

Abyssal benthos of the central Indian Ocean

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Abstract—Quantitative studies of the abyssal benthos (3600 to 5300 m) of the central Indian Ocean show a rich fauna and high standing crops. Density of 3 meiofaunal and 12 macrofaunal taxa are large (2175 to 15233; \bar{x} = 6441 m⁻²). Polychaetes (41.6%), peracarid crustaceans (31.7%), ophiuroids (12.2%), echiuroid-bryozoa (9.7%), molluscs (4.8%), and agglutinating rhizopod protozoans form the macrofauna. Meiofaunal taxa are nematodes (69.4%), harpacticoid copepods (26.6%), and ostracods (4%). Meiofauna abundances are positively correlated with distance from shore, whereas the distribution and abundance of macrofauna are independent of variations in depth and distance from the shore. Ratio of macro to meiofauna in the total population is 1 to 31.

The benthic standing crop is uniformly high (0.54 to 13.73 g m⁻²; \bar{x} = 2.70 g m⁻²) and many times larger than previously reported for comparable depths in other oceans and from the same region. Biomass values are significantly related to distance from shore and the type of substratum. Contribution of macro and meiofauna to the total standing crop was in the ratio of 31 to 1.

High benthic biomass and rich fauna are consequences of high organic production in the euphotic zone. The correlation between biomass of the total oxidizable organic matter in the water column and the benthic standing crop is statistically significant (r = -0.64) at the P < 0.05 level.

Rich fauna and high standing crop were associated with the occurrence of polymetallic nodules.

INTRODUCTION

SOME information on the deep-sea benthos of the Indian Ocean is available from the hadal depths (BRUUN, 1956; SPORCK, 1956; WOLFF, 1961) and from the bathyal region (THIEL, 1966; MOISEEV, 1971; HUMPHREY, 1972; NEYMANN, SOKOLOVA, VINOGRADOVA and PASTERNAK, 1973; PARULEKAR, HARKANTRA and ANSARI, 1982). However, little is known about the quantitative aspects of bottom fauna of the abyssal region (NEYMANN *et al.*, 1973)—an important biotope in the deep Indian Ocean.

In January and February 1981, an abyssal area of about 10,000 km² in the northern part of the central Indian Ocean was surveyed by R.V. *Gaveshani* (cruises 86 and 87) for the exploration of polymetallic nodules and to study relevant oceanographic features. During the cruises benthic samples were collected; the distribution and abundance of macro and meiofauna in relation to certain environmental factors are discussed.

MATERIAL AND METHODS

Twelve stations (Fig. 1) in the depth range 3600 to 5300 m between 1°S and 7°N and 57 and 69°E were occupied. A 0.18-m² Petersen Okean grab (penetration depth 25 cm) was generally used to collect the bottom fauna. A few samples obtained with a 0.13-m² Free Fall

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(Boomerang) grab (TYP H Prussag Aktiengesellschaft Meerestechnik, Hannover, West Germany) have been considered only for qualitative studies. All macro and meiofauna population and biomass results are means of triplicate samples.

A plexiglass core tube, 2 cm diameter, was used for meiofaunal subsampling from the undisturbed top 10-cm layer of the grab samples. Samples were sieved through a 44- μm mesh and fauna preserved in 1:500 Rose Bengal-formaldehyde solution. Sorting, identification, and enumeration were under a binocular microscope.

Macrofauna subsampling from the grab samples was with a 170-cm² plexiglass quadrant (10 cm penetration) and a 500- μm mesh screen was used for separating the organisms. Biomass was measured on a single-pan electric balance (Keeroy, Benaras, India) with an accuracy of 0.001 g; the values are on wet weight basis, including the exoskeletons. Absolute numbers are used for statistical analysis, however, for the sake of uniformity in comparison, mean values per square meter are represented.

