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COMPARATIVE ACCOUNT ON ZOOPLANKTON IN POLLUTED AND UNPOLLUTED ESTUARIES OF GUJARAT

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ABSTRACT

An assessment of the zooplankton biomass and composition in Kolak, Par, Damanganga and Auranga estuaries was made. Among these four rivers pollution is severe in the first two, moderate in Damanganga and good water quality prevailed in Auranga. The extent of variability in the distribution of zooplankton was in accordance with the intensity of pollution. In the unpolluted estuary zooplankton biomass varied from 1.8 to 10.06 ml/100 m^3 and mean secondary production amounted to 80 mg C/100 m^3/day. The intensely polluted estuaries are characterised by wide fluctuations in zooplankton biomass during the ebb and flood periods. The flood conditions sustained 1.8 to 4.4 times higher biomass than the ebb conditions. Mean rates of secondary production in these estuaries were 138 mg C/100 m^3/day (Par) and 265 mg C/100 m^3/day (Kolak). In the moderately polluted estuary the rate of secondary production was 109 mg C/100 m^3/day.

Dominance of zooplankton groups varied with level of pollution in the unpolluted estuary invariably copepods were predominant. In the polluted estuaries during ebb tide gastropods, mysids and polychaetes formed the major part of the zooplankton. Diversity of different groups of zooplankton was relatively low in polluted estuaries.

Key-words : Zooplankton, pollution, estuaries, Gujarat.

INTRODUCTION

The capacity of an aquatic environment to assimilate the solid or liquid waste is limited. In rivers having seasonal discharge of fresh water, the assimilation capacity will be further reduced. When the assimilation capacity is exceeded the situation becomes hazardous to the ecosystem. Some of the estuaries along the northwest coast of India pose such a situation due to industrial as well as sewage pollution. Conditions may become more alarming during the low tide. A recent study on the zooplankton from a few estuaries of Gujarat indicates the effect of environmental stress on these organisms (Nair, Gajbhiye, Ram and Desai, 1981).

Abundance and diversity of zooplankton can be considered as an index to the health of an aquatic environment. Hence a study of zooplankton from four estuaries of South Gujarat having varying levels of pollution load was taken up. Quantitative and qualitative distribution of zooplankton in these estuaries were compared for evaluating the intensity of pollution.

The estuaries selected for the study are Auranga, Damanganga, Kolak and Par located in the South Gujarat area (Fig. 1). These four rivers join the

