

Biological characteristics of the Vashishti estuary, Maharashtra (west coast of India)

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The estuary and coastal nearshore regions sustained fairly high concentration of chlorophyll *a* (av 3.1 mg/m³) and primary productivity (av 89.9 mgC/m³/h). High rate of primary productivity was observed in the estuarine segments especially along the lower reaches. However, the standing stocks of zooplankton (av. 3 ml/100 m³) and macrobenthos (av. 2.1 g/m²) of the estuarine system were low compared to the nearshore coastal system off Vashishti. A gradual increase in zooplankton faunal group diversity from inner estuary to the coastal waters was evident. There was no marked change in faunal group diversity of macrobenthos between estuarine and coastal system. Selected water quality parameters were correlated with chlorophyll-*a*, phaeophytin, primary productivity, zooplankton and benthos. Fishery resources of the coastal area in terms of catch per unit effort (CPU) was fairly good during premonsoon (33 kg/h) than postmonsoon (3.4 kg/h) period. The observed biological characteristics of the Vashishti river indicated good production only at primary level and the overall potential could be rated as moderate.

Estuarine systems along the Maharashtra coast are becoming prone to the hazards of pollution due to industrialisation. Hence, it is necessary to obtain baseline information of all major river systems of Maharashtra for future monitoring, ecological assessment and conservation. Vashishti is one such important river, in Ratnagiri district of Maharashtra, for which the biological production potential has not been studied. The present attempt is to characterise the estuarine ecology of Vashishti estuary based on phytoplankton pigment, primary productivity, zooplankton, benthos and fishery. A cumulative evaluation of these biological parameters is expected to give a fair idea on the state of equilibrium of marine life in the estuary. This is significant in the context that Maharashtra Industrial Development Corporation has developed an industrial zone mainly to accommodate chemical industries at Lote Parshuram about 12 km from Chiplun in Ratnagiri District. The present wastewater output¹ of about 7000 m³/day from the industrial complex is expected to increase to 45,000 m³/day by AD 2010. The wastewater will be released into the Vashishti river after adequate treatment to meet the environmental standards¹.

Materials and Methods

The Vashishti river has a course of about 50 km

and the river becomes tidal near Chiplun (Fig. 1). Below the island of Govalkot, the river widens in sweeping meanders and after a course of 40 km through low mud banks and mangroves it joins the Arabian Sea at Dabhol. The estuarine mouth is shallow due to sand bar. Apart from Jagbudi a major tributary, several smaller tributaries join Vashishti on either banks. The southwest monsoon influences the river considerably during June to September and an average rainfall is about 350 cm (Chiplun). The freshwater influx during monsoon results in excellent flushing of the estuarine system.

Two series of observations were made during the postmonsoon (November 1989) and premonsoon (April 1990) periods covering seven locations (Fig. 1) spread over to a stretch of around 40 km. Maximum depth observed at sts 1-5 varied from 8-12 m while from sts 6-7 was 5-6 m. Stations 6 and 7 are located at the inner estuary where seawater influence was weak with dominance of riverine flow. At mid-estuarine zone (sts 4 and 5) seawater influence was dependent on tidal condition. The lower estuary where the riverine influence was marginal was represented by sts 2 and 3. Station 1 was selected in the nearshore coastal area for comparison as a reference point.