Statistical analysis of the data on population density and biomass in relation to depth, distance from the coast, and biomass of the oxidizable organic matter in the water column was done on a TDC 316 computer (ECIL, India). Owing to the small number of observations, nonparametric Spearman's rank correlation coefficients are used. Data from stations in the western basin (Fig. 1), excluding the rather anomalous Sta. 1902, have been considered for statistical treatment and only the absolute values (population density and biomass) have been used. Distances are taken with Seychelles as the reference point.

RESULTS

Fauna—distribution and abundance

The bottom fauna comprised 12 macrofaunal and 3 meiofaunal invertebrate taxa (Table 1). Distribution of different taxa was far from continuous. The population density varied from 2 per 10 cm² to 15 per 10 cm² for meiofauna and from 2 per 170 cm² to 5 per 170 cm² for macrofauna.

Amongst the meiofaunal taxa, nematodes, with a 100% occurrence and 69.4% composition, were important. The harpacticoid copepods with population density varying between 2 per 10 cm² and 6 per 10 cm², had an occurrence of 58.3%. Abundance and occurrence of meiofaunal ostracods were low.

In contrast to meiofauna, the distribution of macrofauna as represented by 12 taxa was varied. The polychaetes were most prevalent (66.6%). Next in order of occurrence (Table 1) were the amphipods (33.3%), tanaidaceans (25%), isopods, bryozoans, and ophiuroids (16% each). At Stas 1922, 1927, and 1929 (Table 1), a gelatinous sticky substance was observed which, on detailed examination, turned out to be the pseudopodial mass of agglutinating rhizopod protozoans. HESSLER and JUMARS (1974) also reported the agglutinating rhizopods from the abyssal benthos of the North Pacific.

Polychaetes were the most important macrobenthic organisms and were followed by peracarid crustaceans (5 taxa), ophiuroids, minor phyla (2 taxa), and molluscs (Table 1). Amongst the peracarid crustaceans, amphipods occurred more frequently than the tanaidaceans. Abundance of macrofauna varied within a modest range of 2 to 5 per 170 cm² with an average population count of 3.3 per 170 cm². Population density of meiofauna, on the other hand, fluctuated from 2 to 15 per 10 cm² with a mean count of 6.2 per 10 cm², many times more than reported for the deep-sea meiofauna of the central North Pacific and the east

and west Atlantic continental slopes (WOLFF, 1977), but one tenth of those observed (THIEL, 1966) in the bathyal depths of the northwest Indian Ocean.

Distribution of meiofauna exhibited a negative trend ($r = 0.65$) with variations in depth but a positive trend ($r = -0.64$) with distance from the shore. The correlation coefficients were statistically significant at $P < 0.05$. However, the multiple correlation coefficient between depth, distance from the shore, and the abundance of meiofauna was insignificant even at $P < 0.10$, indicating that meiofaunal population decreases with increasing depth but increases with the distance from the shore. Although the relevance of depth and distance in the distribution and abundance of meiofauna was individually significant, the combined effect was insignificant at $P < 0.10$. The abundance of meiofaunal population, however, was related to the nature of the bottom deposits. The population density ranged from 4 to 15 per 10 cm^2 ($\bar{x} = 10$ per 10 cm^2) in brown oozy sediments with polymetallic nodules in the 3500 to 4500-m depth zone against 2 to 9 per 10^2 ($\bar{x} = 4.3$ per 10 cm^2) in the 4500 to 5500-m depth zone in yellow calcareous oozy deposits with no nodules.

No significant influences ($r = 0.03$) of the depth variations were observed on the distribution and abundance of macrofauna. The correlation between the macrofauna and the distance from the shore, although high ($r = -0.32$), was statistically insignificant even at the $P < 0.10$ level. Thus, it may be inferred that the distribution and abundance of macrofauna in the abyssal region of the northern part of the central Indian Ocean are independent of variations in depth and distance from the shore.