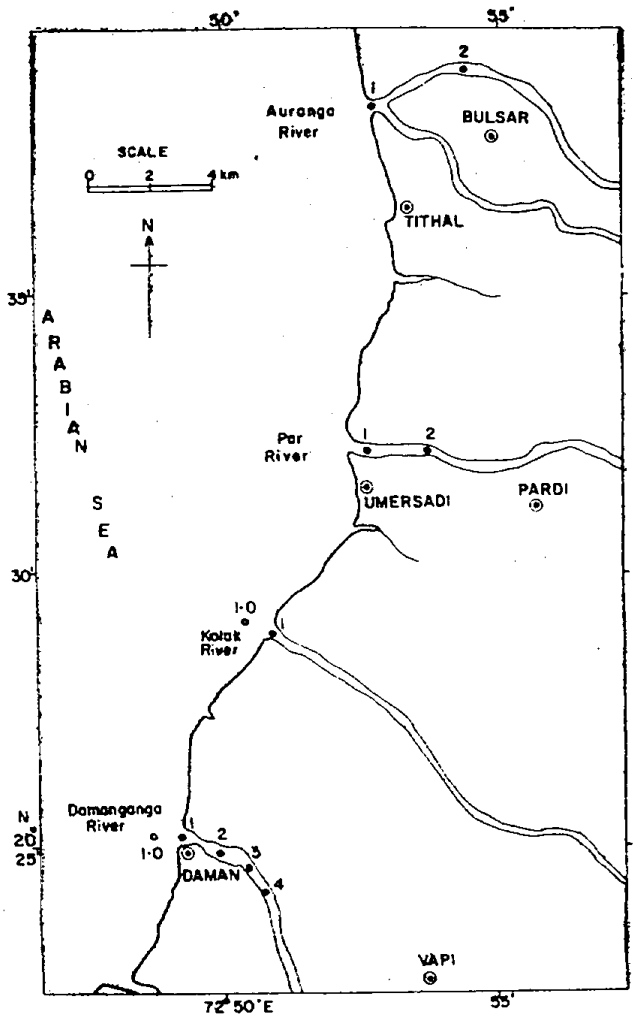

Fig. 1. Gujarat coast showing the four estuaries and location of stations.

Arabian Sea South of Gulf of Cambay. The extensive sand banks found in Auranga are exposed during low tide. The prevailing water quality of this estuary indicated healthy conditions and hence this estuary was considered a typical unpolluted estuary.

The mouth of Damanganga is shallow due to heavy silting. The river receives 3.9 mld of waste water from the industrial estates located at Vapi, Selvasa and adjacent Gujarat Industrial Development Corporation area (NIO, 1980). The area where the effluents are discharged had weak tidal influence. Hence very little water is available during the dry season for dilution. Subsequently, waste water discharged into the river is not completely removed during the ebb tide.

In the Kolak river, the rocky out crops at the shallow mouth region are exposed during low tide. In this river the quality of the water is deteriorating due to the discharge of industrial waste water from the industrial complex at Vapi. About 6 mld of industrial waste water without proper treatment is discharged into the fresh water zone (NIO, 1980). During the dry season very little water is available for dilution at the present discharge site.

The mouth of Par river is also shallow due to heavy silting and is not navigable during low tide. A chemical complex at Atul discharges about 25,000 m^3/day of effluent into a natural drain opening into the upper reaches of the estuarine region. At this point sufficient water for dilution is not available. The incomplete mixing of the effluent with sea water affected the water quality of downstream area.

In all the rivers freshwater influx is maximum during July to September due to southwest monsoon. The flow gradually decreases and becomes negligible from February to May. The tide is of the mixed diurnal type. The physico-chemical conditions of these estuaries have already been reported in detail (Zingde, Sarma and Desai, 1979; Zingde, Sabnis, Mandalia and Desai, 1980; Zindge, Narvekar, Sarma and Desai, 1980).

MATERIALS AND METHODS

Zooplankton collections were made at two stations in Auranga (Fig. 1) during October 1978 – October 1979. Details about these collections were already reported (Nair, Gajbhiye, Ram and Desai, 1981) and the data are considered here as representative of an unpolluted estuary. From the remaining estuaries sampling could be done only during February and May to July 1977 when pollution was maximum due to negligible discharge of river flow. At Damanganga estuary 4 stations were studied while at Kolak and Par estuaries only 1–2 stations were considered because of technical difficulties. For comparison a few collections were made off the mouth of Damanganga and Kolak estuaries.

Zooplankton collections were made by oblique hauls using a HT net (mouth area 0.25 m^2; mesh size 0.3 mm) with an attached flow meter. Sampling was done between 0600 and 1800 hrs covering both the ebb and flood conditions. An aliquot of 25% of each sample was analysed.

RESULTS AND DISCUSSION

Auranga estuary: Variation in salinity during the period of study was from 11.72 to 35.9‰. The range of dissolved oxygen was from 5.1 to 8 ml/litre indicating that the water was free from organic pollution. The prevailing water quality suggested healthy environment (NIO, 1980).

Zooplankton biomass in the estuary varied between 1.8 and 10.06 ml/100 m^3 (Fig. 2). Mean value for the entire estuary was 4.32 ml/100 m^3.

Table 1. Zooplankton distribution (%) in Auranga estuary.

