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Response of Deep-Sea Macrobenthos to a Small-scale Environmental Disturbance

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Abstract

To assess the possible effect of nodule mining on deep-sea environment, the Indian Deep-sea Environment Experiment (INDEX) was undertaken in the Indian Basin. The present investigation is a part of the disturbance and recolonization study. Pre- and post-disturbance sediment samples were collected from 21 stations between 10^0 01' – 10^0 03' S and 75^0 59' - 76^0 02' E at water depths of 5300 - 5350 m to assess the effect of benthic disturbance. There was a significant change in the composition and biomass of macrofauna after the disturbance. Post-disturbance vertical profiles indicated a 63% reduction in the numerical count in the top 0-2-cm layer and high aggregation of macrofauna in deeper (5-10-cm) sediment layer. The impact of the disturbance was severe, as the mean biomass of macrofauna was significantly reduced in the disturbed area, probably due to the displacement and /or mortality caused by the benthic disturber.

Keywords: Environmental disturbance, benthic fauna; Impact assessment; Central Indian Basin.

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1. Introduction

The deep-sea floor of the Central Indian Basin (CIB) is known to harbour a remarkable benthic biodiversity (Neymann *et al*. 1973; Parulekar *et al*. 1982;1992 Ingole *et al.* 1992; Ansari et al. 1996 Ingole et al. 1999; Ansari, 2000; Ingole *et al*. 2000). However, there is very little information on deep-sea benthos of this area in relation to environmental parameters. As compared to the coastal and shallow sub-tidal benthic environment, temperature, salinity and dissolved oxygen fluctuate within a very narrow range at abyssal depths, where food availability is limited (Pfanukuche, 1993). While describing the standing stock of deep-sea benthos Watts et al (1992) and Ingole et al (1992) demonstrated direct relationship between benthic biomass and surface pigment biomass. In the deep-sea environment such as CIB, the production of sediment organic matter is low (Nath & Mudholkar, 1989) and hence benthic biota has to rely on the particulate organic matter that is produced in the euphotic zone. The benthic community has presumably adapted to the prevailing conditions at deep-sea and any disturbance to their environment will certainly bring major changes in the composition and abundance of benthos (Thistle *et al.* 1985; Foell *et al*. 1990).

It is assumed that when an artifical disturbance is created on the seabed, the surface layers of the sediment in the upper few centimeters is disturbed, which could lead to changes in the existing depositional and decompositional biota-sediment processes. Thus, deep-sea mining operations will potentially produce some undesirable environmental effects, both in the water column and on the seabed (Berge *et al*. 1991; Thiel *et al.* 1992). Possible effects are expected to involve biochemical changes resulting in biotic responses (Raghukumar et al. 2001) as well as direct impacts on organisms (Bluhm, 1994;1999; Shirayama, 1999; Ingole et al. 1999). Although commercial mining of nodules from the deep sea may take a few decades, the potential impacts need to be studied in advance. In this respect the results obtained from the environmental impact studies conducted in the coastal areas (Roberts *et al*.1998; Harvey *et al.* 1998) can be used for better understanding and maintaining the ecological balance in the deep-sea benthic environment.

To assess the possible impact of nodule mining on the benthic environment, Indian Deep-sea Environment Experiment (INDEX) was conducted in the Central Indian Basin (CIB). This experiment comprised of baseline and pre-disturbance study, physical disturbance of the sea bottom, and post-disturbance study. In this investigation, we have compiled and presented data on effect of disturbance on macrobenthos collected during pre-and post-disturbance study. The hypothesis we have tested here is that benthic disturbance will reduce the benthic population.

2. Materials & Methods

The sediment samples for the present study were collected from a total of 21 stations (6 pre-disturbance, 15 post-disturbance) distributed in the CIB. The experiment site lies between 10°01'

– 10°03’ S and 75°59' - 76°02' E, with a 5300 - 5350 m depth range (Table 1). A strip 3000m long and 200m wide oriented in a NW-SE direction was selected for the disturbance experiment (Fig.1). Box core (50x50x50-cm size) samples were analysed in the present study. Sub-samples for macrofauna were taken with an 8-cm diameter plastic core tube. The sediment was sectioned at 0-2, 2-5, 5-10, and 10-20-cm. A replicate sample was taken at each station, and all samples were preserved in 10% formalin Rose bengal solution. Faunal components were identified only to the group /order level.