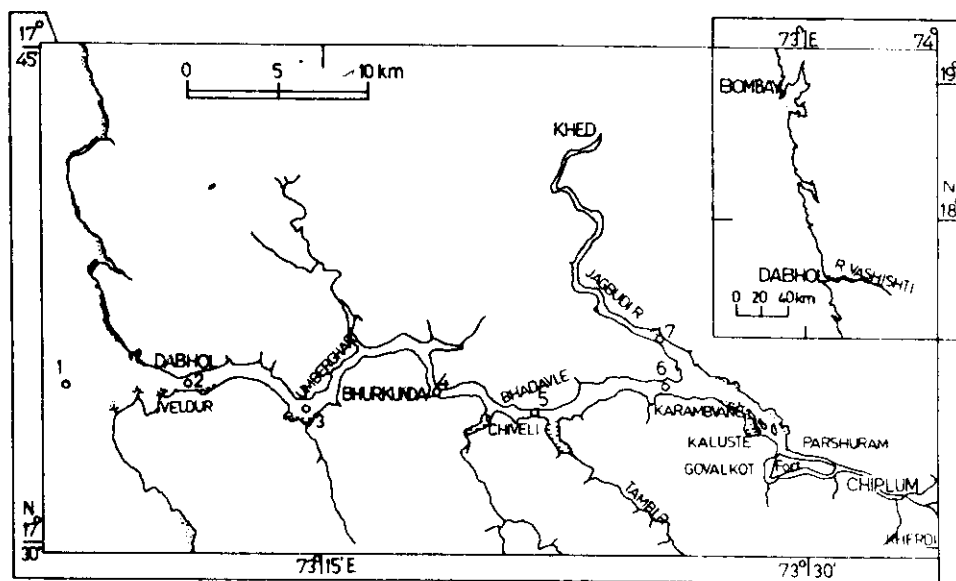


Fig. 1—Station locations

Water samples from surface and bottom (1 m above the bed) were collected for estimation of phytoplankton pigment. For bottom sampling a Niskin sampler with a closing mechanism was used. The analyses were done as per standard method². Rate of primary productivity was measured by ¹⁴C technique at selected stations.

Zooplankton samples were collected by oblique hauls of 6 minutes duration using a Heron Tranter net (mesh size 0.33 mm, mouth area 0.25 m²) with an attached calibrated TSK flow meter. Samples were preserved in formalin. Zooplankton volume (biomass) was obtained by displacement method and 25-50% of the sample was analysed for faunal composition and population count of common groups and the entire sample for rare groups. Sediment samples were collected using a van-Veen grab of 0.04 m² area. The sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formalin. Population (no/m²) and biomass (g/m² wet wt.) of macrobenthos and sediment texture were determined following standard procedures³. Bottom trawling was done using a mechanised trawler. A high opening trawl net of 20.7 m (636 meshes of 50 mm when stretched) was used.

Results and Discussion

Extensive studies on the physico-chemical characteristics of the estuarine system were carried out¹ earlier and the salient features are as follows.

The estuary experienced high spring tidal influence (3.1-3.7 m) as compared with neap periods (0.7-0.9 m). The stratification of the water mass at the mouth of the estuary was marginal whereas the inner estuary experienced marked salinity gradient due to the wedges of saline water spreading along the bottom. The stratification was well defined between sts 3 and 5 during postmonsoon while between sts 4 and 5 during premonsoon period. Spatial and temporal changes in pH, DO, BOD, nitrite, nitrate and phosphate indicated a normal and typical estuarine environment¹. However, nitrate was often high at the surface particularly in the inner estuary. Marked high levels of phosphate was observed at the bottom throughout the estuary probably due to release from bed sediment.

Phytoplankton pigments

Chlorophyll-*a* indicated wide fluctuations during November (Table 1) with high values generally confined to the segments between sts 2-3 and 6-7. The levels were relatively higher in the subsurface waters than at the surface. The average surface averages were comparable during different tidal conditions (ebb av. 3.1 mg/m³ and flood av. 3.2 mg/m³) while the bottom values were higher during the ebb (5.1 mg/m³) as compared to the flood (2.7 mg/m³). During April there was marginal decrease in chlorophyll-*a* especially in the middle and upper segments of the estuary, still the lower segment between sts 2-3 continued to maintain higher

Table 1—Variation in phytoplankton pigments, surface primary productivity, zooplankton biomass and zooplankton population at different stations

