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Effects of bottom trawling on the ecological integrity of macrobenthos off Veraval, Gujarat

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Original Article

Abstract

Experimental bottom trawling was conducted from *MFV Sagarkripa* at five transects of water depths 15-20 m, 21-25 m, 26-30 m, 31-35 m and 36-40 m in commercial trawling grounds to assess the impact of bottom trawling on the macrobenthic fauna off Veraval coast. Trawling was conducted for 12 months in a span of 15 months (September 2005-November 2006) excluding the trawl ban period (June to August). The groups of fauna present were polychaetes, gastropods, bivalves, scaphopods, amphipods, isopods, copepods, cumaceans, ostracods, shrimps, crabs, squilla, balanids, foraminiferans, octocorals, sipunculids, nemerteans, pogonophores, pterobranchia, brittle stars and teleost fishes. A total of 81 species of polychaetes belonging to order Errantia (36 species) and Sedentaria (45 species) were identified. The molluscs were represented by 15 species of gastropods, 13 species of bivalves and one species of scaphopod. One octocoral genus was also identified. The abundance and biomass of the fauna were recorded. The numerical density of macrofauna increased after trawling, exposing them from their natural habitat. The numerical density of macrofauna increased after trawl ban showing that trawl ban is giving some respite to the fauna for rejuvenation. The biodiversity indices were found to be significantly different before and after experimental trawling at 15-20 m and 21-25 m. The ABC curve and w-statistic of the total macrofauna showed that the fauna of the area studied were moderately or grossly stressed. It was also possible to delineate the impact on the fauna by MDS plots. The present study confirms the deleterious effects of bottom trawlers on macrobenthos off Veraval. Cataloguing the biodiversity of macrobenthos, identification of indicator species and updating the new data generated will aid in taking up steps towards conservation of macrobenthos. Suggestions are made for the promotion of eco-friendly gears and for conducting studies on appropriate un-trawled control sites for comparative assessment.

Keywords: *macrobenthos, bottom trawling, Veraval, India*

Introduction

The northwest coast of India has the highest number (23,618) of mechanized vessels operating in the Arabian Sea (Vivekanandan *et al.*, 2005). Among the maritime states in India, Gujarat has the longest coastline (19.7%), the broadest continental shelf (30.9%) and a wide EEZ (10.6%). The recommended optimum fleet size of mechanised trawlers for Gujarat is 1,473 (Kurup and Devaraj, 2000), but presently 7402 commercial trawlers are operating (Anon, 2005). Veraval is the largest trawler port of Gujarat from where 2,793 trawlers are in operation (Anon, 2005). Despite this, there are no studies on the impact of bottom trawling on the benthic fauna off northwest coast. As commercial fishing of India is concentrated in the inshore waters (< 50 m depth) and a periodic data is lacking on the macrobenthos, the present study is the first of its kind carried out in this area.

Macrofauna are small-bodied invertebrate organisms living in or on the sediments. They are retained in the sieve having mesh size between 0.5 mm and 1 mm (Mare, 1942). They are an important component of the marine ecosystem and are indicators of the health of an ecosystem. They play an important role in an ecosystem through trophic dynamics as both prey and predator. The macrofauna, being less mobile than the larger invertebrates and fishes, more accurately reflect the changes in the physical and chemical conditions of the soft-bottom ecosystem than the more mobile organisms. Monitoring the macrofaunal community is important because these organisms live in direct contact with the sediments and often ingest sediments and suspended particulates, which may contain organic food and/or contaminants (Gray *et al.*, 1992; Diener *et al.*, 1995). Soft-bottom sediments provide a long-term record of changing environmental conditions reflecting the effects created by natural or man-made disturbances. Impacts of anthropogenic inputs will be manifested in the sediments by changes in macrofaunal community structure (e.g., abundance, diversity, and biomass). The macrofaunal assemblage can reflect a gradient of tolerances (enhancement to degradation) in relation to environmental (man-made or natural) stresses (Warwick and Clark, 1993, 1994; Diener *et al.*, 1995; Sheppard 1995).

