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Ecological Energetics of Benthic Communities of an Estuarine System of the West Coast of India

Z A ANSARI and A H PARULEKAR
National Institute of Oceanography, Dona Paula, Goa 403 004

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An attempt has been made to measure the biomass and quantify the production rates of different size groups of benthic organisms. The average annual production rates of microphytobenthos, meiobenthos and macrobenthos were estimated to be 42.68, 6.19 and 9.20 gC m^{-2}, respectively. Meiofaunal production was greatly influenced by the presence of large sized nematodes and ostracods, while macrobenthic production was largely constituted by deposit and filter feeding forms such as polychaetes and bivalves. Production of smaller groups of organisms appears to be insufficient to meet the nutritional requirements of the larger faunal groups. Thus it was inferred that the macrobenthic production gets a great deal of its energy source from the detritus rich sediment.

Key Words: Ecological energetics, Benthic communities, Estuarine, System, Biomass

Introduction

The study of the dynamics of the energy flow in marine ecosystems is of fundamental importance (Odum 1971). Benthic ecosystems have diverse types of organisms, both in size and number. Some production estimates on benthos, based on one category of organisms, are available. However, there is no study in which all components of benthos have been considered in a single quantitative investigation. In the present study, we have attempted to analyse the availability of energy and its trophic relation in the benthic system of an estuarine complex.

Materials and Methods

The Mandovi-Zuari estuary and its interconnected Cumbarjua Canal form a complex estuarine system in Goa located along the central west coast of India. Biological features of this estuarine system have been studied in detail earlier (Goswami & Selvakumar 1977, Parulekar et al. 1980 Qasim & Sen Gupta 1981, Ansari et al. 1986, Devassy & Goes 1989).

Along a salinity gradient, six stations, three in Mandovi and three in Zuari, were sampled at monthly intervals from June 1988 to May 1989, covering three broad sediment types, viz.; muddy sand, medium sand and detrital Mud (figure 1). Samples for meiofauna and chlorophyll pigments were collected with a corer using a boat, while macrofauna was collected with the help of a van Veen grab. Replicate samples were collected from each station and different types of benthic fauna were sorted out by sieving.

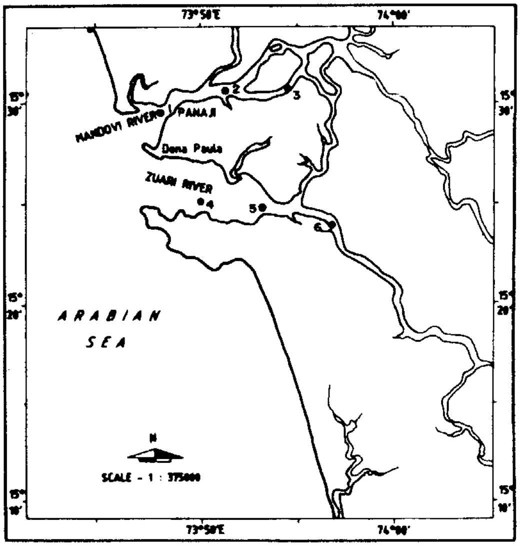

Fig. 1 Map showing the location. of stations in Mandovi and Zuari Esturine system

The biomass of microphytobenthos was estimated from chlorophyll *a* pigment contained in the cores. All animals were enumerated and their dry weight was measured. Production estimates were made using certain factors/turnover ratios taken from the literature. The authors are fully aware that the choice of such factors is arbitrary and has its limitations, but in the absence of the values of actual production or turnover ratios from the area under investigation, it is considered adequate for the estimation of production of different size categories.

Results

Microphytobenthos

Annual mean values of sedimentary chlorophyll *a* and corresponding phaeopigment at six stations in the two estuaries (table 1) ranged from 6.92 to 11.04 μg/g sediment with an overall average of 9.27μg/g sediment for the entire estuarine complex. Pigment content was higher in the muddy sand of lower reaches where phaeopigment content was high in detrital mud. A chlorophyll *a*/phaeopigment ratio of <1 indicated that 50% or more of chlorophyll is actually in degraded form (Tietjen 1968). Carbon estimates of the algal biomass were obtained using an algal carbon/chlorophyll *a* ratio of 40 (Jonge 1980). The estimated values ranged between 2.88 and 4.46 gC m^{-2} with an overall annual average of 3.71 gC m^{-2} for the study area.

Benthic primary production was not measured directly. Many authors have correlated primary production with chlorophyll *a* (Leach 1970). In another study, Cadee & Hegeman (1977) have indicated that a rough estimate of annual benthic primary production can be obtained from the annual chlorophyll *a* values. Thus, taken from the literature a production/chlorophyll *a* ratio of 5 was used to estimate the microphytobenthic production (Bodin et al. 1985). The resultant values are given in table 4.

Meiobenthos

Meiobenthos of the two estuaries have been studied earlier (Ansari 1989). The biomass of different components of meiofauna in grams of carbon were obtained by dividing the dry weight with 2 (Gerlach 1978). Each value (table 2) represents an average of 12 monthly collections and therefore, aptly represents the yearly mean for each sediment type. The total mean biomass was in the range of 0.48-0.74 gC m^{-2}.