St no	Depth	November 1989					April 1990				
		Chloro-phyll- <i>a</i> (mg/m ³)	Phaeo-phytin (mg/m ³)	Primary product-ivity (mgC/m ³ /h)	Zoopl-ankton biomass (ml/100/m ³)	Zoopl-ankton population (no/100m ³)	Chloro-phyll- <i>a</i> (mg/m ³)	Phaeo-phytin (mg/m ³)	Primary product-ivity (mgC/m ³ /h)	Zoopl-ankton biomass (ml/100/m ³)	Zoopl-ankton population (no/100m ³)
1	S	2.4	1.1	—	28.4	17194	3.7	0.9	—	0.6	4694
	B	2.7	0.7				0.8	2.1			
2	S	4.8	1.3	101.3	7.2	19546	4.3	1.6	89.4	2.5	7675
	B	4.0	2.4				4.8	0.9			
3	S	3.5	1.2	—	4.6	16567	4.3	2.3	89.5	1.1	5760
	B	4.5	1.6				2.1	1.2			
4	S	2.4	0.6	96.2	7.1	89481	1.9	2.7	129.7	0.3	821
	B	2.1	2.2				1.6	2.3			
5	S	0.5	2.5		2.1	7959	2.4	7.8	101.3	2.1	1651
	B	2.4	1.2				2.1	1.2			
6	S	3.2	0.9	52.8	3.2	31934	4.0	2.5	82.0	6.2	1835
	B	6.4	2.0				2.2	2.1			
7	S	4.0	1.8	—	3.6	26264	3.0	1.8	95.1	1.5	8745
	B	4.8	0.2				2.0	1.5			

S = surface B = bottom

productivity (Table 1). Unlike the observations made during November the concentration was invariably more at the surface than at the bottom. The surface average for the ebb (3.3 mg/m³) was higher than that obtained for the flood (2.9 mg/m³) and the levels were comparable at the bottom for flood as well as the ebb. On the whole the river sustained fairly high concentration of chlorophyll-*a* with an average of 3.1 mg/m³ which was comparable to that observed at station 1 (av. 3.2 mg/m³).

Primary productivity

During November the rate of primary productivity was estimated for 1% and 100% illumination at selected stations. Production rate at surface (52.8-101.3 mg C/m³/h) was relatively higher at sts 2 and 4 as compared to st 6 (Table 1). The ¹⁴C uptake was measured during April at 100%, 30% and 1% illumination to complement the data on phytoplankton pigments. The euphotic zone varied from 2 to 2.5 m. The production rate (Table 1) at the surface indicated a fluctuation of 82.0 to 129.7 mgC/m³/h with maximum at st 4. Spatial difference in the rate of production at the surface was not well defined while at 30% illumination there was an increase in production rate towards the interior estuary.

Zooplankton

In general, the estuary was not rich in zooplankton during November (Table 1) and the respective averages of biomass for the coastal waters (st 1) and the entire estuarine system were 28.37 and 4.7 ml/100 m³ respectively. There was a general decreasing trend in biomass towards the inner estuary where relatively low standing crop was observed between sts 5 and 7. In general, flood sustained higher biomass (av. 5.8 ml/100 m³) than the ebb conditions (av. 3.4 ml/100 m³). Zooplankton population did not reveal any regular trend and the maximum count was observed at-st 4. Standing stock of zooplankton showed significant decrease during April (Table 1). Within the estuary the biomass reduced drastically by a factor of 43.6 (av. 0.6 ml/100 m³). In the coastal waters decrease was by a factor of 3.7 (av. 1.2 ml/100 m³) at st 1. Marginally higher biomass was observed for the flood (av. 1.5 ml/100 m³) than the ebb (av. 1.0 ml/100 m³). A proportionate decrease in zooplankton population density at different locations was also encountered.

Faunal diversity varied from 5 to 16. A gradual increase in the faunal diversity from inner estuary to the coastal waters was evident (Fig. 2). Copepods were the dominant faunal community in the study

area. Copepods contributed 46.8 and 68.5% respectively during the postmonsoon and premonsoon periods. Decapods formed the next dominant group with comparable contribution for postmonsoon (26.5%) and premonsoon (21.1%) period. *Lucifer*, a decapod, is unusually abundant in the area and the population density of the decapod group was quite high (av. 7.3%). Cladocērans were restricted towards sts 1-3 during November. Chaetognaths, though a common constituent of the estuarine zooplankton community, was rare in this river system. Molluscs, siphonophores, amphipods, polychaetes, foraminiferans, appendicularians, ctenophores, fish eggs and fish larvae were the other groups found in the area.