3. Results

Composition and abundance of macrofauna : Abundances of macrofauna in the CIB area are given in Table 2-3. The average density and biomass recorded down to a depth of 20-cm ranged from 48 to 704 individuals m^{-2} (mean ± SD; 336±463.7, n=6) and 4.6 to 69.3 $mg.m^{-2}$ (mean ± SD; 24.1 ± 25.5, n=6) during the pre-disturbance (Fig. 2). The values for post-disturbance showed wide fluctuations, mainly due to the emergence of larger forms such as holothurians and bivalves. The values ranged from 32 to 1120 individuals m^{-2} (mean ± SD; 391.7± 512.2, n=15; Fig.2) and 1.6 to 246 $mg.m^{-2}$ (mean ± SD; 85.3±79.9, n=15). A total of 17 macrofaunal groups were recorded from the CIB area (Table 2-3).

The community structure of the study area was dominated by polychaetes (bristle worms), which constituted 65% of the total population in pre-disturbance sediments. Next in the order of abundance were crustaceans (31.8%), which included various small but prominent peracarid forms such as Tanaidacea, Isopoda, Amphipoda and Cumacea. The other taxa included Mollusca (1.5%) and Sipunculida (1.4%). Taxonomic composition of the macrofaunal community in the post-disturbance samples indicated the dominance of nematodes (33%), crustaceans (28%) and polychaetes (27%). Small crustaceans, such as cumaceans and harpacticoid copepods, were abundant in most of the samples. Bivalves, gastropods and holothurians were also abundant in few samples and accounted for 12%. A close scrutiny of the numerical abundance after physical disturbance suggested no significant change in the density of macrofauna outside the disturbance track, while a significant reduction in the numerical count was recorded inside the disturbance track (t test, $t=1.0069; p=0.3475$, df=6). A comparison of macrofaunal taxa during pre- and post-disturbance suggested significant deviation in major taxa (Fig. 3). Data on the biomass (wet weight) of pre-disturbance (6 stations) were compared with post-disturbance, it showed significant difference (t test, $t=1.943$, $p<0.07$, df=5).

Vertical Distribution of Macrofauna: The vertical distribution of macrobenthos showed that the majority of the benthic animals were concentrated in the upper 0-5-cm layers during the pre-disturbance study (Fig. 4), with maximum density (61%) in the top 0-2-cm layer (Table 4). Only polychaetes and bivalves were recorded in the deeper layers (10-20-cm). The crustaceans, being epibenthic and detritivores, were restricted to the top 5-cm layers of the sediment. This picture changed somewhat in the post-disturbance samples (Table 4). Polychaetes and crustaceans (isopods) were present in all cores in the post-disturbance samples, but their composition was drastically reduced in the top 0-2-cm sediment layer (Table 4). The emergence of small epibenthic crustaceans such as Cumacea and Isopoda was conspicuous. The abundances of Gastropoda, Bivalvia, Ostracoda and Holothuroidea increased dramatically during the post-disturbance (Fig. 3). The vertical profile indicated high aggregations of macrofauna in much deeper (5-10-cm) layers and almost 63% reduction in the top 0-2-cm sediment layer during the post-disturbance (Fig. 4).

4. Discussion

Polychaetes generally have been found to be dense in the deep-sea benthic environment (Gage, 1978; Parulekar et al. 1982; Ingole et al. 1992). This trend also was observed in the present study, with crustaceans coming second in abundance particularly after disturbance. The vertical profile showed aggregation of macroinvertebrates in the top 0-5-cm in pre-disturbance. This picture completely changed during the post-disturbance particularly in the top 0-2-cm sediment layer (Fig.4). The numbers generally decreased in the disturbance track, while outside the track there was marginal increase in the mean density of macrofauna (Fig. 2). It is believed that the sediment disturbance at deep-sea level is deleterious to the buried in-fauna; however, disturbance also increases the food resources for larger benthic animals by exposing the organic-rich sediment to the surface (Bluhm, 1994). During post-disturbance, many organisms of the top layer may either die or get carried to other areas. Since the post-disturbance study was conducted immediately after the disturbance, the number of animals outside the track could increase further with time.

