Indian Journal of Marine Sciences
Vol. 22, March 1993, pp. 63-69

Zooplankton composition in Dharamtar creek adjoining Bombay harbour

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Received 1 November 1991; revised 8 December 1992

Dharamtar creek maintained rich zooplankton standing stock (av. 30.3 ml.100 m^{-3}) with peak production during August-November. Zooplankton production rate for the entire system amounted to 10.32 mg C.100 $m^{-3}.d^{-1}$ with an annual turnover of 29 ton C.km^{-2}. A major share of the zooplankton community was contributed by copepods (71.9%), decapods (11.4%) and chaetognaths (8.3%). Copepod diversity was maximum in October. Among the 46 species of copepods, *Acartia spinicauda* and *Acrocalanus* sp. dominated the outer and inner zones of the creek respectively. Brachyuran larvae predominated among the decapods. Swarming of *Lucifer* was observed in November at the outer zone. Three species of chaetognaths were found in the area and *Sagitta bedoti* was the true inhabitant. In general zooplankton production indicated 1.5 fold increase towards the upper reaches of the creek where salinity variations were drastic. A more diversified faunal assemblage of oceanic and neritic species characterised the lower estuarine zone having less salinity fluctuations.

Unlike earlier studies on zooplankton, mostly confined to Bombay harbour, the recent ones are extended to areas like Versova, Mahim, Thana and Bassein creeks[1-3]. The present study monitors water quality and zooplankton of Dharamtar creek, the estuarine complex of Amba river opening into the southern limits of Bombay harbour. With new industries cropping up along the creek in the Nagothana area, it is imperative to study the biological production potential of the area to assess the status of the ecosystem. The study evaluates production and community structure of zooplankton which serves as baseline information for future ecological assessment.

Materials and Methods

Samples of water and zooplankton were collected from 5 stations, 2 in the outer zone (sts 1 and 2) located in the open sea off the creek and 3 in the inner zone (sts 3-5) located towards the upper reaches of the creek (Fig. 1). The average depth of the water column at the outer zone was 8-11 m while at the interior zone it ranged between 5 and 7 m. Sampling was done monthly (September 1984-November 1985) covering intermediate phase of the tide to avoid tidal effect, if any. Subsurface water was collected using a Niskin water sampler. Selected physico-chemical parameters of the water (temperature, *p*H, salinity, dissolved oxygen, BOD, PO_4-P, NO_2-N, NO_3-N and NH_3-N) were estimated using standard analytical methods[4-6]. Zooplankton was collected by oblique hauls using HT net (mesh 0.3 mm, mouth area

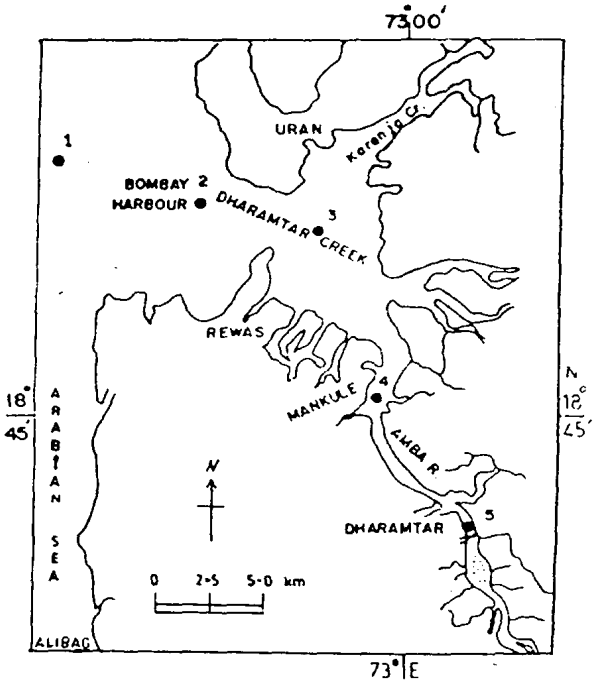

Fig. 1—Location of stations

0.25 m^2) fitted with a TSK flowmeter. Biomass (ml.100 m^{-3}) was measured as volume adopting displacement method while population density (no.100 m^{-3}) was determined by analysing aliquots of 25-50% of the sample for common forms and the entire sample for rare groups. Separate samples were collected from sts 1, 3 and 5 for estimation of organic carbon in zooplankton[7] and the data were utilised for computing secondary and tertiary production[8,9].