Sediment texture

In general, a sandy or silty sand substratum was observed at majority of the stations (Fig. 3). The texture of the sediment varied especially at the middle reaches of the estuary between sts 3 and 5 during November and April suggesting the seasonal changes in the substratum characteristics. A marginal increase in the percentage of silt and clay

in the above segment (sts 3 to 5) during April (Fig. 3) can be due to the active deposition of silt/clay matter during the premonsoon period. Again the erosion of silty bottom at the upper and middle segments of the estuary and the transportation of eroded materials further down stream during postmonsoon period, were evident. The percentage of organic matter in sediment varied from 0.2 to 3.3. In general, the values were low excepting at sts 3 and 4 (Fig. 3). Marginal decrease in the organic matter during premonsoon period (0.8%) as compared to the postmonsoon period (1.1%) was evident.

Macrofauna

Macrofaunal population density was higher in the inner estuary (sts 5, 6) as compared to the outer estuarine segment (sts 2 to 4). The maximum population density was recorded (Fig. 3) at st 5 (November) and at st 6 (April). In terms of population count the coastal nearshore region was marginally more productive (av. 9063/m²) than the estuary (av. 8008/m²). Seasonally the postmonsoon period sustained higher population density while the

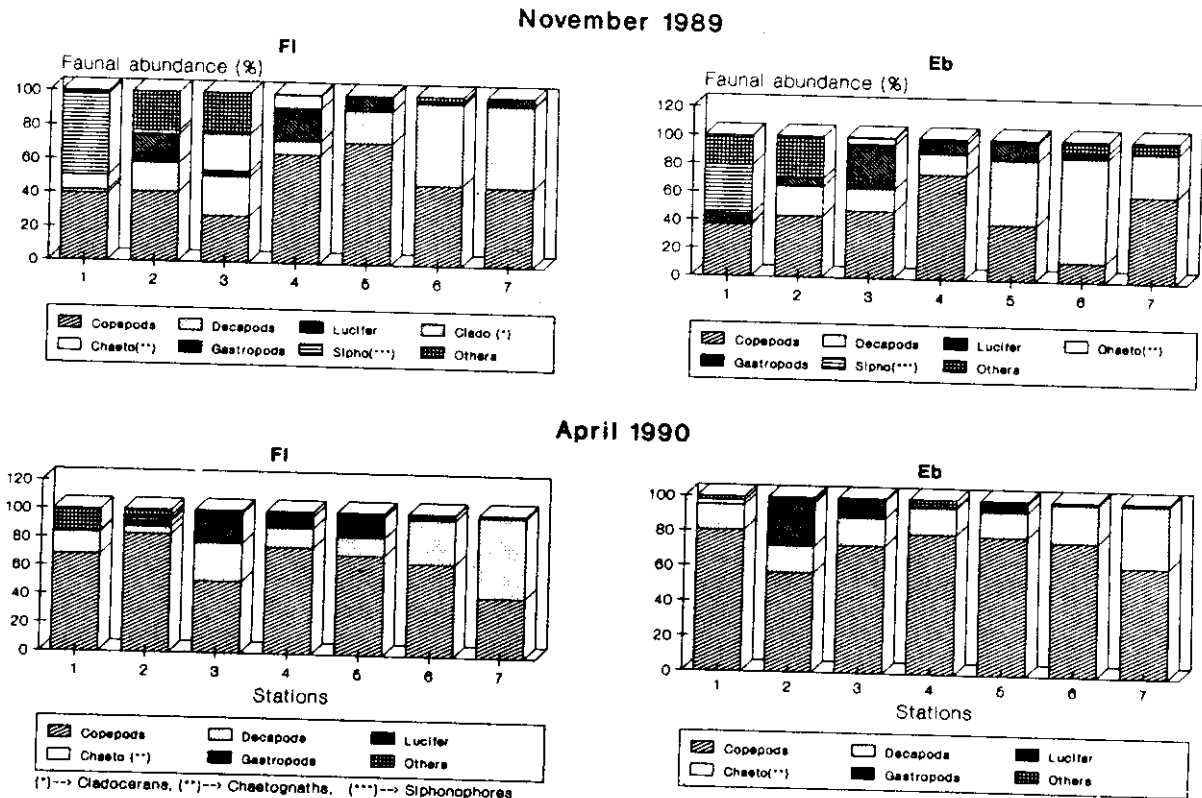


Fig. 2—Percentage composition of different groups of zooplankton for the flood (FI) and ebb (Eb) during two seasons.

population declined by a factor of 5 and 6.8 times respectively, at the coastal station and the estuarine system during the premonsoon period.