As the quantity of the available food at the abyssal depths is considered an important factor determining the deep-sea benthic standing stock (Thiel et al. 1989, Pfannkuche,1993), the vertical profile of sediment organic carbon in CIB also was studied (Anon, 1997). It was suggested that the high concentration of organic carbon in deep sediment layer, could be due to the presence of refractory fraction of organic matter left after the carbon mineralization (Anon, 1997). Significant increase in the sediment organic carbon in top 0-2-cm sediment layer during post-disturbance was due to the shifting of organic-rich deeper sediment to the surface (Ingole *et al*. 1999). Therefore, the operation of disturber at deep-sea may actually enhance the food supply to the benthic organisms by altering the sediment layers (similar to the large-scale bioturbation process).

While comparing the vertical distribution of metazoan meiofauna during pre-and post-disturbance, Ingole et al (1999) reported significant reduction in the abundance of meiofauna with no obvious change in composition. In the present case, not only the macrofaunal abundance was changed during post-disturbance but also the community composition was affected. The polychaetes, which are normally dominant in the deep-sea environment, were replaced by smaller crustaceans (Cumacea and Harpacticoida) and nematodes during post-disturbance. This was evident particularly in the top 0-2 cm sediment layer (Table 4). The significant reduction in macrobenthic population on the disturbance track (in top 0-2-cm layer) could be due to the mortality of epifaunal organisms that are exposed to the predators after disturbance. Secondly, the possibility of mobile macro- and megafauna moving to other undisturbed areas cannot be ruled out. This statement is supported by our observation on the biomass distribution. Increased macrobenthic biomass during post-disturbance and its significant variation (Two-way ANOVA, $F=3.352$; $p<0.1$; $n=5$) from pre-disturbance data (Fig. 2) clearly suggests the movement of larger mobile forms to the nearby-undisturbed area. Thus, the impact of the disturbance was severe as the mean biomass of macrofauna was significantly reduced (52% reduction) in the disturbed area, probably due to the displacement and /or mortality caused by the benthic disturber. However, the changes in benthic community observed here should be considered at macro level only because the sampling for post-disturbance was conducted immediately (i.e., < 2-months of disturbance-experiment), and the finer changes after resettlement of the disturbed sediment have not yet been monitored. Nevertheless, the impact of the disturbance was significant on the benthic macrofauna.

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Table 1: Details of the box corer sampling in the Central Indian Ocean.

Station No.	Sampling Date	Depth (m)	Geographical position	
Pre-disturbance			Latitude (S)	Longitude (E)
BC-11	24.6.97	5330	10°02' 058"	76°01' 332"
BC-12	24.6.97	5320	10°01' 373"	76°00' 610"
BC-13	25.6.97	5320	10°01' 512"	76°00' 328"
BC-15	26.6.97	5330	10°02' 408"	76°00' 027"
BC-16	28.6.97	5330	10°02' 593"	76°00' 940"
BC-17	30.6.97	5300	10^0 02' 090"	76°00' 762"
Post-disturbance				
BC-02	22.8.97	5320	10°02' 313"	76°01' 067"
BC-03	22.8.97	5320	10°02' 056"	76°00' 569"
BC-04	21.8.97	5320	10°01' 498"	75°59' 680"
BC-05	20.8.97	5320	10°01' 787"	76°00' 122"
BC-06	23.8.97	5320	10°02' 643"	76°01' 820"
BC-07	26.8.97	5330	10°02' 313"	76°00' 470"
BC-11	25.8.97	5330	10°02' 105"	76°01' 236"
BC-12	23.8.97	5320	10°01' 382"	76°00' 591"
BC-13	23.8.97	5320	10°01' 522"	76°00' 341"
BC-14	25.8.97	5330	10°02' 172"	76°00' 120"
BC-15	27.8.97	5330	10°02' 172"	76°00' 012"
BC-16	26.8.97	5330	10°02' 606"	76°00' 947"
BC-18	28.8.97	5320	10°02' 729"	76°00' 613"
BC-19	27.8.97	5320	10°02' 173"	76°00' 819"
BC-20	26.8.97	5300	10°01' 925"	76°00' 347"

Table 2: Composition and abundance of macrofauna (mean nos.m^{-2}) in CIB studied during INDEX (Pre-disturbance) cruises.