Results and Discussion

Physico-chemical parameters—Variations in different water quality parameters (Table 1) were within the expected levels for a tropical estuary suggesting that the area was free from any environmental stress. The difference between surface and bottom temperature was generally insignificant (0.5°C) indicating lack of vertical stratification due to shallowness of the estuary. Changes in water temperature were mainly induced by variations in atmospheric temperature. *p*H varied in a range of 7.5 to 8.4 with higher values during premonsoon season (February-May) and low values during peak monsoon season (June-September). During premonsoon period salinity increased to 38×10^{-3} and the entire water column was homogeneous due to limited freshwater influx. During the monsoon season due to incursion of freshwater from Amba river, salinity drastically decreased to 0.07×10^{-3} at sts 4 and 5. Vertical stratification leading to salt wedge formation was observed at the outer zone. Differences in salinity between surface and bottom were well defined at st 2 (20.2×10^{-3} in July; 5.4×10^{-3} in August) and st 3 (23.8×10^{-3} in June; 19.5×10^{-3} in July; 11.3×10^{-3} in August). Gradient in salinity at st 1 was comparatively low ($2.3\text{-}6.7 \times 10^{-3}$). During postmonsoon period (October-January) the stratification was broken as the creek came under the influence of seawater and restored the homogeneous condition of premonsoon. Fairly high level of DO and low BOD indicated effective assimilation of organic load. Nutrients in Dharamtar creek indicated seasonal variations with maximum concentration during the monsoon period[10]. Range in phosphate and nitrate showed comparable values at all stations (Table 1). Levels of nitrate showed enhanced values at the interior-most part of the creek system.

Table 1—Range of selected physico-chemical parameters for surface and bottom at different stations (Mean values are in parentheses)

	Stations				
	1	2	3	4	5
Temp (°C)	24.7-31.5 (27.6)	23.6-32.0 (27.7)	24.0-32.2 (27.8)	24.0-32.4 (28.1)	24.4-33.6 (27.9)
*p*H	7.5-8.3 (7.8)	7.5-8.2 (7.8)	7.5-8.4 (7.8)	7.5-8.3 (7.7)	7.5-8.3 (7.7)
Sal. ($\times 10^{-3}$)	23.6-36.6 (32.8)	8.1-36.9 (31.6)	1.7-36.5 (27.7)	0.2-37.2 (23.9)	0.1-38.0 (21.2)
DO (ml.l^{-1})	3.1-6.3 (4.1)	3.4-5.4 (4.3)	3.0-5.3 (4.4)	3.1-5.3 (4.2)	3.0-5.2 (4.3)
BOD (ml.l^{-1})	0.2-3.8 (1.4)	0.2-3.4 (1.3)	0.4-2.9 (1.3)	0.4-3.3 (1.4)	0.2-2.9 (1.4)
PO_4-P (μg-at.l^{-1})	0.6-3.4 (1.9)	0.6-3.5 (2.0)	0.6-3.1 (1.7)	0.4-3.6 (1.8)	0.6-3.0 (1.7)
NO_2-N (μg-at.l^{-1})	0.2-3.1 (1.1)	0.1-1.9 (0.7)	0.2-2.2 (0.9)	0.2-2.3 (0.8)	0.2-2.8 (0.9)
NO_3-N (μg-at.l^{-1})	5.1-21.8 (13.7)	1.0-33.9 (15.1)	3.6-24.3 (16.1)	3.9-30.6 (17.9)	4.2-42.4 (18.8)
NH_3-N (μg-at.l^{-1})	0.2-6.6 (1.5)	0.1-6.8 (1.5)	0.1-5.1 (1.2)	0.1-4.9 (1.5)	0.1-5.6 (1.7)