Meiofaunal components were dominated by nematodes, harpacticoids, polychaetes, turbellarians and ostracods. Nematodes alone contributed the bulk of fauna ($>60\%$) numerically in all the sediment types and formed about 32% of the biomass. However, benthic ostracods, although lower in numbers, contributed maximum (40%) to the total biomass because of their larger size. Contribution by the other groups was less than 20%.

Table 1 *Average value of chlorophyll a content and microphytobenthic biomass at the study stations [Values in parenthesis are standard deviation)*

Station	Sediment type	Depth (m)	Total observation	Chl. *a* (μ/g)	Phaeopigment (μg/g)	Chl.*a*./Phaeo ratio	Microphyto-benthic biomass (gC m^{-2})
1	muddy and	7	12	11.04	12.90	0.85	4.46
				(3.56)	(4.29)		(1.08)
2	medium sand	5	12	8.33	10.20	0.81	3.13
				(2.17)	(2.56)		(1.22)
3	detrital mud	4	12	8.87	13.60	0.65	3.60
				(1.89)	(2.88)		(0.89)
4	muddy sand	8	12	10.40	12.40	0.83	4.16
				3.08)	(4.16)		(1.45)
5	silty sand	6	12	10.10	11.80	0.85	4.04
				2.92)	(3.19)		(0.73)
6	medium sand	4	12	6.92	14.90	0.46	2.88
				(1.12)	(4.71)		(0.38)

Table 2 *Mean biomass (gC m^{-2}) of different components of the meiofauna at the study stations*

Station	N	C	P	T	O	Others	Total
1	0.21	0.085	0.055	0.048	0.33	0.02	0.748
2	0.18	0.09	0.055	0.028	0.15	0.016	0.51
3	0.16	0.06	0.047	0.029	0.37	0.015	0.68
4	0.26	0.065	0.055	0.042	0.19	0.015	0.62
5	0.21	0.09	0.047	0.03	0.29	0.022	0.68
6	0.18	0.055	0.047	0.026	0.13	0.018	0.48

N, Nematode; *C*, Copepod, P, Polychaete, *T*, Turbellaria; *O*, Ostracod

Meiobenthic production has been estimated from the P/B ratio and the generation time of different individuals. In the present study, however, the annual production was estimated by multiplying the mean biomass of meiofauna with a P/B ratio of 10 and the values are given in table 4. There was a good agreement of these values with the other studies made earlier (McIntyre 1968, McLachlan 1977, Gerlach 1978) that the P/B ratio of meiofauna is about 10.

Macrobenthos

Faunal density showed decreasing trend from the euhaline sector (lower reaches) to the mesohaline zone (upper reaches) of the estuaries (table 3). There was a similar trend in the distribution of biomass, although the values fluctuated much more due to the presence/absence of the estuarine clam, *Meretrix casta* in the two estuaries. Changes observed in the abundance were accompanied by changes in diversity indices.

The macrofaunal component was dominated by the polychaetes at all the stations followed by crustaceans and molluscs. The highest density of macrofauna was obtained in the more stable muddy sand and this was because of the high density of

Table 3 *Mean density (D) (No. m^{-2}), number of species (s), diversity (Margalef index) and biomass (B) (gc m^{-2}) of the macrofauna at the study stations*

Station	D	S	Margalef index	B
1	906	17	3.48	4.63
2	822	12	2.94	3.29
3	346	8	2.09	3.74
4	1044	15	3.18	3.45
5	921	13	3.01	4.12
6	472	8	2.14	3.58

deposit feeders, mainly polychaetes, such as the spionid and capitellid worms. In the sandy bottom, the filter feeding forms dominated by the bivalves, were observed. The crustaceans, largely amphipods and isopods, being detritivores were not restricted to any particular sediment type, although their density was higher in the detrital mud. Thus it is evident that the macrofaunal species get confined to specific substrata, according to their nutritional requirements. This feature indicates the importance of sediment grain size in the distribution of benthic organisms.

Fishery

The annual fish catch of the two estuaries including the riverine regions varies from 150 to 350 tonnes with an average value for the last five years being around 200 tonnes (unpublished data. Goa State Fisheries Department). Demersal fish, mainly prawns and fin fish, contribute from 50 to 70% in the total catch. The dominant group of demersal resources of the estuaries, which directly feed on bottom fauna include cat fishes, sciaenids, flat fishes, groupers, rock cods, sand whiting and prawns. Besides these there are extensive beds of the estuarine clam, *Meretrix casta* in the two estuaries. The average annual yield of clams from different bed is estimated to be around 80 tonnes (Ansari 1978).