Month	Tide	Total population (no/m³)	Copepods	Polychaetes	Lamelli-branchiates	Gastro-pods	Mysids	Decapods	Chaetog-naths	Fish eggs
					STATION 1					
Oct '78	Flood	2375	97.99	0.004	—	1.56	0.18	0.1	0.14	0.008
Oct '78	Ebb	2746	98.16	0.008	—	1.48	0.16	0.06	0.12	0.012
Jan '79	Flood	41	96.72	—	1.17	1.14	—	0.97	—	—
Jan '79	Ebb	155	95.96	0.05	1.17	—	2.7	—	0.12	—
May '79*	Flood	674	92.34	0.185	2.75	0.175	1.45	1.67	1.20	0.23
May '79	Ebb	878	96.84	0.015	1.75	—	0.45	0.61	0.33	0.005
Oct '79*	Flood	60	97.9	—	—	—	1.5	19.4	10.8	0.4
Oct '79	Ebb	83	4.9	0.3	1.5	60.7	0.98	3.8	27.5	0.32
					STATION 2					
Oct '78	Flood	192	91.4	0.01	—	8.4	0.07	0.07	0.12	0.01
Oct '78	Ebb	174	88.25	—	—	9.9	0.05	1.70	0.1	—
Jan '79	Flood	72	89.16	0.08	9.7	—	0.9	—	0.16	—
Jan '79	Ebb	116	78.5	—	7.2	8.9	1.2	1.1	3.1	—
May '79*	Flood	460	79.41	0.002	0.045	18.17	0.96	0.86	0.16	0.003
May '79	Ebb	549	97.4	0.004	0.125	0.16	1.99	0.198	0.045	0.078
Oct '79*	Flood	25	75.0	—	—	4.3	6.5	8.7	0.7	4.8
Oct '79	Ebb	114	10.3	—	—	60.69	1.09	5.32	16.3	6.3

* Incidence of foraminiferans, coelenterates and amphipods.

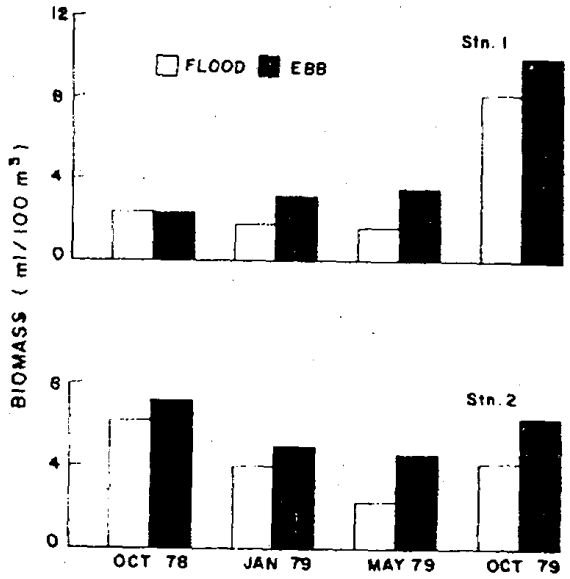

Fig. 2. Variation in zooplankton biomass at two stations in Auranga estuary.

In general, higher biomass was recorded at station 1 except in October 1979. Relatively steady values were obtained in January and May. The ebb period sustained higher biomass of zooplankton than the flood period. At both the stations the mean biomass during ebb tide was about 1.4 times greater than that of flood period.

Total population of zooplankton at station 1 ranged from 41 to 2746/m3 while at station 2 from 25 to 549/m3. Copepods formed the dominant component throughout the period of observation excepting the ebb period of October 1979 when gastropods outnumbered the copepod population (Table I). The other common groups were gastropods, chaetognaths, decapod larvae and mysids. At station 1 gastropods, mysids and decapods were caught in high density during the flood tide. The copepod population was more for the flood period at station 2. Lamellibranchiates, polychaetes and fish eggs and larvae contributed only a small percentage of the total population. Representation of different groups at both the stations are comparable. Relatively high density of chaetognaths was observed in October 1979 and during the ebb tide of October their population was greater than that of copepods. Foraminiferans, coelenterates and amphipods were sparsely represented.