Biomass and total population—While biomass varied from 1.12 (st 2; January '85) to 135.53 ml. 100 m^{-3} (st 5; September '85) population density (no. 100 m^{-3})fluctuated from 3091-1723786 (Table 2). Mean values of biomass and population for the entire creek system were respectively 30.28 ml.100 m^{-3} and 126986 no. 100 m^{-3}. A clear cut increase in biomass and population was noticed from the outer to the inner zone (Table 2), and the respective average values were 24.97 ml.100 m^{-3}; 81755 no. 100 m^{-3} and 33.84 ml.100 m^{-3}; 157040 no. 100 m^{-3}. Maximum zooplankton in terms of biomass was noticed during October '85 at st. 1 while at other stations during monsoon period of August and September '85. St 1 is located towards the Bombay harbour and earlier reports[1-3] also indicate peak in zooplankton production during October to November. In estuaries of south Gujarat and Goa located towards north and south of Dharamtar creek high saline periods are known to accelerate zooplankton production[8,11,12]. In contrast to this, in

Table 2—Distribution of zooplankton biomass (ml.100 m^{-3}) and population (no. 100 m^{-3}) at different stations (Population values are given in parentheses)

Month	Stations				
	1	2	3	4	5
Sept. 1984	9.94	23.35	11.86	8.01	10.75
	(54473)	(144365)	(73459)	(62405)	(230472)
Oct.	40.13	29.52	24.21	81.75	46.22
	(198157)	(239894)	(153912)	(211748)	(52885)
Nov.	38.87	33.48	32.59	10.49	37.92
	(54325)	(58534)	(45774)	(55275)	(66749)
Dec.	4.86	4.23	1.51	6.34	10.35
	(28182)	(24412)	(8682)	(58623)	(50685)
Jan. 1985	1.34	1.12	3.21	8.20	3.04
	(3091)	(4349)	(21494)	(84175)	(13877)
Feb.	7.57	25.98	8.30	14.43	24.08
	(24727)	(56528)	(56008)	(18916)	(26776)
March	2.76	1.41	8.10	2.19	3.73
	(18433)	(6212)	(34248)	(6703)	(36398)
April	13.25	5.26	24.86	20.37	26.63
	(27542)	(15916)	(70921)	(35408)	(40707)
May	11.20	7.73	13.54	16.35	24.55
	(114328)	(25963)	(40944)	(25897)	(23668)
June	8.06	4.65	55.67	4.94	5.74
	(26453)	(11429)	(97653)	(25387)	(11687)
July	5.61	8.76	16.54	1.17	1.29
	(23207)	(61781)	(60512)	(12382)	(11492)
Aug.	36.63	25.77	86.70	125.99	32.53
	(122577)	(50366)	(32938)	(800325)	(1105240)
Sept.	32.98	103.92	76.12	81.96	135.33
	(84785)	(454694)	(434175)	(556597)	(1723786)
Oct.	84.59	72.52	72.32	80.97	80.01
	(101004)	(173558)	(186535)	(125433)	(90924)
Nov.	51.82	51.80	70.64	55.60	56.02
	(188660)	(54699)	(64112)	(45921)	(74906)

Dharamtar creek zooplankton abundance was seen between August and October when relatively low and moderate salinities prevailed over the areas. Correlation for zooplankton biomass and population was positive and very significant at all the stations. The correlation was significant at 1% level at sts 1 (0.67), 2 (0.84), 4 (0.84) and 5 (0.69), while at st 3 (0.52) it was only at 5% level. High standing stock of zooplankton very often synchronized with phytoplankton abundance indicating a direct relationship[10] though individual samples did not always show a proportionate correlation probably due to variation in composition of flora and fauna.