The aim of the present investigation is to bring out the possible impact of bottom trawling on the macrobenthos in the commercial trawling grounds off Veraval. This study is also the first attempt to document the macrofaunal species of the study area.

Material and methods

Experimental bottom trawling was carried out, for 12 months September 2005- November 2006 excluding the trawl ban period (June to August) along Veraval coast (20º54'40"N lat; 70º22'12"E long). Trawling was carried out from CIFT Research vessel *MFV Sagarkripa* (15.5 m OAL steel stern trawler equipped with 124 hp ALM 412, marine engine), along five transects representing five water depth zones ranging from 15 to 40 m. The selected transects are fishing grounds for traditional and mechanised fishing vessels conducting single day fishing. The experimental design involves the collection of sediment samples before and after experimental trawling along the pre-identified track. Transect, corresponding to a particular depth zone was fixed using a Garmin GPS (with an accuracy of 4-6 m) installed onboard the vessel and coordinates were stored for navigation to the respective stations for sample collection. A 50/200 dual frequency Simrad Fish Finder was also used to fix transects by avoiding areas with rocky bottom and other physical disturbances. The five transects included five depth zones of 15-20 m, 21-25 m, 26-30 m, 31-35 m and 36-40 m. The stations at these depth zones were designated as D_j ; j = 1,2,3,4 and 5 for stations at the five discrete water depths from 15 to 40 m at 5 m interval. The trawling mode was indicated as T_i ; i = 1 for before and 2 for after trawling. The coordinates of each transect is shown in Fig.1. From the point fixed in the pre-identified depth zone, sediment samples were collected using a van Veen Grab (0.1m^2 mouth area) before and after experimental trawling. The specifications of the trawl net used are as follows: four seam high opening bottom trawl net with 23 kg of sinkers, seven numbers of 150 mm Ø plastic floats, a pair of 80 kg V- form steel otterboards, 34 m head rope, 38 m footrope, 400 mm wing section mesh size, 300 mm throat mesh size, four sections in the belly having 200, 140, 120 and 90 mm mesh size and codend of 40 mm mesh. This type of trawl net is commonly used by fishermen of Veraval. The trawling intensity was fixed as one tow for one hour and this was repeated at each depth zone.

After hauling the van Veen grab, the sediment samples were sieved through a 500μm sieve. The sediments retained by the sieve were transferred to one litre plastic bottles and preserved in 7% buffered formalin. In the laboratory, the sediment samples were again sieved through 500μm sieve for further identification. The organisms retained in the sieve were sorted out and preserved in 5% formalin. All organisms were identified to group level. Polychaetes (Fauvel, 1953; Day 1967) and molluscs (Dance, 1976; Carpenter and Niem, 1998) were identified to species/ genus level as far as possible using a stereomicroscope. The numerical abundance and wet weight were recorded. The molluscs were weighed along with shell (wet weight). The numerical abundance was expressed as number metre^{-2} and biomass as gram metre^{-2}.