Damanganga estuary: During the period of investigation salinity increased from 20.5‰ (Feb.) to around 34.8‰ just before the commencement of the monsoon. At station 1–3 during May to June the range of dissolved oxygen (5.2–7.8 mg/l) and BOD (0.7–8.5 mg/l) was quite normal. However, the low level of dissolved oxygen (3.1–3.8 mg/l) and relatively high BOD (14.6 to 24 mg/l) at station 4 indicated the prevailing unhealthy condition.

Table II. Zooplankton distribution (%) in Damanganga estuary and off the river mouth.

Date	Tide	Total population (no/m³)	Copepods	Gastropods	Lamelibranchiates	Decapods	Mysids	Amphipods	Fish eggs & larvae	Chaetognaths	Isopods	Polychaetes
					STATION 1							
19.2.77	Flood	5100	99.96	—	—	—	—	—	.04	—	—	—
19.2.77†	Ebb	2343	91.72	—	1.64	.09	6.1	—	.04	.41	—	—
16.5.77*	Ebb	683	56.92	37.39	—	.38	.07	—	—	5.24	—	—
7.6.77**	Flood	750	81.28	7.08	—	2.09	5.46	.43	.18	3.48	—	—
7.6.77**	Ebb	631	89.75	.21	.67	.15	8.92	.06	.24	—	—	—
28.6.77	Flood	13	80.06	.48	.14	8.14	—	2.83	.48	—	1.18	6.69
28.6.77	Ebb	2	8.93	—	—	5.59	—	43.62	.45	—	2.46	38.93
1.7.77	Flood	155	97.48	.08	.16	.19	.58	.58	.27	.5	.14	.02
1.7.77	Ebb	22	86.84	2.1	—	1.4	1.2	4.7	3.22	—	.4	.14
					STATION 2							
16.5.77*	Ebb	1544	3.96	94.65	—	.29	.51	—	.03	.55	.01	—
7.6.77	Flood	791	84.0	1.74	11.24	.34	.07	—	.03	2.58	—	—
7.6.77*	Ebb	600	83.42	.21	.44	9.91	3.96	.26	.44	1.36	—	—
28.6.77	Flood	133	40.59	—	1.49	7.52	.1	11.28	.69	2.26	36.07	—
28.6.77	Ebb	7	14.9	—	6.5	2.0	1.0	24.36	1.0	—	2.49	47.75
					STATION 3							
16.5.77*	Ebb	18431	20.5	78.91	—	.24	.27	—	.01	.06	.01	—
7.6.77	Flood	1259	98.42	.05	.05	.41	.24	.01	.05	.77	—	—
7.6.77	Ebb	218	96.93	.97	.12	1.14	.24	.05	.07	.48	—	—
28.6.77	Flood	300	89.76	1.0	—	6.2	—	.4	1.2	0.1	—	1.34
28.6.77	Ebb	252	8.02	3.21	—	4.28	—	34.76	2.14	—	2.67	44.92
					STATION 4							
7.6.77	Flood	172	83.42	0.21	0.44	9.91	3.91	.26	.44	1.36	—	—
7.6.77	Ebb	3	10.33	—	—	4.55	—	38.84	2.07	—	4.37	39.84
16.5.77§	Flood	490	91.23	.04	—	.83	.35	—	.09	7.29	—	.13
16.5.77	Ebb	390	78.11	7.74	—	.46	1.76	.36	.63	7.39	—	.35
7.6.77	Flood	533	73.79	4.22	15.2	.88	1.23	—	.25	4.04	—	.39
7.6.77**	Ebb	391	73.49	3.06	17.6	.37	1.16	.12	—	3.35	—	.95

* Presence of coelenterates, ** Presence of cirripedes, † Presence of cladocerans, § Presence of foraminiferans.