Standing crop

The macrofaunal biomass varied from 9 to 226.4 mg per 170 cm^2 or from 0.47 g m^{-2} to 13.32 g m^{-2} with an overall mean value of 44.6 mg per 170 cm^2 or 2.62 g m^{-2} (Table 1). No significant ($r = 0.07$) influence of depth on the standing crop was observed. However, the correlation between the macrofaunal biomass and the distance from the shore was significant ($r = -0.083$) at the $P < 0.05$ level. A positive trend was observed between the type of substratum and the magnitude of standing crop. Accordingly the bottom deposits, characterized by brown oozy sediments harbouring polymetallic nodules, had almost three times the biomass (5.16 g m^{-2}) of the yellow calcareous oozy sediments without nodules (1.78 g m^{-2}).

Meiofauna contributed insignificantly to the total standing crop and the biomass values varied from 0.02 mg per 10 cm^2 to 0.41 mg per 10 cm^2 or from 0.02 m^{-2} to 0.41 g m^{-2} with a mean value of 0.08 g m^{-2} (Table 1). Though the meiofaunal biomass tended to decrease with increasing depth, no statistically significant correlation could be found. Similar to the observed dependence of macrofaunal biomass on the distance from the shore, a relationship between the meiofaunal standing crop and the distance was observed. While the macrofaunal biomass decreased away from the shore, the meiofaunal biomass increased with distance. Thus, there was a distance-dependent inverse relationship between the macro and meiofaunal biomass. Overall, the contribution of macro and meiofauna biomass to the benthic standing crop was in the ratio of 31 to 1.

The relationship of the productivity of the overlying water column to the benthic standing crop was positive. The total oxidizable organic content of the water column, as a measure of column productivity, varied from 201.5 to 778 g m^{-2} ($\bar{x} = 439.8 \text{ g m}^{-2}$), whereas the benthic standing crop (macro + meio) for the same part of the western basin ranged from 0.54 to 4.14 g m^{-2} with a mean value of 0.92 g m^{-2} (Table 1). The correlation coefficient was statistically significant ($r = -0.64$) at the $P < 0.05$ level. The combined influence of depth and distance on the benthic standing crop was insignificant.

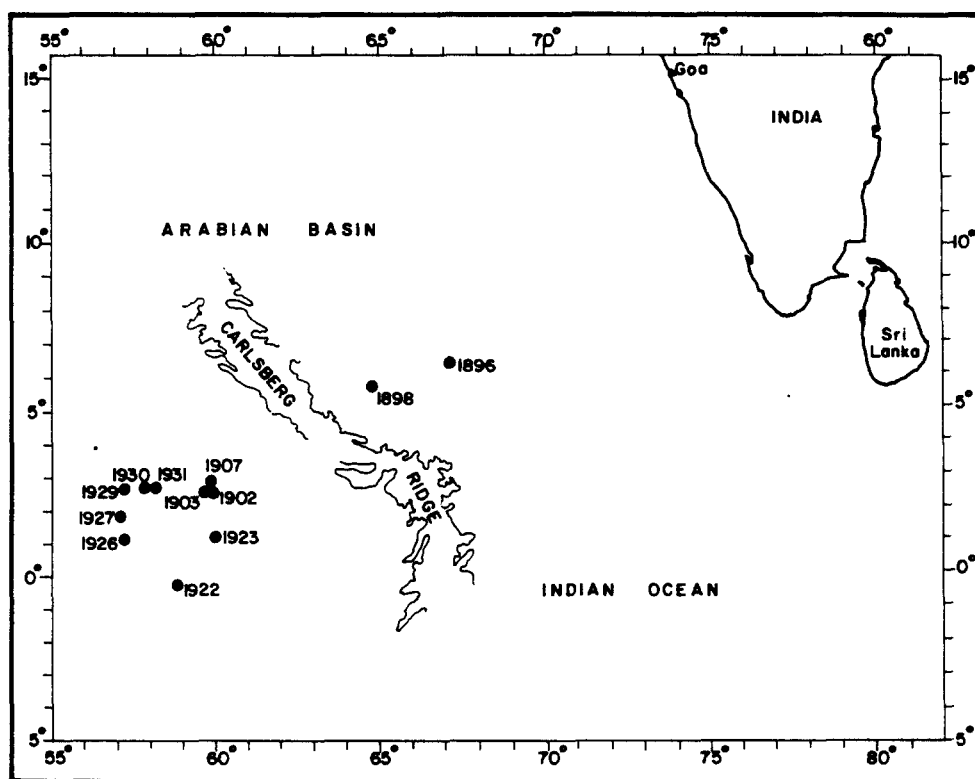


Fig. 1. Sampling locations in the central Indian Ocean.