		Stations						
Depth (cms)	Taxa	11	12	13	14	15	16	Mean±sd
0-2	Polychaeta	80	80	32	128	32	32	64.0±39.2
	Harpacticoida	80	80	0	16	16	0	32±37.9
	Tanaidacea	32	32	0	0	16	16	16.0±14.3
	Nematoda	16	336	16	48	0	48	77.3±128.2
	Sipunculida	0	32	0	0	0	0	5.3±13.1
	Oligochaeta	16	0	0	0	0	0	2.7±6.5
	Unidentified	0	32	0	0	0	0	5.3±13.1
2—5	Polychaeta	0	0	0	0	32	32	10.7±16.5
	Harpacticoida	32	0	0	0	0	16	8.0±13.4
	Tanaidacea	0	0	0	0	16	0	2.7±6.5
	Nematoda	0	32	0	48	0	0	13.3±21.3
5-10	Polychaeta	48	0	0	16	32	16	18.7±18.7
	Harpacticoida	0	0	0	0	48	32	13.3±21.3
	Tanaidacea	0	0	0	16	32	0	8.0±13.3
	Nematoda	32	0	0	32	16	0	13.3±15.7
10-20	Polychaeta	0	0	0	0	32	0	5.3±13.0
	Harpacticoida	0	16	0	0	0	0	2.7±6.5
	Tanaidacea	0	64	0	32	16	0	18.7±25.6
	Cumacea	0	0	0	16	0	0	2.7±6.5
	Nematoda	16	0	0	32	0	0	8.0±13.4
	Gastropoda	0	0	0	0	32	0	5.3±13.1
	Ostracoda	0	0	0	0	16	0	2.7±6.5
Total		352	704	48	384	336	192	336±463.7

Table 3: Composition and abundance of macrofauna (mean nos. m^{-2}) in CIB studied during INDEX (Post-disturbance) cruises.

(Depth (cms)	Taxa	Stations															
		2	3	4	5	6	7	11	12	13	14	15	16	18	19	20	Mean±sd
0—2	Polychaeta	0	0	16	16	0	32	48	16	0	80	0	0	16	32	16	18.1±22.5
	Harpacticoida	0	0	48	0	32	16	32	32	16	48	0	0	80	0	16	21.3±23.9
	Cumacea	0	0	0	16	32	0	32	16	0	16	0	0	0	0	0	7.5±11.9
	Nematoda	0	32	32	0	128	32	48	16	16	16	0	32	64	0	48	30.9±33.3
	Gastropoda	0	0	64	0	0	32	0	0	48	0	0	0	0	0	0	9.6±20.7
	Holothuroidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	1.3±5.16
2--5	Polychaeta	16	48	16	0	64	112	32	16	0	32	48	0	128	48	0	37.3±39.5
	Harpacticoida	0	32	0	0	48	48	16	0	0	0	32	0	224	112	0	34.1±61.0
	Cumacea	0	16	16	0	32	16	0	0	0	0	16	0	64	32	0	12.8±18.3
	Nematoda	0	80	144	32	16	96	64	0	32	32	16	16	128	48	0	46.9±46.2
	Bivalvia	0	16	0	0	16	0	0	0	16	0	0	0	32	16	0	6.4±10.1
	Gastropoda	0	0	0	0	0	0	0	32	0	0	0	0	32	0	0	4.2±11.2
	Holothuroidea	0	0	16	0	0	0	0	0	0	0	16	0	0	0	0	2.1±5.6
5—10	Polychaeta	0	128	48	0	0	64	16	16	16	80	0	0	64	176	48	43.7±52.5
	Harpacticoida	0	32	0	0	0	16	0	0	0	16	0	32	16	32	32	11.7±14.1
	Cumacea	0	0	0	0	0	0	0	0	0	0	16	0	32	0	16	4.3±9.5
	Nematoda	0	32	32	0	16	48	32	48	48	48	16	16	128	96	16	38.4±34.6
	Bivalvia	0	32	64	0	0	0	0	0	0	0	0	48	64	32	0	16±24.9
	Gastropoda	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	3.2±12.4
10-20	Polychaeta	0	32	0	32	0	0	0	0	0	0	0	0	0	32	0	6.4±13.2
	Harpacticoida	16	16	16	0	0	16	0	0	16	16	0	16	16	32	0	10.7±9.9
	Cumacea	0	0	0	0	0	0	16	0	16	16	0	0	16	0	0	4.3±7.3
	Nematoda	0	16	16	0	0	32	32	48	16	80	0	0	16	48	0	20.3±23.7
Total		32	512	528	96	384	560	368	288	240	480	160	160	1120	736	212	391.7±512.2