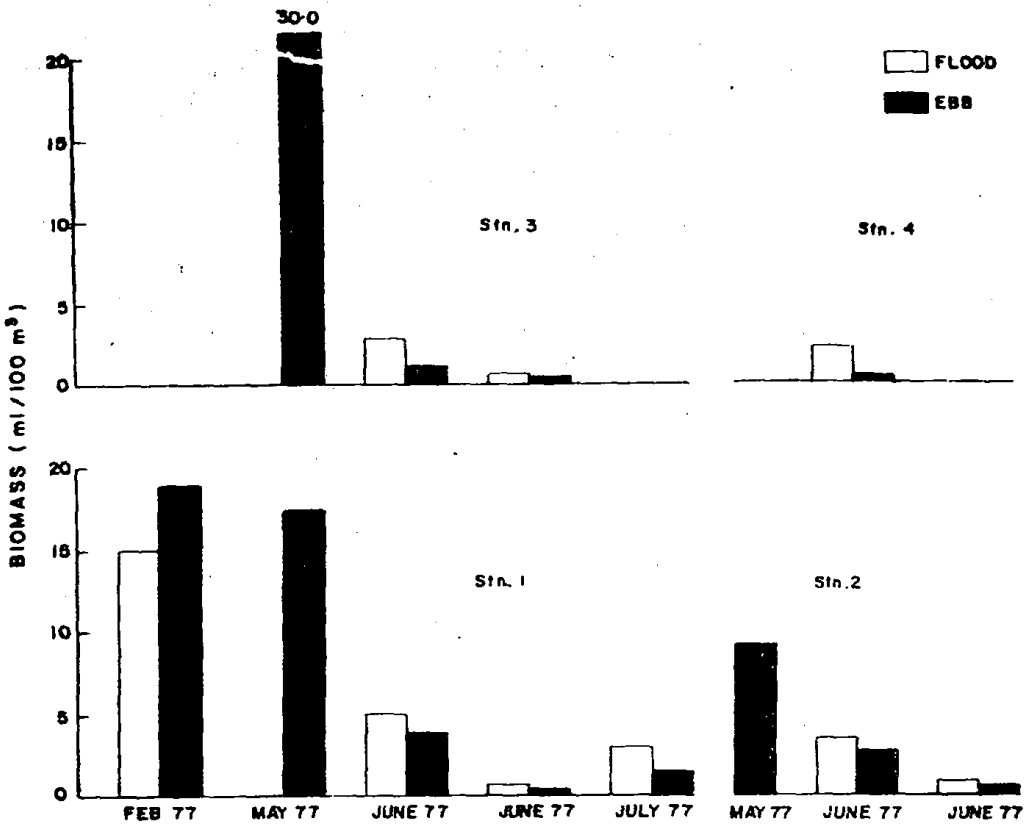

Fig. 3. Variation in zooplankton biomass at four stations in Damanganga estuary.

Zooplankton biomass in the area fluctuated between 0.59 to 30.0 ml/100 m³ (Fig. 3). The mean biomass obtained was 5.86 ml/100 m³. The low biomass recorded in June coincided with the time of maximum pollution. During June–July higher biomass was recorded during the flood tide. Mean biomass value for the flood tide was 1.1 times greater than that of the ebb tide.

Total population ranged from 2 to 18431/m³. Copepods formed the dominant group in 62% of the samples (Table II). Gastropods and amphipods were the next abundant groups. Other groups found in the collections were chaetognaths, decapods, mysids, lamellibranchiates and fish eggs and larvae. Polychaetes were observed in appreciable numbers in June. Coelenterates, cirripedes, cladocerans and foraminiferans were sparsely represented.

The zooplankton off Damanganga was in the range of 2.8 to 12.8 ml/100 m³ (average 7.28 ml/100 m³). The total population was almost steady. Copepods dominated in all the samples. Other common groups were lamellibranchiates, chaetognaths and gastropods.