DISCUSSION

The information available on the distribution and abundance of the Indian Ocean bottom fauna, especially the deep regions is scant. The earlier quantitative work on the abyssal benthos (NEYMANN *et al.*, 1973) pertains only to macrobenthos, and there is no information on meiobenthos except possibly the work of THIEL (1966) on the quantitative distribution of meiofauna (but not the biomass) of the bathyal depths near the northwest coast of Africa.

The abyssal benthic fauna of the central Indian Ocean is quite rich. The earlier workers (NEYMANN *et al.*, 1973) reported low ($<0.2 \text{ g m}^{-2}$) benthic biomass in the open sea and abyssal regions of the tropical zone of the Indian Ocean. Lower biomass values (0.05 to 0.1 g m^{-2}) have been reported for areas north of the equator between 55 and 70°E . The present investigation of the same area shows a high biomass. The macrobenthic biomass values from the western basin (Fig. 1) found during the present study are higher by an order of magnitude, but the results are not comparable because different procedures were used and the information on the abyssal benthos is generally inadequate.

There is no well-defined decrease in standing crop, either with the increasing depth or with the distance from the shore. This contradicts the conclusions by ZENKEVITCH, BARSANOVA and BELYAEV (1960), who found that the biomass of the fauna of the abyssal zone was highest near the coast and in shallow depths and a great decrease was observed with both increasing depth and increasing distance from the land. Such patterns are not so conspicuously evident

in the tropics as in boreal environments because the abundant influx of organic matter from the neritic region over-rides the effect of increasing depth beyond the upper 1000 m (VINOGRADOVA, 1959).

The relatively high abyssal biomass in this part of the central Indian Ocean is probably due to high biological productivity (HUMPHREY, 1972). QASIM (1977) inferred that organic production in the Indian Ocean is almost 75% higher than that of the Pacific and 17% greater than that of the Atlantic. Similar to the Pacific and Atlantic (MOISEEV, 1971), close relationship between primary productivity and benthic standing crop was observed in the present study. GAGE (1978) postulated that high standing crops of deep-sea benthos are directly related to deep-water circulation transporting organic matter from the shelf and slope to abyssal depths. This may also be the case for our study area, where much terrestrial plant debris was found on the sea floor, especially up to 4500 m.

WYRTKI (1973) noted that both bottom and the deep waters of the Indian Ocean are derived from the Atlantic and spread by active flow, at least upon crossing the sills in the various ridges dividing the deep-sea basins. The Antarctic bottom water warms as it spreads northwards and fills the deep basins of the central Indian Ocean. Thus, the area of study has active deep-sea circulation and replenishment. NEYMANN *et al.* (1973) called the northern part of the central Indian Ocean basin, i.e., the present study area, an eutrophic area with adequate food supply. This corroborates our findings of a rich benthic biomass in the abyssal environment.

The faunal distribution and abundance in the abyssal region of the central Indian Ocean fit into the overall pattern of distribution of deep-sea benthos of the Indian Ocean (NEYMANN *et al.*, 1973). Polychaetes in the macrofauna and nematodes in meiofauna were the important taxa (WOLFF, 1977).

The occurrence of a rich benthic fauna associated with polymetallic nodules is of interest. While there are similar reports from the North Pacific (HESSLER and JUMARS, 1974) and the Aleutian Trench (JUMARS and HESSLER, 1974), impoverishment has generally been reported (NEYMANN *et al.*, 1973) for the abyssal fauna associated with ferro-manganese concretions in the 3000 to 4000-m deep region of the southern part of the central Indian Ocean basin. The probable reasons for impoverishment were oligotrophic feeding conditions. This supports the hypothesis that the abundance of deep-sea benthos is a function of currents and productivity.

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