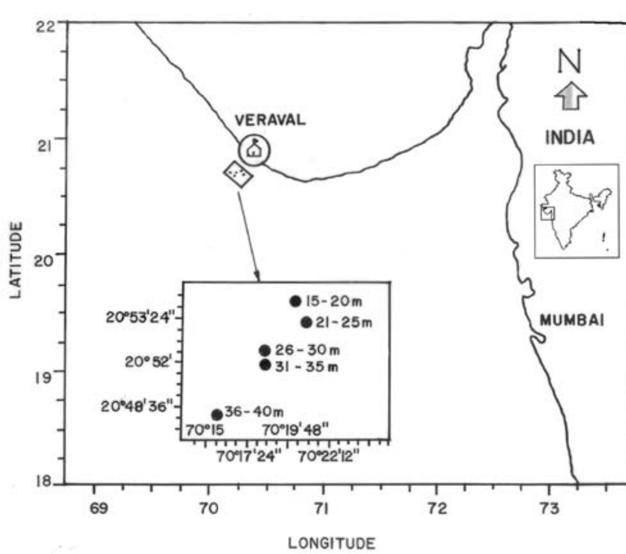


Fig. 1 Map showing study sites

The statistical analysis was performed by SPSS (version 12; 0.1). An array of diversity indices was calculated using PRIMER software package ver. 5.2.9 (Clarke and Warwick, 2001). The biodiversity indices such as total number of species (S), number (N), Margalef index (d), Pielou's evenness index (J'), Brillouin index (H), Fisher's Alpha (α), Shannon index (H'), Simpson index (1-λ') and Hill's no. (N1 and N2) were analysed. The $\log_{10}$ (X+1) transformed indices were used for paired t-test to find out probable significant difference in the mean value of the indices before and after trawling in each depth zone. The statistical significance was measured at $p < 0.05$. Abundance-Biomass Comparison (ABC) curves were plotted in order to ascertain whether the benthic communities had undergone any stress due to trawling pressure. The multidimensional-scaling (MDS) plots were constructed to visually determine the disturbance on macrofaunal assemblages before and after trawling.

Results and discussion

The groups of macrofauna represented were polychaetes, molluscs (gastropods, bivalves and scaphopods), crustaceans (crabs, shrimps, cumaceans, amphipods, ostracods, isopods, copepods, squilla, balanids), foraminiferans, nemerteans, cnidaria (octocorals), sipunculids, teleost fishes (mainly *Trypauchen vagina* followed by *Filimanus similis*, leptocephalus and *Cynoglossus* sp.), pogonophores, pterobranchia and brittle stars. A total of 81 species of polychaetes belonging to order Errantia (36) and Sedentaria (45) were recorded. The molluscs constituted of 15 species of gastropods, 13 species of bivalves and one species of scaphopod. One macrobenthic octocoral was also recorded.

The characteristic features of trawling impact i.e., the occurrence of broken polychaete tubes, mollusc shells and brittle stars were observed in the study area. The molluscs were dominant at 40 m depth. Bivalves were found mostly in damaged condition whereas gastropods were found with intact shells. The intact shells of gastropods exhibited more diversity than bivalves. The damaged shells were mostly of *Paphia textile, Dosinia cretacea and Arca navicularis*. The sessile or erect structures like hydroids which were abundant in September (after trawl ban), were not found after trawling. According to Lokkeborg (2005), bottom trawling resulted in a significant decline in the abundance of erect sessile invertebrates.

The total numerical density of macrofauna increased after trawling exposing them from their natural habitat (Fig 2). This is similar to the studies of Ball *et al* (2000), Pranovi *et al.* (2000), Sanchez *et al.* (2000), Gowda (2004), Zacharia (2004), Kurup (2004) and Krishnan *et al.* (2005) who have also recorded an increase in the abundance of macrobenthos immediately