Organic carbon—Variations in organic carbon content of zooplankton were from 21.4 to 37.8% at different locations in the estuary (Table 3). Relatively higher values of organic carbon were found in zooplankton from st 5 than sts 1 and 3. Seasonally, monsoon period showed higher values at sts 1, 3 and 5 than premonsoon and postmonsoon periods. These values are comparable to those reported from Mandovi and Zuari estuaties[13] and relatively pollution-free waters off Bombay[9].

Secondary production—The estimated rate of secondary production was in the range of 8.3-5260.64 mg C.100 $m^{-3}.d^{-1}$ (Table 4). Lack of correlation between high biomass values and proportionate increase in the rate of secondary production in some samples could be attributed to the composition of the zooplankton. The rate of production was low during January and March and high from June to November. Average values for sts 1-5 were 732.8, 1099.8, 1285.7, 1063.3 and 978.1 mg C.100 $m^{-3}.d^{-1}$ respectively. The average for the entire creek, 1032 mg C.100 $m^{-3}.d^{-1}$ was relatively higher than the rate reported (790 mg C.100 $m^{-3}.d^{-1}$) for Bombay harbour-Thana-Bassein creek system[3].

Zooplankton composition—Abundance of various zooplankton in the estuary fluctuated in accordance with salinity regime. Copepods, decapods and chaetognaths which contributed to the major part of zooplankton were studied in detail and the remaining groups were clubbed together as other taxonomic groups (Fig. 2).

Copepods: Copepods formed the largest fraction of zooplankton in Dharamtar creek contributing 71.8% (Fig. 2) with a population density ranging from 731 to 1686611 (av. 109252) no. 100 m^{-3} (Table 5). The peak in copepod population was observed during August-October. There was direct correlation between total zooplankton biomass and copepod population. A total of 46 species belonging to 23 genera were encountered in the collections. The average contribution of Calanoida, Cyclopoida and Harpacticoida was 98.7, 1.1 and 0.2% respectively. The most common species were *Acartia spinicauda, Acrocalanus* sp., *Eucalanus pileatus* and *A. centrura. A. spinicauda* dominated at the outer zone while the creek area was predominated by *Acrocalanus* sp. Shannon and Weaver diversity index (H') ranged between 0.44 and 3.4 (av. 2.54) showing relatively

Table 3—Variations in organic carbon content (%) of zooplankton at different stations

Month	Stations		
	1	3	5
Sept. 1984	28.8	27.0	—
Oct.	24.6	22.8	32.4
Nov.	25.2	27.6	25.8
Dec.	22.8	33.0	29.4
Jan. 1985	27.0	27.0	21.4
Feb.	25.2	34.2	32.4
March	31.2	30.6	34.2
April	28.2	28.2	27.6
May	27.6	30.0	31.8
June	33.6	27.6	—
July	30.6	31.8	35.4
Aug.	36.6	34.8	37.2
Sept.	31.2	35.4	37.8
Oct.	34.8	34.2	34.8
Nov.	33.0	34.2	35.4

Table 4—Rate of secondary production (mg C.100 $m^{-3}.d^{-1}$) at different stations

Month	Stations				
	1	2	3	4	5
Sept. 1984	242.56	901.54	457.91	174.00	233.52
Oct.	725.99	990.92	811.92	3731.22	2109.57
Nov.	1640.51	1107.72	1047.00	107.74	389.48
Dec.	103.82	121.07	43.22	111.17	181.48
Jan. 1985	11.76	15.47	44.33	200.57	74.36
Feb.	103.01	858.31	274.21	335.69	560.18
March	70.03	32.92	189.14	61.79	105.24
April	230.84	103.83	490.74	514.99	673.25
May	433.79	147.63	258.59	270.35	405.96
June	317.56	171.17	2049.22	160.95	187.01
July	369.08	213.22	402.58	8.30	9.15
Aug.	841.97	865.95	2913.37	2932.08	757.05
Sept.	871.85	5260.64	3853.35	2588.45	4273.98
Oct.	2164.82	3645.87	3638.04	3969.37	3922.31
Nov.	2864.01	2062.10	2812.09	783.56	789.48

