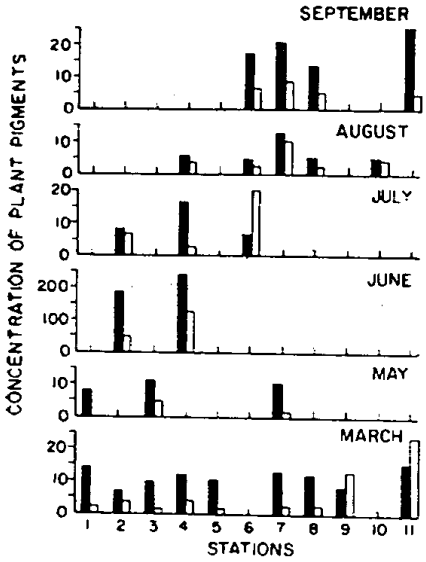

Fig. 2. Concentration of phytoplankton pigments in the Narmada estuary during March to September 1979. Darkened area, total chlorophyll (mg/m³); open area, total carotenoids (m-SPU/m³).

plankton pigment was recorded it was associated with medium value of salinity obtained for the particular station.

The most dominant plant pigment were chl. *c* and plant carotenoids chl. *b* was usually less than chl. *a*. During the period of observation chl. *a*. *b* and *c* values fluctuated between 0·05–44·57, 0·04–55·01 and 0·73–142·73 mg/m³ respectively (Table II). Maximum values for different fractions of chlorophyll were observed in the month of June at St. 4. Concentration of chl. *a* at different regions showed higher values at the fresh water zone than in the estuarine zone except during September (Table I).

At Bukki creek pigment values were quite high and comparable to the value obtained for St. 4 in July. The total carotenoids gave a mean concentration of 20·71 m-SPU/m³. Pigment concentration was low at Dahej creek and the mean values for chl. *a*, *b* and *c* were 0·75, 0·74 and 2·08 mg/m³ respectively. A concomitant lowering of the mean carotenoid fraction (2·42 m-SPU/m³) was also observed.

Zooplankton

Biomass: Zooplankton volume varied between 0·11 to 4·61 ml/100 m³ (Fig. 3). In March, at most of the stations excluding 1 and 2 fairly high values were noted with maximum at St. 7. At St 2 higher value was recorded in June than in March. During July and August zooplankton production was low, but showed an increasing trend in September soon after the monsoon. In general, stations located in the estuarine zone sustained relatively higher abundance of zooplankton than the fresh water zone (Table I). Zooplankton biomass at St. 12 (0·66 ml/100 m³) was comparable to that of upstream stations in Narmada river. In July and August the recorded biomass at St. 13 were 3·46 and 0·8 ml/100 m³ which were relatively high values for a monsoon period.

Composition : The numerical abundance of different groups of zooplankton encountered in the collection are given in Table III. Copepods formed the dominant component of total zooplankton. The pattern of distribution of copepods closely followed that of biomass with relatively higher value in March, a decreasing trend from July–August and showing again a rise in September. Decapod larvae were very common in the samples. Prawn larvae and zoea contributed to an appreciable part of the decapod larvae and they were better represented at stations located towards the mouth of the river. Other crustaceans like mysids, cumaceans and amphipods were not very common, but their density was more in March. Cladocerans were rarely reported and whenever present were confined to the interior stations. Larvae of insects

were occasionally encountered in the samples particularly during the monsoon period. Gastropods and lamellibranchiates were common in the estuary and the former was more abundant than the latter. Polychaetes were found mainly in the month of July.

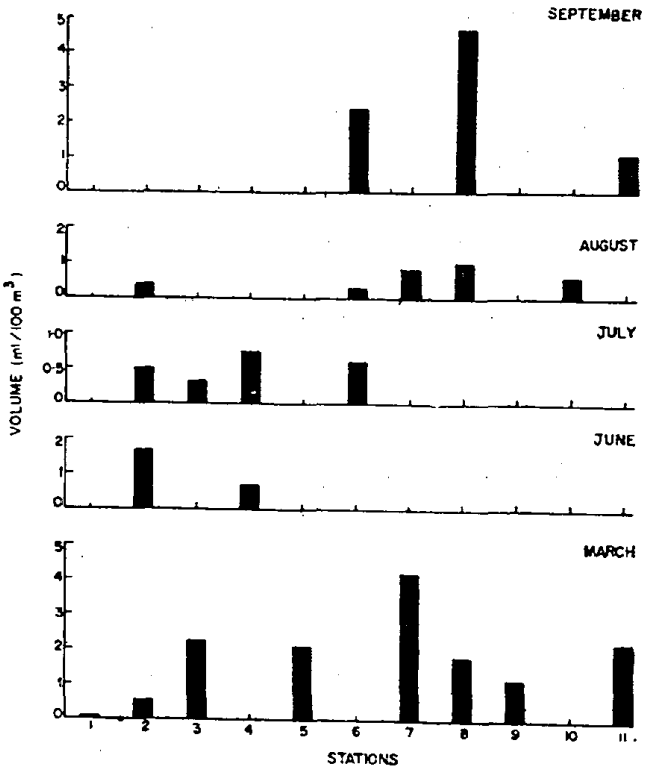

Fig. 3. Zooplankton biomass in the Narmada estuary during March to September 1979.