The inner estuary sustained high standing stock during both the seasons (Fig. 3). Exceptionally high biomass due to unusual aggregation of bivalves was observed at st 7 recording an average standing crop of 1239 g/m². In general, the estuary (sts 2 to 6) supported relatively lower biomass (av. 3.9 g/m²) than the coastal station (av. 8.2 g/m²). No clear cut correlation was noticed between macrofaunal density or biomass and sediment texture.

The macrofauna was mainly constituted by polychaetes, molluscs and crustaceans (Fig.4). Bivalves, gastropods and molluscan larvae were the major constituents of molluscs. Crustaceans were represented by copepods, isopods, amphipods and cumaceans. In the coastal zone (st. 1) the polychaetes predominated (88%) during the postmonsoon period while foraminiferans (62.6%) were the dominant group in premonsoon period. Group diversity at the coastal zone remained the same during both the seasons. In the estuarine zone during November molluscs (86%), polychaetes

(7%) and crustaceans (3.8%) were the major faunal group. The group diversity for the season varied from 3 to 7 with maximum at st 3. During April, the major constituents were crustaceans (44.8%), polychaetes (34.8%) and molluscs (11.7%) and this season also did not indicate any change in group diversity (3-7) with maximum at st. 5. A mean macrofaunal density of 8008 g/m² and biomass of 3.9 g/m² suggest a moderate benthic productivity of the estuary as compared to the nearshore coastal region (av. 8.2 g/m²). The Jagmudi river mouth (st. 7), a tributary of Vashishti also reveals a very high benthic standing stock in terms of biomass as compared to the estuarine region of Vashishti river.

Fishery

Due to unfavourable topography of the estuary trawling could be done only at sts 1 and 2. During November, the catch rate was low (av. 3.4 kg/h) with comparable values at both the locations. *Tetrodon* dominated the area. The pomfret *Pampus argenteus* contributed a major share of the total fish catch (28.5%) from st 1 while the catch rate of the species reduced by a factor of 4 towards st 2.