Discussion

Major role of benthic communities is to convert the organic detritus into invertebrate biomass which provides food energy to demersal fish stocks and other predators (Mann 1982). The trophic relation and energetics between each size category in benthic studies require an analysis of the real trophic relationship in order to bring out the clear picture of the energy flow and its pathways. In temperate waters, an ecological efficiency of 20% has been considered for secondary production (Steel, 1974, Mann 1982). The transfer coefficient of secondary production of the estuarine system under consideration, has been computed and was found to vary from 1.7 to 39.9% (Bhattathiri et al. 1976). By selecting an average transfer coefficient of 10%

Table 4 *Food demand and production (gC m^{-2} yr^{-1}) of different size catagories at the study stations*

Station	Microphyto-benthos production	Meiobenthos		Macrobenthos	
		Food demand	Production	Food demand	Production
1	52.7	70.48	7.48	115.7	11.57
2	41.65	51.00	5.10	82.2	8.22
3	44.35	68.00	6.80	93.5	9.35
4	52.30	62.00	6.20	86.2	8.62
5	50.50	68.00	6.80	103.0	10.30
6	34.60	40.80	4.80	89.5	8.95

(Parulekar et al. 1980), it was possible to assess the food demand of each category (table 4).

Microphytobenthos production varied between 34.6 and 52.7 gC m^{-2} yr^{-1}. The production of meiofauna was modest, ranging between 4.8 and 7.48 gC m^{-2} yr^{-1}. It is clear from table 4 that the food demand of meiofauna was greater than the actual phytobenthic production could provide. The demand varied in different sediment types, suggesting that the energy requirement of the sediment varies according to its faunal composition and the stability of the environment. Thus, the meiobenthos must find other food sources in the estuaries. This is probably met by detritus (Qasim 1970). There is high amount of detritus produced by the fringing mangrove vegetation which can sustain a high microbial population probably to feed the meiofauna. It has been suggested that the meiofauna takes about 81% of its total energy requirement from the sediment carbon and about 19% from water column (Warwick et al. 1979). It is unlikely that all benthic primary production is utilised by meiofauna and therefore the dissolved organic matter and detritus play an important role in supplying the additional energy for the meiofauna (Qasim et al. 1969, Qasim & Sankaranarayanan 1972).

Macrofaunal production was generally found to be higher than the meiofauna and it varied between 8.22 and 11.57 gC m^{-2} yr^{-1}. This gave an annual average value of 9.2 gC m^{-2} which is close to 8.16 gC m^{-2} reported by Parulekar et al. (1980) for the same estuarine system earlier. The food requirement of macrobenthos was probably of the order of 82.2 to 115.7 gC m^{-2} yr^{-1}. This is much greater than what the total meiobenthic production could provide (table 4). Hence the rest has to come from other available sources. McIntyre (1968) also reported an inadequate supply of meiobenthic food to macrobenthos in a flatfish nursery ground and suggested that the deficit could be met from other sources such as primary production in the sediment and the organic matter derived from the macrophytes and the dead organisms falling from overlying water column into the sediment. Similarly, Wolff and Wolf (1977) observed inadequate supply of food to macrobenthos in a temperature estuary and suggested that 80 to 90% of the food supply must come from particulate organic carbon derived from primary production and organic detritus. The particulate organic carbon of this estuarine system is reported to vary from 0.28 to 5.24 mg/l (Verlencar & Qasim 1985). Considering the phytoplankton production of the present estuarine system at 186 gC m^{-2} yr^{-1} (Devassy & Goes 1989) and zooplankton production of 8.09 gC m^{-2} yr^{-1} (Goswami & Selvakumar 1977), a significant amount of carbon produced in the water column is likely to reach the bottom to be used by the benthic communities.

Macrobenthic species are generally filter feeders, and deposit feeders. They derive organic matter occurring in suspension or from the sediment before either bacteria or meiofauna have had time to denature it (Mann 1982). Some could also be carnivores and derive food from smaller organisms present in the sediment. Hence it could be possible that the macrobenthos get only about half of their energy from the sediment carbon alone and the rest from other sources. Warwick et al. (1979) showed that macrofauna utilise about 65% of the primary carbon from sediment and 35% from the water column and that only 16% of the meiofauna production was used as food by the macrofauna. Therefore meiofauna contributed only a small part of this energy flow.

Tertiary Production

Benthic production has been directly

correlated with demersal fishery production (Parulekar et al., 1982). In his classic study Steele (1974) hypothesised that 60% of macrobenthos production is channelled to demersal fish and 40% to other carnivores in the North Sea. A tentative estimate of tertiary production was also estimated from the present set of data in which only macrobenthic biomass values were considered. It is probably sufficient to consider only the macrobenthos production for the purpose of calculating the production of benthic predators (Mann 1982). While estimating the biological productivity of the Indian Ocean Qasim (1977) has projected tertiary production as 10% of the secondary production. Based on this assumption, the tertiary production was taken as 10% of the macrobenthic production in terms of gC m^{-2}. The carbon values were then raised to live weight and the exploitable yield was taken as 25% of the standing stock, as applied by Qasim (1977). The calculated exploitable demersal fish yield was 252.56 tonnes for the estuarine complex.

It may be concluded that benthic food web in the estuarine system is not a simple chain of phytoplankton, herbivores and carnivores but a complex interaction exists with the other available energy sources. The production of smaller organisms if assumed that these are all eaten up, is totally insufficient to meet the requirement of larger animal categories. Therefore, it is extremely important to consider the role of microbial biomass and detritus in the trophic system of benthos.

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