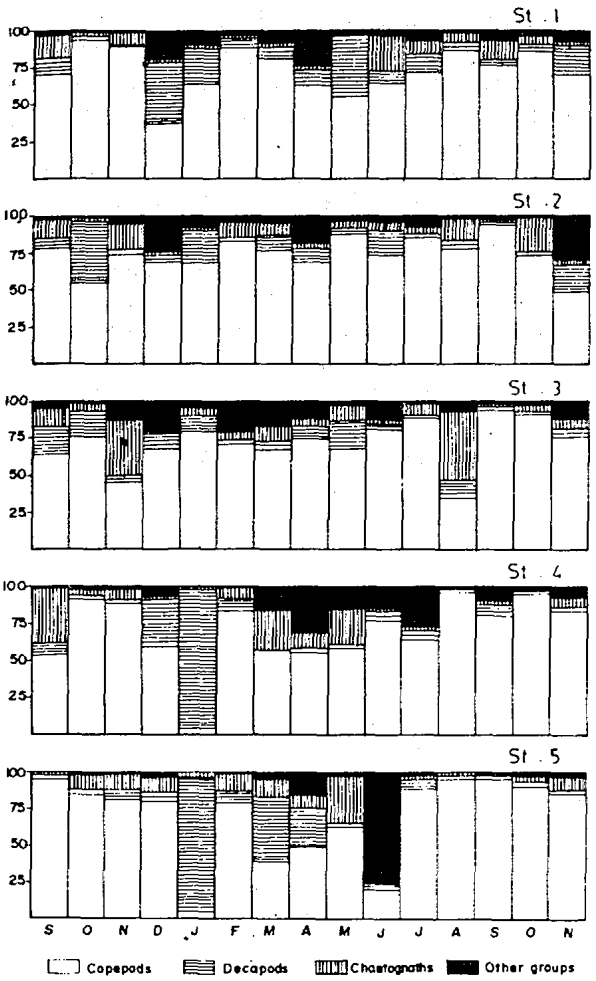

Fig. 2—Percentage composition of different groups of zooplankton at 5 stations during 1984-85

Table 5—Average population (no. 100 m^{-3}) of different groups of zooplankton in outer (sts 1, 2) and interior (sts 3-5) zones of Dharamtar creek

Zooplankton group	Outer zone	Interior zone
Copepods	64073	139372
Decapods	8369	6933
Chaetognaths	5549	5255
Medusae	548	1250
Siphonophores	162	146
Ctenophores	83	42
Platyhelminthes	1	1
Polychaetes	93	83
Cladocerans	52	481
Ostracods	5	8
Mysids	115	357
Cumaceans	14	54
Isopods	4	17
Amphipods	54	90
Stomatopods	168	207
Crustacean nauplii	692	76
Pycnogonids	2	1
Gastropods	382	1626
Bivalves	796	634
Echinoderm larvae	3	6
Copelates	107	17
Salps and doliolids	15	0
Fish eggs	115	82
Fish larvae	351	300

low diversity in the creek than the outer zone. Out of 46 species recorded from Dharamtar creek *Paracalanus parvus, Euchaeta wolfendeni, Euchaeta* sp., *Centropages tenuiremis, Centropages* sp., *Temora discaudata, Pontella securifer, Microsetella* sp. and *Corycaeus* sp. were restricted exclusively to st 1 while *Heliodiaptomus* sp., *Neodiaptomus* sp., *Pseudodiaptopmus annandalei, P. sewelli, P. tollingerae, Temora* sp., *Acartiella gravelyi, Miracia* sp. and *Mesocyclops* sp. were recorded only at st 5. *Helidiaptomus* sp. *Neodiaptomus* sp., *P. tollingerae* and *Mesocyclops* sp. were observed only during the monsoon months suggesting their preference to very low saline or limnetic conditions. Pseudodiaptomidae and Acartiidae were the most successful copepods in Dharamtar creek. Species typical of limnetic realms were found exclusively in the creek zone.