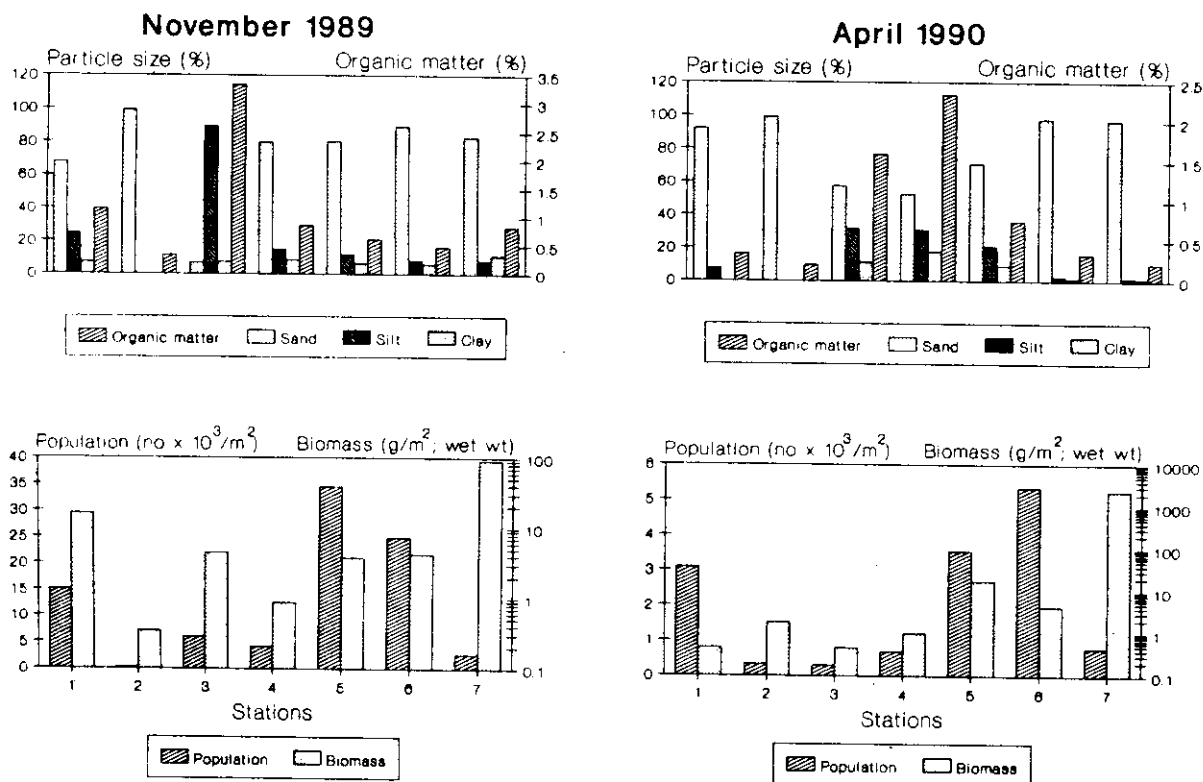


Fig. 3—Sediment characteristics and macrofaunal standing stock during two seasons.

Table 2—Baseline biological characteristics of the Vashishti estuary and adjacent coastal environment (1989-90)

Parameter	Nearshore waters	Lower estuary	Upper estuary
Chlorophyll- <i>a</i> (mg/m ³)	2.2 - 2.6 (2.4)	1.7 - 4.4 (3.4)	1.4 - 4.8 (2.9)
Primary productivity (Surface:mgC/m ³ /h)	—	89.4 - 129.7 (101.2)	52.8 - 101.3 (78.7)
Zooplankton biomass (ml/100m ³)	0.6 - 28.4 (14.5)	0.3 - 7.2 (3.7)	0.2 - 3.2 (1.9)
Zooplankton population (no/100m ³)	4694 - 17194 (10944)	821 - 89481 (23308)	1615 - 31934 (10845)
Zooplankton groups (no)	11 - 12 (12)	5 - 9 (7)	3 - 5 (4)
Macrobenthic biomass (g/m ² ; wet wt)	0.5 - 16.0 (8.3)	0.3 - 4.5 (1.5)	3.8 - 17.5 (7.5)
Macrobenthic population (no/m ²)	3076 - 15050 (9063)	301 - 6025 (1953)	3539 - 34550 (17091)
Macrobenthic groups (no)	5 (5)	3 - 7 (5)	3 - 7 (5)
Fishery(catch/h)	3 - 37 (18)	—	—
Total number of species	13 - 24 (17)	—	—

However, good catch of *Ilisha* was recorded (15%) between sts 1 and 2. During November, 17 species were identified from the area. Major catch during November was contributed by *Tetradon inermis* (29.5%), *Pampus argenteus* (18%), *Lepturacanthus savala* (13%), *Scoliodon laticaudus* (17.6%) and *Ilisha megaloptera* (8.5%).