The predator community in this estuarine system is represented mainly by chaetognaths and fish larvae. Chaetognaths were common in the estuarine zone during the premonsoon period and their density increased from St. 7 to St. 11. In July and August, chaetognaths were very rare and in September with the increase in salinity their abundance also increased. Chaetognaths were represented by two species *Sagitta bedoti* and *S. pulchra*. *S. bedoti* was the dominant species and was the only species represented from St. 7 to 10. *S. Pulchra* was encountered in few numbers (2–4%) at St. 11. Siphonophores were very rare and recorded only at the mouth of the river in March and September. Fish eggs and larvae were well represented and the latter was more abundant. At the different stations during March–September fish larvae were distributed almost uniformly. Relatively high abundance of fish larvae was observed in September.

In the Bukki creek only six groups of zooplankton were found. Copepods formed the major part of the zooplankton followed by decapod larvae and fish larvae. Dahej creek was relatively more diverse in the representation of different groups. Copepods, mysids and decapod larvae were the common groups at Dahej station. Chaetognath fauna of this area consisted mainly of *S. bedoti*. *S. ferox* and *S. pulchra* were encountered in small numbers. Incidence of hydromedusae was noticed only at this station.

DISCUSSION

The results indicate that the Narmada estuary sustains an appreciable concentration of phytoplankton pigments. In the premonsoon period the mean total chlorophyll value amounted to 31.48 mg/m^3. During the monsoon period the mean pigment concentration decreased to 7.8 mg/m^3. Average value of total chlorophyll showed a rise (19.3 mg/m^3) at the beginning of the postmonsoon period. Among the different fractions of chlorophyll, *a* is considered to be the most dominant

pigment of the phytoplankton organisms, *b* an accessory pigment and *c* may have a greater significance than was once realised (Strickland, 1960). The chlorophyll values are comparable with those reported for Cochin backwaters (Qasim and Reddy, 1967). Again, in the present observation also chl. *c* concentration was usually higher than the other two fractions similar to the reported levels at Cochin backwaters. Peak in phytoplankton pigments values was found to be just before the monsoon (Bhargava and Dwivedi, 1976) and in the Narmada also maximum chlorophyll was observed in June just before the southwest monsoon. High pigment values could be associated with high nutrient concentration. However, the conspicuous increase in nitrate values in August was not followed by a concomitant rise in pigment cocentration.

In an estuarine system substantial quantity of dead chlorophyll coming from detritus and stirred up sediments also contribute to the high values of chl. *c* and carotenoids (Qasim and Reddy, 1967). This might be the reason for high recorded values at some of the stations, particularly in June. In the river suspended load was reported to be high possibly associated with fast tidal currents (NIO Report, 1980).

Zooplankton abundance in the Narmada river was not very high. Average zooplankton biomass in the Narmada showed variations during the three seasons with maximum in postmonsoon (2·72 ml/100 m^3). In the premonsoon period average biomass was 1·68 ml/100 m^3 and the lowest was recorded during the monsoon period (0·41 ml/100 m^3). The mean biomass in Narmada, Bukki creek and Dahej creek were 1·3, 0·7 and 2·1 ml/100 m^3 respectively.

Diversity of different groups of zooplankton was more at stations 8–11 and Dahej creek (Table III). Siphonophores were restricted to the mouth area. The common estuarine groups like lucifers, ctenophores and hydromedusae were not represented in the present collections from Narmada estuary. Like any other estuarine habitat cheatognath distribution was directly correlated to the prevailing salinity. At stations

Table II. Values of chlorophyll *a*, *b* and *c* (mg/m^3) at different stations in the Narmada estuary, Bukki creek and Dahej creek during the year 1979.

St.	Month	chl. *a*	chl. *b*	chl. *c*	St.	Month	chl. *a*	chl. *b*	chl. *c*
1	Mar.	2·02	2·12	10·11	4	July	2·43	2·81	11.30
2	,,	1·20	2·24	4·72	6	,,	1·12	1·27	4·30
3	,,	2·25	0·04	7·52	12	,,	13·02	9·60	6·83
4	,,	2·03	2·30	7·91	13	,,	0·05	0·28	0.73
5	,,	2·66	1·81	6·42	4	Aug.	1·66	1·26	2·59
7	,,	1·82	4·49	6·82	6	,,	1·56	1·26	1·49
8	,,	1·78	1·77	8·65	7	,,	2·36	1·94	8·55
9	,,	1·90	3·13	3·41	8	,,	0·68	1·10	3·03
11	,,	1·70	2·05	11·89	10	,,	0·71	0·76	3·12
1	May	3·68	1·81	2·68	13	,,	1·40	0.98	2·81
3	,,	1·88	1·23	7·88	6	Sept.	3·74	3.32	9·94
2	June	27·80	32·34	125·38	7	,,	5·23	4·51	10·96
4	,,	44·57	55·01	142·73	8	,,	3·12	2·05	8·42
2	July	1·86	2·79	3·41	11	,,	11·92	5·87	7·12

Table III. Abundance of different groups of zooplankton in the Narmada estuary, Bukki creek and Dahej creek during the year 1979. Values given are No./100 m³.