Decapods: This group was largely constituted by larval stages. Decapods formed the second largest group of zooplankton in order of abundance as well as percentage composition. Their population varied between 151 and 80217 (av. 7508) no. 100 m^{-3}. Their contribution was 11.44% to the total zooplankton population. Highest density was recorded in January at st 4 due to outburst of crab zoeae and their population was 80082 no. 100 m^{-3}. Seasonally, postmonsoon period sustained higher population than other seasons. Twenty six forms of planktonic decapods belonging to Penaeidae, Sergestidae, Caridea, Scyllaridae, Stenopidae, Thalassinidae, Anomura and Brachyura were encountered in the present collections. On an average brachyuran larvae formed major part of the decapod population throughout except at st 1 where the members of Sergestidae outnumbered them. Penaeidae was represented by protozoeae and mysid stages of *Metapenaeus, Parapenaeiopsis* and *Penaeus* with the first dominating all over. Larvae of *Penaeus* were observed only at sts 1 and 2. Sergestidae was represented by *Sergestes, Acetes, Lucifer hanseni, Lucifer typus* and protozoeae of *Lucifer* and *Acetes.* An

outburst of *Lucifer* was observed at st 1 in November '85 with population density of 28504 and 3455 no. 100 m^{-3} respectively for *L. hanseni* and *L. typus*. Caridean larvae belonged to the families Pasipheidae, Pandalidae, Hippolytidae, Processidae, Alpheidae and Palaemonidae. While Alpheidae was dominant at st 1 Palaemonidae dominated at the remaining stations. Scyllaridae, represented by phyllosoma larvae, were restricted only to the outer zone of the creek. Stenopidae larvae were confined to st 1. Thalassinidae was represented by members of families Axiidae and Upogebidae. Porcellanid and pagurid larvae were the representative of Anomura. Zoea, megalopa and glaucothoeae of crabs represented Brachyura which dominated over other decapods.

Occurrence of epiplanktonic species of *Lucifer* and *Acetes* which form a major diet of shore fishes and larger shrimps, and those of palaemonid carideans and brachyuran larvae in good numbers is an indication of non-penaeid prawn and crab resources of the Dharamtar creek.

Chaetognaths: The group contributed 8.38% of total zooplankton population forming the third largest group of zooplankton. Variation in chaetognath population was from 0 to 40818 (av. 5373) no. 100 m^{-3}. *Sagitta bedoti* was common at all stations while *S. enflata* was largely noticed towards the lower reaches. *S. oceania* was more abundant at the interior region than the outer zone. At sts 1 and 2 with salinity ranging from 8 to 36.9×10^{-3}, chaetognaths were fairly abundant throughout with peaks recorded in September and November. At st 5 their population rose to a peak only in May coinciding with the maximum salinity of 37.8×10^{-3}. During monsoon months when freshwater dominated the estuary chaetognaths were either absent or very sparse.

