

Organic enrichment and benthic fauna—Some ecological consideration

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In the present study, synoptic data on the structure of macroinfauna and total organic content of sediment collected from different sources were analyzed to look for patterns of association consistent with conceptual model predictions and to identify total organic carbon (TOC) critical points corresponding to major shifts in the benthic fauna. The density and biomass peaked at moderate TOC (<20 mg/g) and reduced at TOC >30 mg/g. It is clear that sediment organic matter, depending on its quality and quantity, could act as a food source or as a stress source for the benthic community. Present study further demonstrated the general trend of modeled hypothesis with some variation in tropical condition.

[**Keywords:** Benthic fauna, Indicators, Organic enrichment, Climate change]

Introduction

Seas around India and its coastal marine ecosystems have become quite vulnerable and are increasingly affected by environmental stress created by input of pollutants¹. Large number of studies related to benthos and pollution have been carried in Indian seas (see review by Raman²). These pollutants may contribute to climate change. Indicator species of environmental perturbation are often used in assessing the health of the ecosystem³. Benthos is an effective tool used to analyze anthropogenically induced stress in semi-enclosed water bodies⁴⁻⁶. In the classical study Sanders⁷ was one of the first to explore the relationships between sediment characteristics and trophic functional adaptations of soft bottom communities. Today a large number of research programmes have addressed these problems within various coastal regions and have produced highly useful comprehensive data-sets on environmental and biotic conditions within these systems. The development

of sensitive, reliable, and broadly applicable indicators of ocean health is relevant to Chapter 40 (Information for Decision-Making) of the Agenda 21 of UNCED (United Nations Conference on Environment and Development), which calls for sustainable use of the ocean environment. An example of efforts to develop and evaluate indicators from a global (multi-regional) perspective was provided through presentations by the UNESCO-sponsored Ad-hoc Study Group on Benthic Indicators⁸. While there is a wealth of information from temperate zone, it is not clearly understood whether benthos responses to environmental perturbations, especially organic enrichment, are similar under tropical conditions. The data used are mainly collected from the Oceanographic data centre of NIO and published papers.

Organic enrichment–benthic fauna: conceptual model

The benthic fauna-organic carbon conceptual model developed by Pearson & Rosenberg⁹ implies

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that the abundance and biomass of macrofauna would increase to varying level in relation to increasing organic enrichment to a limit and then would decline (Fig. 1). This decline of the biological variables (density, biomass species diversity) indicates towards

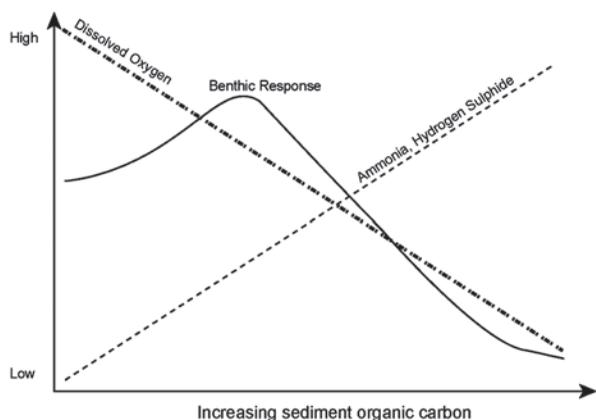


Fig. 1—Conceptual model of benthic response to organic enrichment (modified after Pearson and Rosenberg, 1978)

the formation of physiological stress in a degraded environment caused mainly by organic enrichment (see review by Diaz & Rosenberg¹⁰). This model was tested with fresh data from tropical Indian sea to enhance the utility of the model in different geographical conditions.