Station	Month	Hydrome-dusae	Siphono-phores	Polycha-etes	Lamelli-branchiates	Gastro-pods	Clado-cerans	Cope-pods	My-sids
1	Mar.	—	—	—	—	47	—	1267	—
2	,,	—	—	—	—	—	45	313	—
3	,,	—	—	3	—	841	—	6083	8
5	,,	—	—	—	26	324	—	18179	36
7	,,	—	—	—	575	38355	—	66229	31
8	,,	—	—	5	119	34	—	24750	3
9	,,	—	—	—	63	19	—	7372	3
11	,,	—	4	1	41	85	—	6763	5
2	June	—	—	—	18	98	—	3486	—
4	,,	—	—	8	—	95	—	2472	—
2	July	—	—	42	6	1	2	676	—
3	,,	—	—	19	8	2	271	227	—
4	,,	—	—	61	—	9	1	1343	—
6	,,	—	—	2	5	14	—	2908	1
12	,,	—	—	—	—	—	—	5487	6
13	,,	1	—	5	31	16	—	101262	209
4	Aug.	—	—	—	—	—	—	166	—
6	,,	—	—	—	21	—	—	124	—
7	,,	—	—	—	26	—	—	563	—
8	,,	—	—	—	22	382	—	30743	—
10	,,	—	—	—	—	—	—	2273	—
13	,,	—	—	1681	—	—	—	7130	18
6	Sept.	—	—	—	—	11	—	25295	7
8	,,	—	3	1	9	—	—	30479	11
11	,,	—	6	—	7	23	—	1795	—

Station	Cuma-ceans	Iso-pods	Amphi-pods	Decapod larvae	Insect larvae	Chaeto-gnaths	Fish-eggs	Fish larvae	Total No.
1	—	—	—	—	—	—	—	2	1316
2	—	—	—	107	—	—	—	—	465
3	49	—	5	33	—	—	2	24	7048
5	142	—	9	35	5	—	—	34	18790
7	20	—	4	158	—	245	21	44	105682
8	—	—	12	39	—	376	6	3	25347
9	—	—	11	110	—	434	—	13	8025
11	—	—	7	276	—	326	3	33	7544
2	—	—	—	72	4	—	—	27	3705
4	15	—	—	23	—	—	—	15	2628
2	—	—	—	52	52	—	—	42	873
3	—	—	—	10	47	—	—	—	584
4	—	1	—	59	43	—	30	45	1592
6	4	1	1	18	5	—	2	25	2986
12	1	—	—	10	—	—	1	10	5515
13	1	1	—	32	3	9	14	9	101593
4	—	—	—	2	4	—	14	50	236
6	21	—	—	31	21	—	17	73	308
7	—	—	—	35	3	—	—	49	676
8	—	—	—	202	—	10	—	11	31370
10	—	10	13	24	5	22	—	27	2374
13	—	—	2	22	—	45	—	1	8899
6	—	—	7	50	—	20	241	1885	27516
8	5	—	—	184	—	55	128	1277	32152
11	—	—	10	91	—	84	2	165	2183

1–6 salinity was always less than 0.1‰. In the estuarine zone salinity varied from 1‰ (St. 7) to 31.63‰ (St. 11) in the premonsoon period. During the monsoon period salinity was very low in the estuarine zone and an increase in salinity was observed soon after the monsoon (Table I). In accordance with the salinity gradient in the estuarine zone chaetognaths were more abundant towards the mouth of river. *S. ferox* and *S. pulchra* are typical oceanic species (Nair, 1977) and their presence at St. 11 and 13 indicated the influence of offshore water. Eventhough *S. enflata* was reported from Cochin backwaters (Nair, 1972) and Mondovi–Zuari estuaries (Nair and Selvakumar, 1979) this species was not encountered in the present collections. In an earlier observation from Gulf of Cambay (Rao, Rao, Wagh and Desai, 1971), a few samples were collected off the mouth of Narmada river and in these samples also *S. enflata* was not represented. The chaetognath fauna of an estuarine region is dependant on the type of species present in the incoming waters (Nair, 1974).

Molluscan veligers, decapod larvae and fish larvae were noted throughout the period of study. High abundance of fish eggs and larvae in September would indicate the peak breeding season of fishes.

Rate of zooplankton production for the estuarine system was estimated following the method of Selvakumar, Nair and Madhupratap (1980). Zooplankton production in the surveyed region (approximately 452 km^2) had a production rate of 24.47 mg C/m^3 day which can sustain an estimated fish potential of 25.33×10^3 tonnes. The overall productivity of the area suggests a healthy condition which can maintain a good fishery.

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