In April, fairly good catch was obtained including 8 to 11 times increase in fishery potential. Total fish catch was higher towards st. 2 than that obtained from st. 1. However, during the season *Squilla*, which is not an economically important group dominated the fish catch. Total number of species found during April was 24. *Acetes* sp. (12.4%), *Pampus argenteus* (11%), *Lepturacanthus savala* (10.6%) and *Johnius* sp. (10.1%) were the most common species. Percentage contribution of prawn (*Metapenaeus* sp. and *Parapenaeopsis* sp.) was fairly high during the premonsoon (7.2%) than the postmonsoon (2%) season.

Correlations between chlorophyll-*a*, phaeophytin, primary productivity and different environmental

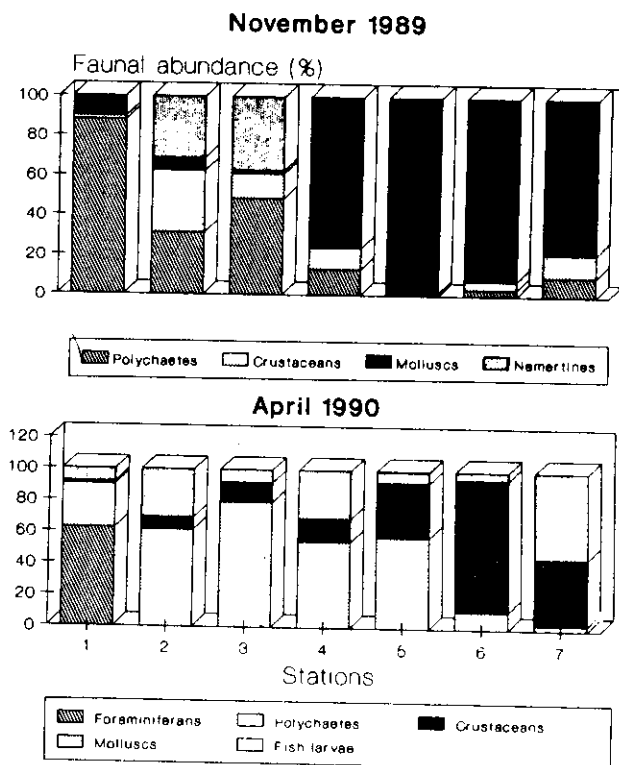


Fig. 4—Percentage composition of different groups of macrofauna during two seasons.

parameters were worked out. In November significant positive correlation at 0.1% level was observed between phaeophytin-chlorophyll-*a*, suspended solid-primary productivity and salinity - primary productivity while DO and primary productivity indicated negative correlation at the same level. In general, nutrients showed negative correlation with phytoplankton pigments and primary productivity. Correlation between environmental parameters and chlorophyll-*a*/primary productivity was at a low profile. Suspended solids, salinity and phosphate showed correlation at 5% level with chlorophyll-*a*. Correlation between different biological parameters during November indicated significant positive correlation at 0.1% level between benthic biomass and population and zooplankton biomass-primary productivity. Negative correlation (0.1% level) was observed between zooplankton population-chlorophyll-*a*, primary productivity-macro-benthic biomass, zooplankton biomass-macro-benthic biomass, zooplankton biomass-macro-benthic population and primary productivity-macro-benthic population.

Although primary productivity was fairly high, the standing stock of zooplankton and benthos were low in the estuary as compared to the coastal

waters. The fish catch off the estuarine mouth was fairly good. The overall biological production potential of the estuary was moderate (Table 2). Production at primary level in the estuarine system is not effectively utilized at the higher trophic levels as indicated by the low zooplankton and benthic standing stocks of the estuarine system. Overall productivity at different trophic levels did not indicate a balanced ecosystem and this cannot be considered as an inherent characteristic of the Vashishti estuary. It would appear that the waste water from the industrial complex might be exerting stress on biota leading to initial stages of ecosystem modifications and this needs to be confirmed through further detailed investigation.

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