Table 4: Mean density (mean nos. per m^2) and composition (%) of major macrobenthic taxa in the sediment layer during pre- and post-disturbance study.

Sediment depth (cms)	Taxon	Pre-disturbance		Post-disturbance	
		Density	%	Density	%
0—2	Annelida	149	44.5	49	12.4
	Crustacea	48	14.3	29	7.34
	Mollusca	0	0	10	2.53
	Holothuria	0	0	2	0.51
	Sipunculida	5	1.4	0	0
2—5	Annelida	24	7.1	84	21.27
	Crustacea	11	3.3	47	11.9
	Mollusca	0	0	11	2.8
	Holothuria	0	0	2	0.5
5—10	Annelida	32	9.5	82	20.7
	Crustacea	21	6.2	18	4.5
	Mollusca	0	0	19	4.8
10--20	Annelida	13	3.9	27	6.8
	Crustacea	27	8.0	15	3.8
	Mollusca	5	1.5	0	0

Figures:

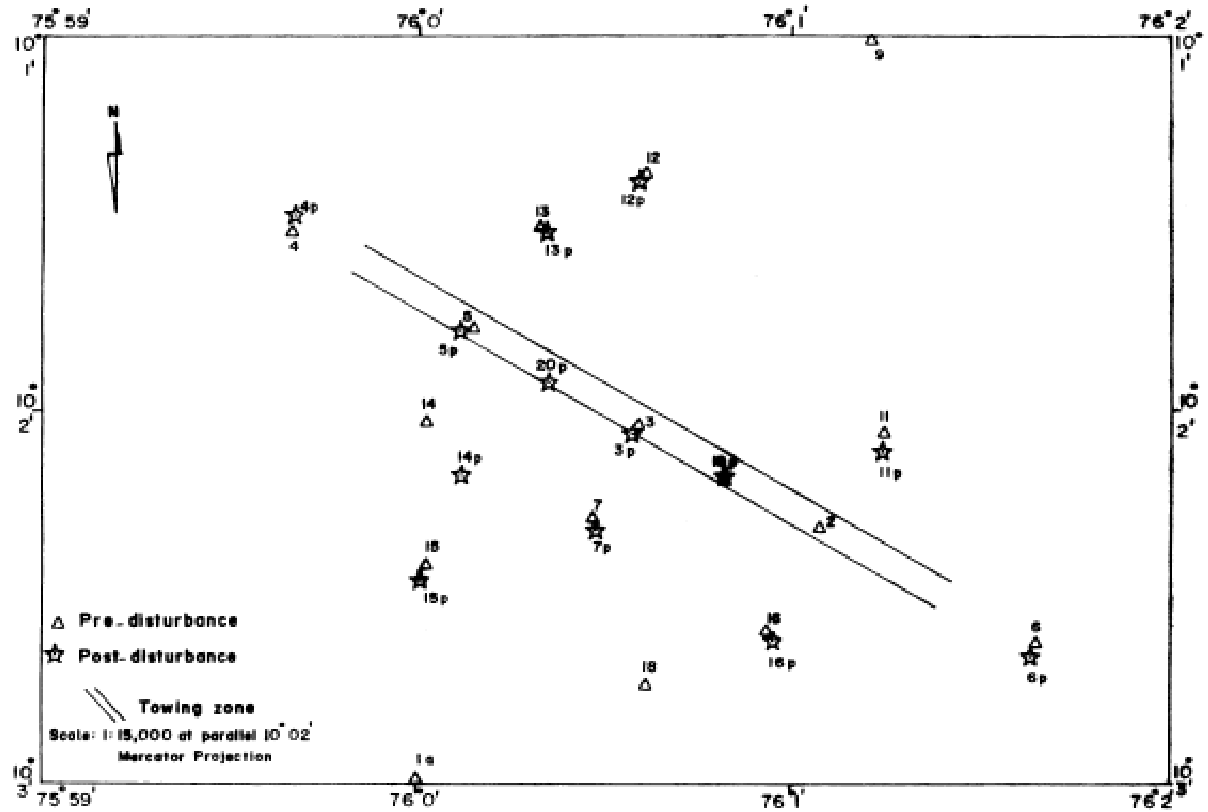

Figure 1: Location of the sampling stations.

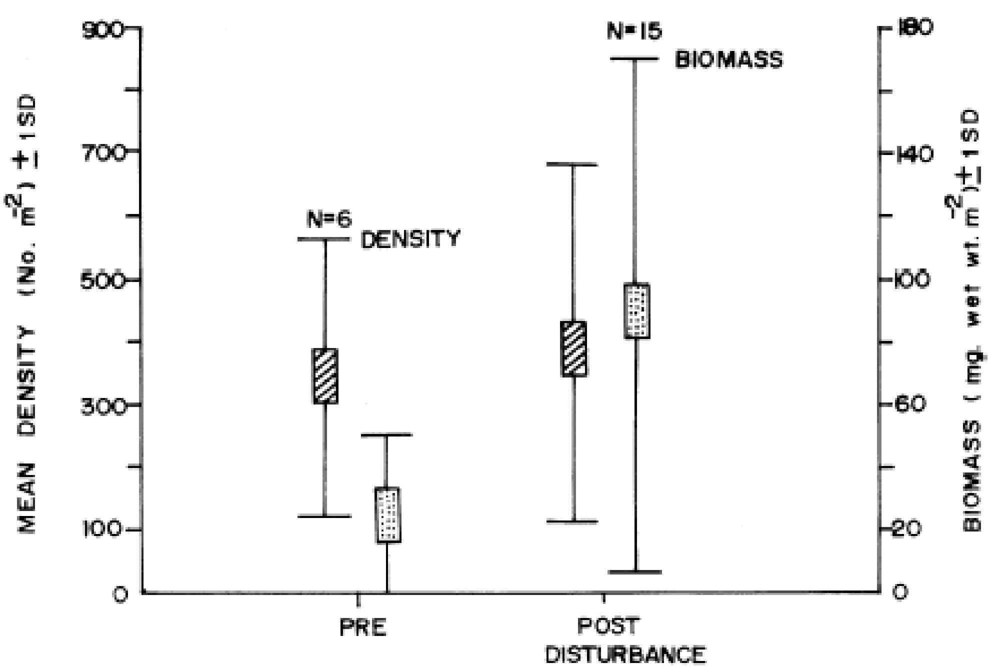

Figure 2: Mean density and biomass (vertical bar represents standard deviations) of macrobenthos pre- and post-disturbance study.