The Organic enrichment by domestic effluent and other house hold garbage is the most common type of pollution reported from shallow seas^{11,12}. Organic matter in sediment is often considered as an important food resource for the sediment community¹³ and can be used as a measurement of the trophic status of the benthic marine ecosystem. Trophic organization in the benthic system has usually been related to the nature of the substratum and its organic matter¹⁴. At a given time in a polluted area the conservative benthic species are less favored and are the first casualty while the more opportunistic species are favored and often become the biomass dominant as well as the numerical dominant species. The further increase in organic input could become a source of stress in the benthic system^{8,15} and may lead to elimination of some of the opportunistic species^{16,17}. This has direct impact on the benthic diversity. High

organic enrichment induces the formation of hydrogen sulphides and elimination of benthic biota from the area. Considering the IOC mandate on the development of robust indicators of benthic health (see. Magni *et al*)¹⁸ it is important that we develop the appropriate benchmark based on the benthic data of the Indian coast.

Organic wastes such as domestic sewage is essentially rich in nutrients and when introduced to water bodies in moderate quantity, may act as bio-stimulating agent. However the introduction of such enriched material in large quantity to semi-enclosed water bodies such as estuaries and bays may act as retarding factor by bringing major changes in physical environment and biological characteristic manner with distance from the source of organic enrichment⁸. Generally these zones are recognized: grossly polluted, polluted and unpolluted. A fourth zone called enriched zone where individual number and biomass may increase above the levels encountered in the normal zone, has also been recognized and reported by Pearson and Rosenberg⁸.

Benthic communities are derived and developed either by biologically accommodative method or by physically controlled method¹⁹. It is suggested that systems already subjected to energy requiring stress are more likely to resist changes than those adapted to relatively constant environment. Benthic organisms with high adaptability (biochemical pathways and non-specialized ways of feeding) show more tolerance towards pollution and are frequently used as indicator organisms based on their presence/absence in an area²⁰.

Environmental factors and benthic response to organic enrichment

A heavy input of organic material to water bodies reduces the oxygen concentration in all except extremely well flushed system at the first instance. Considerable increase in suspended solids and organic load in the sediment will lead to the formation of hydrogen sulphide and the development of redox potential discontinuity layer¹³. All these will lead to an acidic medium where survival become difficult for

most of the benthic organisms. If the amount of organic material reaching the sediment is very high then this is the overwhelmingly important environmental factor and that the species adapted to survive in this circumstances are very few¹⁵. As the importance of this factor diminishes than the effect of the other variable will become significant and the species diversity increases both within the community and between the communities in different areas. Under the Indian scenario similar conditions were observed where meio and macrofauna showed gradient of response with distance from the source of organic pollution^{5,6}. According to Hyland *et al*²¹ the concentration of organic carbon in the sediment above 3.5% acts as reducing factor for benthic abundance, biomass and species diversity. In the tropical Indian scenario the response of macrofauna of the Bay of Bengal (Fig. 2) was very similar to the hypothetical model but not so well defined for the Arabian Sea

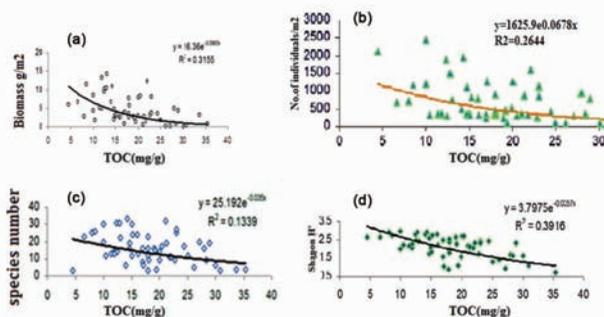


Fig. 2 Distribution of various measures of macrobenthos along a TOC gradient in Bay of Bengal: (a) Biomass (b) number of individuals (c) species number (d) Shannon wiener diversity