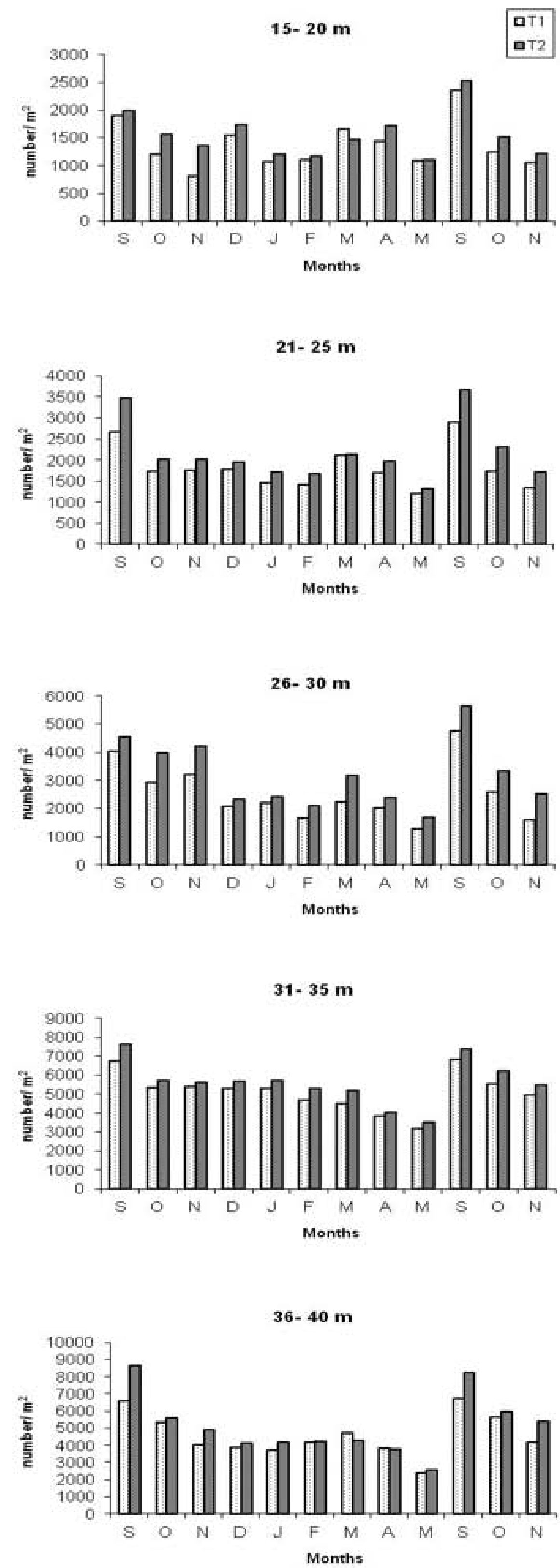


Fig. 2. Variations in total numerical density (no.m^{-2}) of macrofauna before and after trawling during September 2005 to November 2006. T_i indicate trawling mode, i = 1 for before and 2 for after trawling