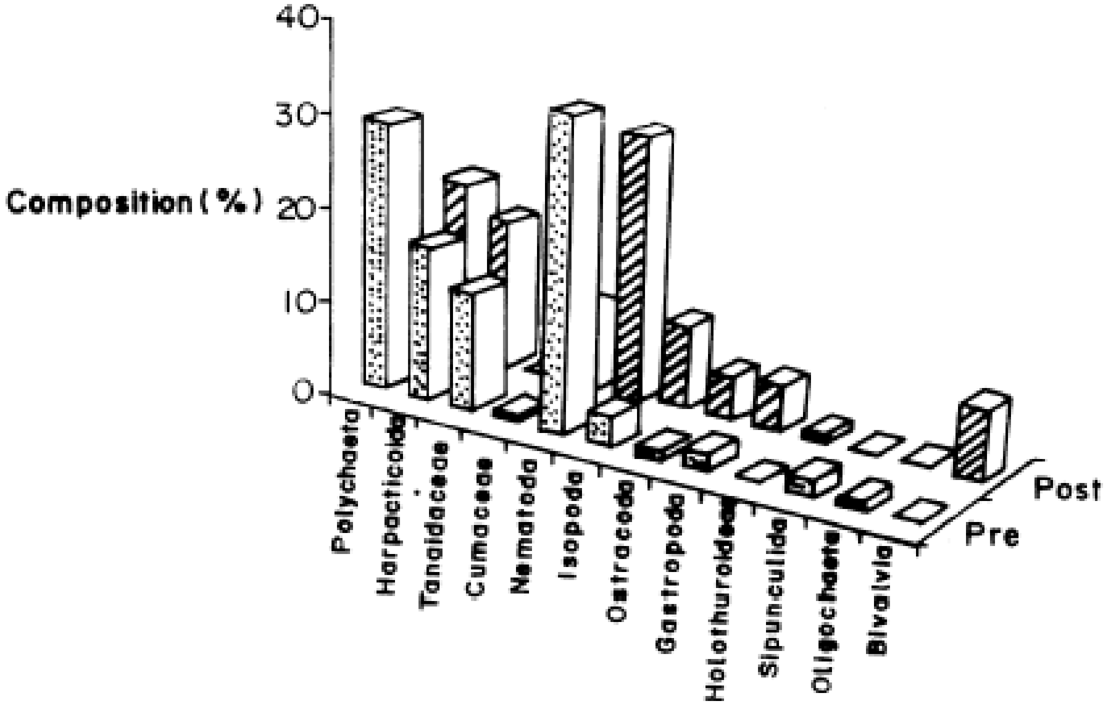

Figure 3: Abundance (no. per m^2) of major macrofaunal groups during pre- and post-disturbance study.

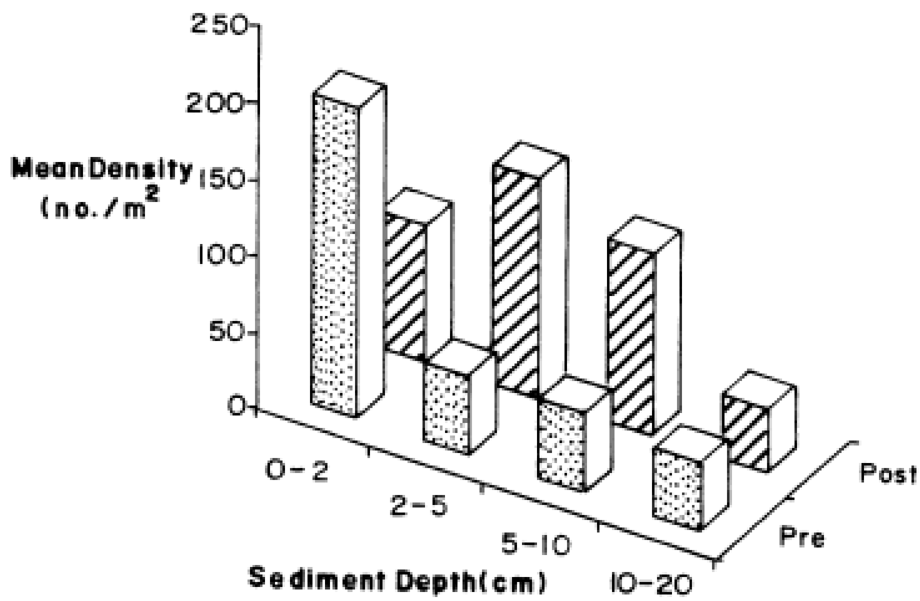

Figure 4: Vertical distribution of macrofauna during pre-& post-disturbance study.