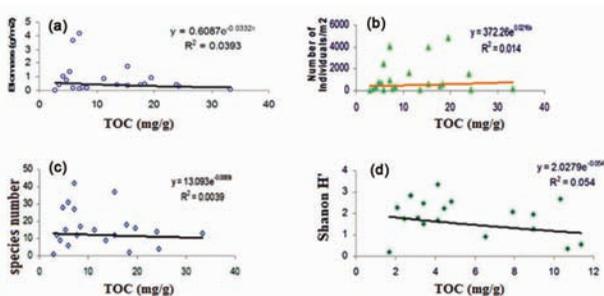


Fig 3–Distribution of various measures of macrobenthos along a TOC gradient in Arabian Sea: (a) Biomass (b) number of individuals (c) species number (d) Shannon diversity

(Fig. 3). One plausible explanation for this could be the conservative nature of organic carbon in marine sediment and its nutritional value. For instance, it is reported that biochemical composition of organic matter is a more evident index of changes in trophic state of the sediment than mere organic carbon or organic matter concentration²².

Changes in benthic community structure due to organic enrichment in space and time.

Spatial changes:

Benthic ecosystem is more or less a stable environment and benthos undergo little annual changes except in shallow seas. The shallow areas of estuaries and bays undergo spatial and temporal changes in community attributes such as abundance benthic biomass, species diversity and richness as a consequence to environmental changes²³. In the extreme and under the abnormal circumstances of organic enrichment and suspended load, the benthic community stability is disturbed⁶. The spatial changes in benthic community of water bodies receiving high organic inputs become visible in an environmental gradient.

The spatial changes in the basic faunal parameter occur in along a gradient of organic pollution, originating at the effluent discharge point and culminating in areas beyond the effects of the discharge material is shown in Table 1. Sediment in the vicinity of discharge point has fewer benthic fauna. Further away form the discharge point the number of taxa slowly increased and after some distance the number increase more rapidly towards asymptotic value. Thus the effects are most pronounced in the vicinity of discharge and decreased progressively with increasing distance from the source of organic pollution²⁴. An example of this is demonstrated in Table 1. Ingole *et al*¹² while studying the macrobenthic community of some harbors of west coast of India, recorded lowest number of individuals and species in the harbor where the organic carbon value was 3.5%. The highest density and diversity was recorded in the sediment with low organic carbon (1.4%).

Table 1–Effect of organic enrichment on beach meiofauna (10 cm core sample).
Values in parenthesis are mean*

S. No	Organic carbon %	PO ₄ mg/l	Interstitial water		D.Oml/l	Total meiofauna (no/10cm ²)
			NO ₃ mg/l	NH ₃ mg/l		
1	3.76-4.44 (4.05)	8.68-11.41 (9.04)	4.55-7.81 (6.04)	19.75-106.35 (65.33)	0.23-0.46 (0.28)	204-1158 (706)
2	2.04-3.28 (2.24)	2.49-5.64 (3.45)	0.27-5.91 (2.29)	12.82-26.01 (19.28)	1.74-1.90 (1.76)	371-2840 (1689)
3	0.88-1.60 (1.25)	0.54-1.72 (1.27)	0.51-2.08 (1.53)	0.68-4.07 (2.14)	1.62-2.92 (2.33)	292-2541 (1259)

*Ansari *et al* 1984,

The numerical abundance rises dramatically close to the discharge point as proposed in the hypothesis of Pearson and Rosenberg⁹. The increase is caused by extremely abundant population of one or two opportunistic species. They had narrow distribution and their number fall equally rapidly down to the ecotone point as the distance from organic input is increased. Following this the abundance declined to a steady state usually found in normal conditions. Such effects are also reported by others²⁵. The changes in numerical abundance are also discernible in benthic biomass. The abnormally high biomass and numerical

abundance can be seen in the enriched zone where opportunistic species such as *Dendronereis aestuarina*, *Prionospio polybranchiata* and *Lumbriconereis polydesma* were the main contributor (Table 2). The dominance of opportunistic species like *Prionospio pinnata*, *Notomastus sp.* and *Mediomastus sp.* in the organic rich sediment is also reported by Ingole *et al*¹². Finally the biomass stabilizes at a somewhat lower level as the normal non-polluted communities developed away from the source of pollution. It has been reported that untreated sewage favours high abundance of some opportunistic