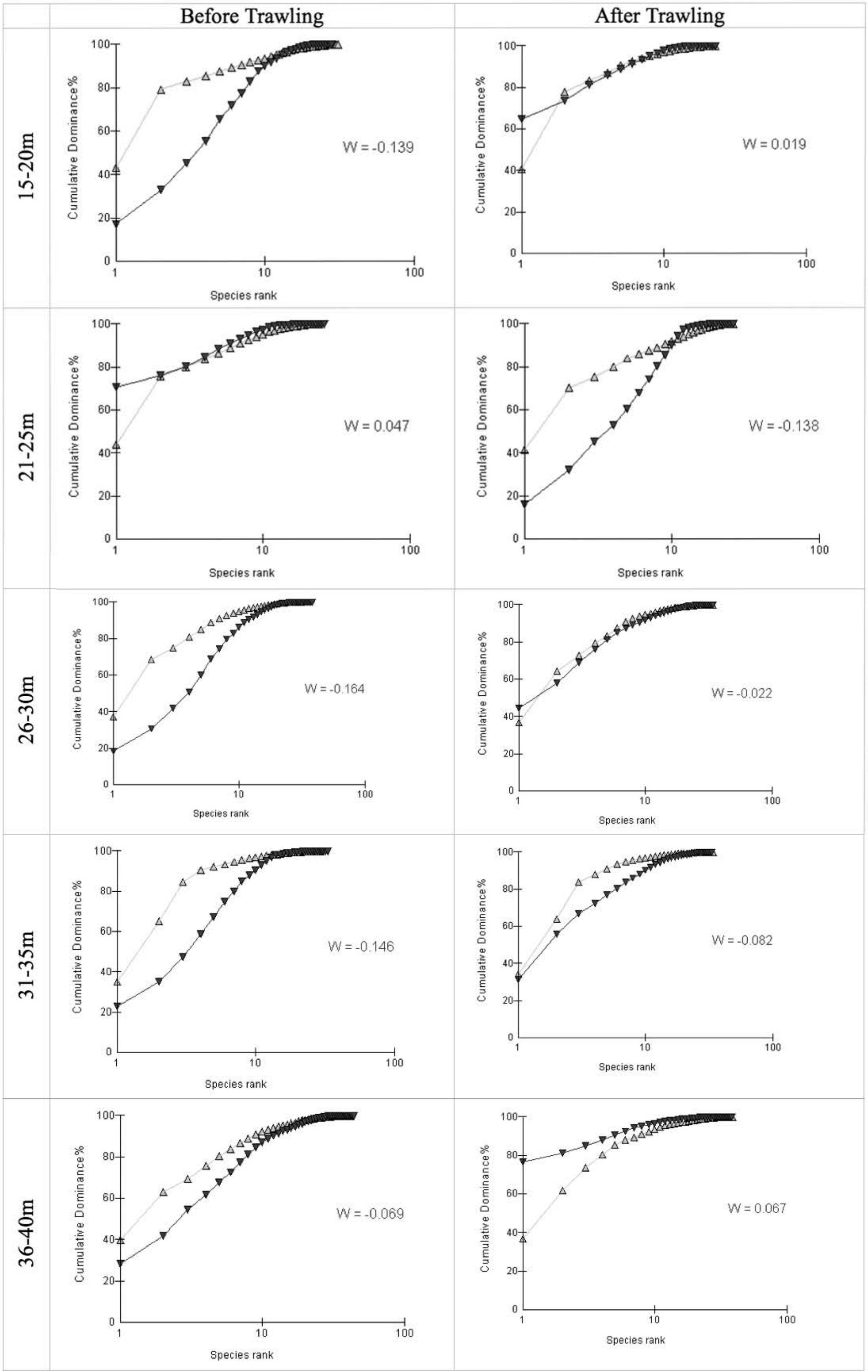
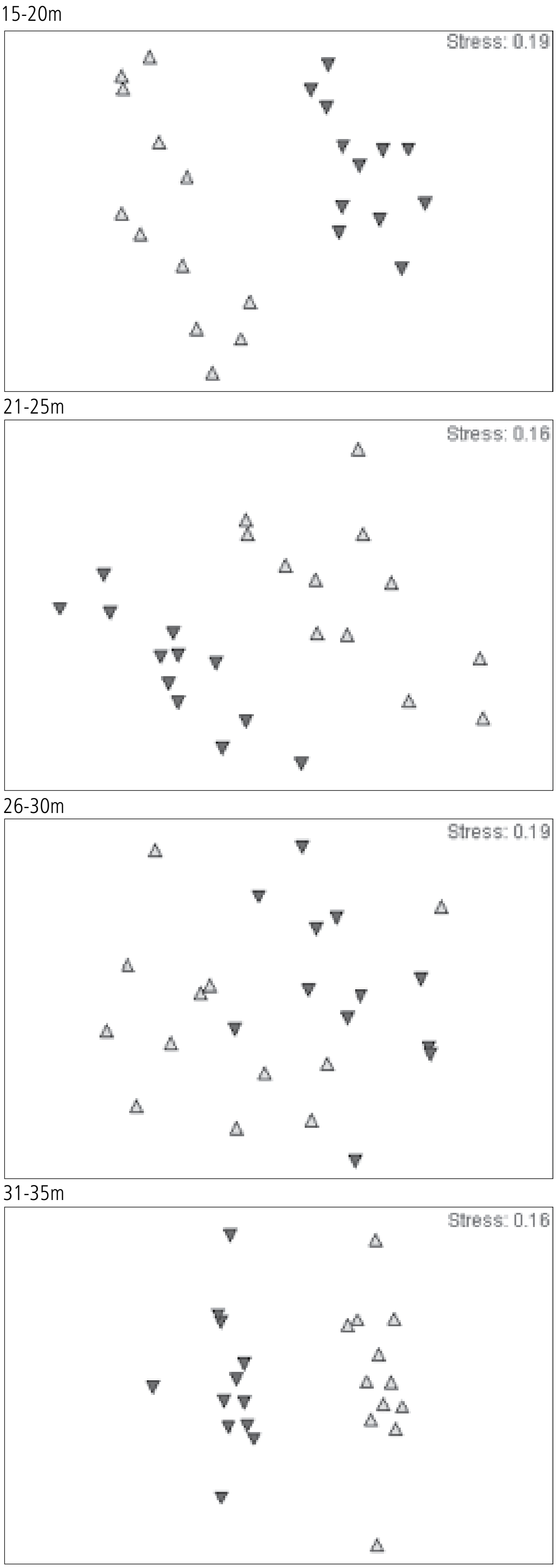