Table III. Distribution of zooplankton (%) in Kolak and Par estuaries.

Month	Tide	Total population (no/m³)	Copepods	Gastro-pods	Lamellibran-chiates	Decapods	Poly-chaetes	Amphi-pods	Chaetog-nath	Mysids	Fish eggs & larvae
February	Flood	60	87.31	0.46	1.11	0.09	1.19	0.65	1.05	7.67	0.46
February	Ebb	12	19.5	47.1	—	0.05	0.2	—	0.9	32.25	—
May	Flood	577	78.36	10.74	—	1.11	0.26	0.09	8.18	1.02	0.24
May	Ebb	55	20.03	58.67	1.08	0.36	—	—	2.37	17.41	0.08
					Mouth of Kolak						
May*	Flood	490	91.23	0.04	0.04	0.83	0.13	—	7.29	0.37	0.09
May	Ebb	390	78.11	7.74	1.2	2.46	0.36	0.35	7.39	1.76	0.63
June	Flood	302	73.79	4.22	15.11	0.88	0.17	—	4.04	1.23	0.56
June**	Ebb	341	73.49	3.06	17.6	0.37	0.95	0.12	3.25	1.16	—
					Station 1 of Par estuary						
June	Flood	1462	97.78	0.72	0.045	0.003	0.045	—	1.40	1.4	—
June	Ebb	320	20.75	75.95	2.61	—	—	—	0.69	0.69	—
					Station 2 of Par estuary						
June	Flood	3865	99.36	0.25	0.05	0.03	0.01	0.001	0.28	0.28	—
June	Ebb	2	10.00	89.15	—	—	—	—	—	—	—

* Incidence of foraminiferans. ** Incidence of ostracods.

Kolak estuary : At its mouth, the physico-chemical conditions were better than the upstream area and dissolved oxygen level was 6.9 mg/l. In May along the upstream the DO level decreased to less than 0.5 mg/l indicating severe pollution and many areas became anaerobic with the evolution of hydrogen sulphide (Zingde, Sabnis, Mandalia and Desai, 1980).

The fluctuation in zooplankton biomass was 6.81 to 23.51 ml/100 m^3 (average 14.26 ml/100 m^3). During the period of study flood conditions always sustained higher biomass and the mean biomass value was 1.8 times greater than that during the ebb tide (Fig. 4). Copepods dominated the flood tide collections while gastropods and mysids formed the predominant component during the ebb period (Table III). Chaetognaths, decapods and fish eggs and larvae were more common during the flood tide, while the remaining groups contributed only a small percentage of the total population.

The biomass recorded at the offshore station ranged from 3.91 to 15 ml/100 m^3 (average 8.33 ml/100 m^3). Copepods invariably formed the dominant group. Lamellibranchiates, chaetognaths and decapod became more common. There was appreciable decrease in the population of gastropods and mysids. Other groups were sparsely represented.