Other groups: Many other groups were also represented in the collections (Table 5) whose ocurrence and abundance were sporadic, even though they collectively dominated zooplankton at times. Medusae were common in the area except during June to August at the interior zone. Siphonophores were more abundant at sts 1-3 than the remaining locations. Even though ctenophores were well represented in the creek, the population density was low during the monsoon period. Planktonic platyhelminthes, a rare group was represented solely by marine flukes. Polychaetes were more frequent at st 1. *Evadne* and *Monia* contributed to the cladoceran community. During June-July freshwater *Monia* became abundant at the interior part of the creek contributing 56.2% to total zooplankton population at st 5. *Cypridina dentata* was the single ostracod species rarely found in the collections. Mysids were common at all stations and were represented by *Mesopodopsis zeylanica* and *Lycomysis platycauda*. Cumaceans, pycnogonids and echinoderm larvae were rare in the area while isopods and amphipods were found in fairly large numbers. Naupli of crustaceans and alima larvae were observed in fairly large proportion to the total zooplankton. Planktonic gastropods and bivalves were common at all stations, the latter being less frequent as compared to gastropods. However, at st 2 in November '85 bivalves became the second largest group contributing 23% to the total zooplankton community. Copelates were more common towards the outer zone. Salps and doliolids were sparsely represented towards the creek mouth.

Fish eggs were commonly found at all stations and occasionally found in large numbers. Frequency of occurrence was less at st 5. The highest population (739 no. 100^{-3}) was observed at st 3 in December. Fish larvae constituted another very common group in Dharamtar creek. Their maximum population 6031 no. 100 m^{-3} was recorded at st 5 during August. On an average, the outer zone sustained relatively higher population of fish eggs and larvae than the interior zone. Being carnivores, chaetognaths and medusae often engulf fish eggs and larvae leading to larval fish mortality. In this context higher population of medusae towards the interior part of the creek coinciding with lower population density of fish eggs and larvae is significant. Predation of fish larvae by medusae appeared to be well defined at st 4 with highest record of medusae (av. 1849 no. 100 m^{-3}) coinciding with the lowest density of fish larvae (av. 82 no. 100 m^{-3}). Occurrence of fish eggs and larvae in higher number in the outer zone than the interior zone is contrary to the assumption that the interior creek areas are more congenial for the development of these larvae. The possibility of predation of fish eggs and larvae by carnivores like medusae leading to depletion in population density of fish eggs and larvae can not be ruled out. However, the incidence of fish eggs and larvae within the entire creek system in fairly good numbers suggests the existence of breeding ground of fishes in the vicinity of this creek.

Present study indicates that the water quality of the outer zone of Dharamtar creek was comparable to the nearshore coastal marine environments except for the relatively higher values of salinity. Drastic difference in salinity between seasons with increase in nutrient levels during the

monsoon period was a unique feature of the interior zone. In general the area maintained rich zooplankton standing stock. Zooplankton production indicated 1.5 fold increase towards the interior segment. The average population density of different groups also indicated that the interior part of the creek is richer than the outer area (Table 5). A more diversified faunal community of oceanic and neritic species characterized the lower reaches of the creek system.

Zooplankton production rate for the entire system was 10.32 mg $C.m^{-3}.d^{-1}$ which led to a total production of 0.079 $ton.C.km^{-2}$ or 29.0 $ton.C.km^{-2}.y^{-1}$. Assuming a 10% conversion efficiency and raising the values using a factor of 7.47 for obtaining the wet weight of fish[8,9], the yield will be 0.059 $ton.km^{-2}.d^{-1}$ or 21.68 $ton.km^{-2}.y^{-1}$. Experimental trawling done at different parts of Dharamtar creek during different seasons gave a catch rate of 3-16.6 $kg.h^{-1}$. The average of 7 $kg.h^{-1}$ indicated a fishery potential of 0.188 $ton.km^{-2}.d^{-1}$. This indicated that zooplankton contributed only for 31.4% of the fishery potential leaving the remaining share to be contributed through other food chains.

Acknowledgement

The first author is greatly indebted to Dr. B.N. Desai, Director, and Dr. M.D. Zingde, Scientist-in-Charge, RC of NIO, Bombay for permitting to conduct the studies at the Institute. He is grateful to Dr. V.T. Paulinose, RC of NIO, Cochin for help in the identification of decapods.

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