Fig. 3 ABC curves for total macrobenthos before and after trawling during September 2005 to November 2006



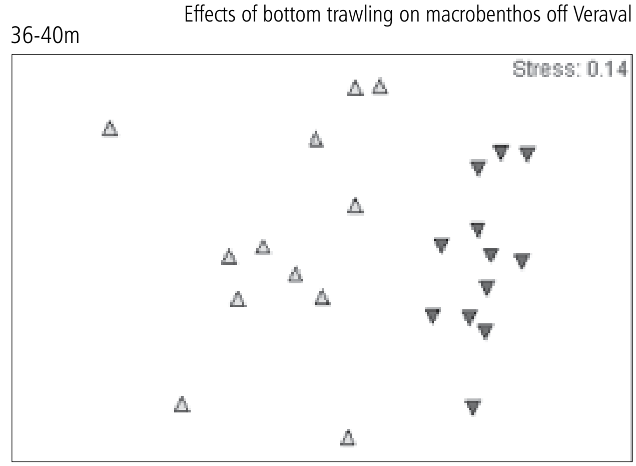


Fig. 4. MDS plots for total macrobenthos during September 2005 to November 2006

▲ Before trawling ▼After trawling

after trawling. In the present study, the numerical density of macrofauna increased after trawl ban showing that trawl ban is giving some respite to the fauna for rejuvenation (Fig 2). According to Thomas and Kurup (2005) and Thomas *et al.* (2006) the polychaetes increased in abundance and biomass during July when there was a ban on bottom trawlers in Kerala. They opined that the ban is useful for the regeneration and recoupement of polychaetes. The increase in number of polychaetes has been attributed to the survival of opportunistic species in response to bottom trawling (Gowda, 2004; Kurup, 2004). The experimental trawling operations conducted along Kerala coast showed that the abundance, biomass and diversity of the polychaetes increased immediately after trawling. This was attributed to their exposure due to the removal of top sediment. According to Thomas and Kurup (2006) the fast growing and continuous breeding species dominated the trawl ban period. The macrobenthic octocoral *Lituaria* sp was found almost throughout the year (Table 1) because they escape from trawling effect to a certain extent as they live buried in sediment. The average numerical density of *Lituaria* sp. was 13-14 no.m^{-2} before trawling and 19-20 no.m^{-2} after trawling. The average biomass was 0.06 g.m^{-2} before trawling and 0.09 g.m^{-2} after trawling. The increase in the number and biomass after trawling shows that they are exposed during bottom trawling.