Table 2–Comparison of mean data on macrobenthos from a polluted and unpolluted area in Mandovi estuary, Goa*

Area	Biomass g/m ²	Density No/m ²	No of species	Diversity	Dominant species
Polluted	1.19 ± 0.95	947 ± 284	9.82 ± 1.80	2.79 ± 0.3	<i>Dendronereis aestuarina</i> , <i>Prionospio polybranchiata</i> , <i>Nephtys polybranchia</i> , <i>Lumbriconereis polydesma</i>
Unpolluted	0.35 ± 0.27	476 ± 162	7.25 ± 1.04	2.25 ± 0.6	<i>Diopatra neapolitana</i> , <i>G. alba</i> and <i>Lepidonotus tenuisetosus</i>

*Ansari *et al*, 1986.

species in the vicinity of sewage outfall⁶. The secondary biomass maxima probably occurs in that area of the gradient where organic enrichment of the sediments is sufficient to provide a rich source but not yet high enough to cause serious oxygen depletion and limiting factor.

Temporal changes

The changing species, abundance and biomass described above as taking place along a gradient in space of decreasing organic enrichment may also be shown to occur along similar gradients in time. Whether the gradient is one of increasing organic input to an area over time, or of reduced input, the changes are expected to follow the above pattern. Thus as input increase species number and biomass initially increase, then decrease to the ecotone point, followed by secondary maxima of biomass abundance. With further increase in input of organic enrichment the population will fall rapidly to an afaunal state. Conversely if an area receiving high initial inputs of material is studied over a period when those input are reduced the river series of changes may be founded. To study the full scale of such changes along the whole gradient, basic knowledge of faunal composition in the particular area before the changes in discharged organic takes place, is highly desirable.

Indicator species have been used to characterize the degree of organic pollution. Species change along the gradient of increasing of organic enrichment take the form of a continuous succession rather than a series of distinct grouping. The growth and decay period of population of various species overlap in a complex manner, even in small number of species present. Such successional processes can be divided into phases which will allow easy comparison between two areas. The presence of large salinity gradient, sedimentary particle size gradient, or other variable environmental stresses associated with organic enrichment distorts the pattern of the ecological changes observed and gives rise to considerable difference in the resulting species distribution.

Organic enrichment & Changes in trophic structure

Trophic relationships are particularly influenced by the gradient of organic input and are important in any study on organic pollution. Trophic relationship are simplified as the gradient increases and occurrence of different trophic groups changes in space and time with the increasing input. The analysis of community changes in relation to organic input is considered an important fundamental tool. Ratio of different trophic groups (selective and nonselective deposit feeders, scrapers, suspension feeders, etc) will vary in different sediment granulometry and under different influence of organic inputs²⁶.

The ability of many species to change their feeding methods to adjust to any changes in potential food supply must be one of the basic mechanisms underlying community stability. There is a decline of suspension feeding elements and increase in deposit feeders as organic input to the sediment increase. The increasing sedimentary instability brought about by the deposit feeders may physically clog the celliary and siphonal mechanism and is instrumental in reducing suspension feeding population in area subject to high inputs of particulate organic matter. The selective surface feeder and subsurface feeder also decline as inputs increases. The community is adjusted through increase or decrease of trophic groups and their physiological activities.

Conclusion

Increased organic enrichment brings changes in physical environment and biological parameter and the consequent changes in benthic community. Organic enrichment of high magnitude will super impose its gradient on the environment and induce changes in the distribution of organisms controlled initially by environment. Benthic animals show characteristic response gradient with distance from the source of organic inputs in space and time. Population increases with moderate input of organic enrichment. An excessive organic load, on the other hand, create stress condition for benthos. Changes

in the trophic structure and sedimentary stability along the gradient are accompanied by changes in the genera and families. There is a need to extend this type of study to larger geographical areas to find the suitability of the model for evaluation and assessment of the health of the ecosystem.

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