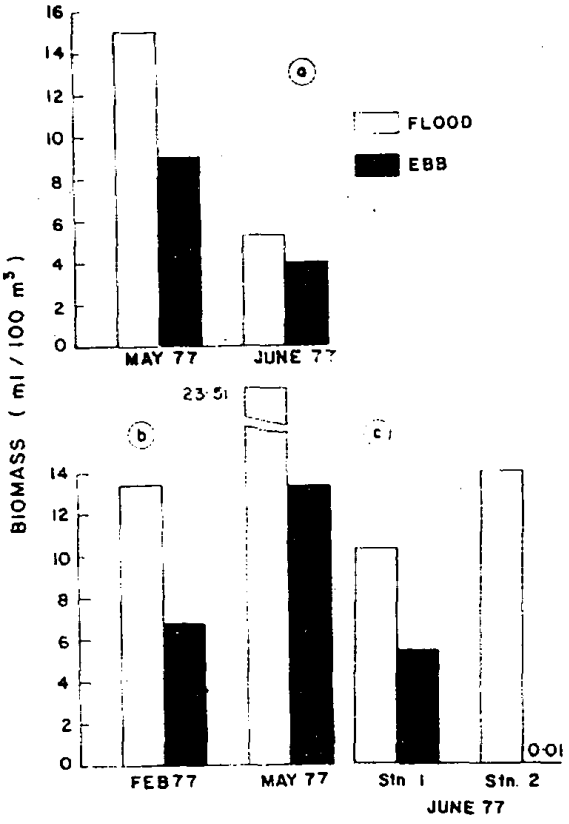

Fig. 4. Variation in zooplankton biomass off Kolak river. (a), mouth of Kolak river (b) and mouth of Par river (c).

Par estuary : High salinity (20.9 to 35.3‰) observed in this estuary during the premonsoon period indicated low fresh water discharge. The pH at the place of effluent discharge was less than 3 and the BOD load (100–323 mg/l) of the effluent influence the dissolved oxygen during low tide. Dissolved oxygen levels decreased from the mouth towards upstream and this varied with tide (Zingde, Sarma and Desai, 1979). At station 2 the dissolved oxygen of 6.2 mg/l decreased to 2.5 mg/l during low tide in June.

Zooplankton biomass varied at a range of 0.01 to 13.05 ml/100 m^3 (average 7.43 ml/100 m^3). There was drastic difference in biomass between flood and ebb tide (Table III). The mean biomass values indicated that flood tide sustained 4.4 times higher biomass than the ebb period. Copepods dominated the collections during flood tide while gastropods were predominant during ebb tide. During ebb conditions the number of groups represented was relatively low.

The foregoing account on zooplankton in the four estuaries indicates difference in total population as well as dominance of various groups. In the unpolluted estuary of Auranga variation in zooplankton biomass was within reasonable limit. Fluctuations in zooplankton biomass was more in polluted estuaries. In intensely polluted estuary of Par, very low biomass values obtained during ebb tide seems to be compensated by high values recorded for the flood tide. It appears that the relatively high incidence of mysids and gastropods in the Kolak and Par estuaries contributed to high biomass values. So when mean production is estimated considering the factor suggested by Nair (1980) relatively high values were obtained for the highly polluted estuaries. The calculated rate of secondary production for Auranga, Damanganga, Par and Kolak were 80, 109, 138 and 263 mg C/100 m^3/day.

In an estuarine habitat usually copepods form the major part of the total population of zooplankton as found in the unpolluted estuary. However, in polluted estuaries copepods which predominated during the flood tide were replaced during the ebb tide by gastropods, mysids and polychaetes. Group diversity of zooplankton was low in polluted estuaries than in unpolluted estuary.

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REFERENCES

Nair, V.R., 1980. Organic carbon content of tropical zooplankton. *Indian Journal of Marine Sciences*, 9 : 114–116.

Nair, V.R., S.N. Gajbhiye, M.J. Ram and B.N. Desai, 1981. Biomass and composition of zooplankton in Auranga, Ambika, Purna and Mindola estuaries of South Gujarat. *Indian Journal of Marine Sciences*, 10 : 116–122.

NIO Report, 1980. *Pollution assessment and hydrographic studies of the four rivers in South Gujarat*. National Institute of Oceanography, Regional Centre, Bombay, 377 pp.

Zingde M.D., P.V. Narvekar, R.V. Sarma and B.N. Desai, 1980. Water quality of the river Damanganga (Gujarat). *Indian Journal of Marine Sciences*, 9 : 94–99.

Zingde, M.D., M.M. Sabnis, A.V. Mandalia and B.N. Desai, 1980. Effects of industrial waste disposal on the water quality of the river Kolak. *Mahasagar — Bulletin of the National Institute of Oceanography*, 13 : 99–110.

Zingde, M.D., R.V. Sarma and B.N. Desai, 1979. Pollution in river Par and its abatement. *Indian Journal of Marine Sciences*, 8 : 266–270.