The biodiversity indices before and after trawling at five water depths are given in Table 2. On performing paired t test, it was found that total number of species (S), number (N), Margalef index (d), Brillouin index (H), Fisher's Alpha (α), Shannon index (H') and Hill's no. (N1) were significantly different before and after trawling ($P < 0.05$) at D_1. At D_2, species (S), number (N), Margalef index (d), Pielou's evenness index (J'), Brillouin index (H), Shannon index (H'), Simpson index ($1-\lambda'$) and Hill's no. (N1 and N2) were significantly

Table 1 The numerical density of *Lituaria* sp. (no./m^{-2}) before and after trawling during September 2005 to November 2006 off Veraval

Water Depth	T_1/ T_2	S	O	N	D	J	F	M	A	M	S	O	N
15-20	T_1	Not recorded											
	T_2												
21-25	T_1	-	-	-	-	40	-	-	-	-	-		
	T_2	-	-	-	-	-	-	20	-	-	-		
26-30	T_1	-	-	-	-	10	-	-	40	-	-		
	T_2	-	-	110	-	-	-	20	30	-	-		
31-35	T_1	-	-	-	10	140	-	-	-	20	-	10	20
	T_2	-	20	10	20	260	-	-	-	20	-	20	10
36-40	T_1	-	-	-	-	20	60	100	-	10	10	10	
	T_2	-	-	-	-	-	120	-	-	30	-	20	100

Table 2 Biodiversity indices (mean ± S.E.) before and after trawling at different depth zones

Diversity Index	T_1D_1	T_2D_1	T_1D_2	T_2D_2	T_1D_3	T_2D_3	T_1D_4	T_2D_4	T_1D_5	T_2D_5
S	31.08 ±3.47	21.92 ±2.16a	25.33 ±2.67	29.33 ±2.34a	26.25 ±2.31	30.33 ±4.55	36.00 ±3.12	37.25 ±4.10	46.42 ±5.57	46.92 ±4.33
N	1369.17 ±125.61	1546.67 ±119.23a	1817.50 ±148.97	2157.50 ±204.11a	2553.33 ±299.54	3200.83 ±340.74a	5115.00 ±301.26	5615.00 ±336.95a	4595.83 ± 363.82	5134.17 ±512.24a
Margalef	4.14 ±0.42	2.84 ±0.27a	3.22 ± 0.32	3.68 ± 0.27a	3.21 ± 0.25	3.60 ± 0.51	4.09 ± 0.34	4.18 ± 0.44	5.36 ± 0.61	5.36 ± 0.45
Pieolu	0.82 ±0.02	0.81 ±0.01	0.82 ± 0.01	0.88 ± 0.01a	0.79 ± 0.01	0.80 ± 0.01	0.69 ± 0.01	0.67 ±0.01	0.82 ± 0.01	0.83 ± 0.02
Brillouin	2.71 ±0.09	2.44 ±0.09a	2.58 ± 0.09	2.92 ± 0.09a	2.53 ± 0.07	2.59 ± 0.09	2.41 ± 0.04	2.37 ± 0.05	3.06 ± 0.08	3.14 ± 0.03
Fisher	5.68 ±0.67	3.63 ±0.38a	4.17 ± 0.46	4.81 ± 0.38	4.09 ± 0.34	4.66 ± 0.75	5.25 ± 0.49	5.38 ± 0.65	7.23 ± 0.94	7.15 ± 0.66
Shannon	2.76 ±0.09	2.47 ±0.09a	2.62 ± 0.09	2.95 ± 0.09a	2.56 ± 0.07	2.62 ± 0.09	2.43 ± 0.04	2.39 ± 0.05	3.09 ± 0.08	3.16 ± 0.03
Simpson	0.89 ±0.01	0.87 ±0.01	0.90 ± 0.01	0.93 ± 0.01a	0.89 ± 0.01	0.89 ± 0.01	0.82 ± 0.01	0.82 ± 0.01	0.92 ± 0.01	0.93 ± 0.01
Hill_1	16.60 ±1.65	12.46 ±1.26a	14.37 ± 1.42	20.01 ± 1.70a	13.32 ± 0.94	14.28 ± 1.27	11.40 ± 0.43	11.08 ± 0.61	22.89 ± 2.12	23.84 ± 0.85
Hill_2	10.42 ±0.99	8.66 ±0.85	10.40 ± 0.93	14.89 ± 1.23a	9.53 ± 0.70	9.46 ± 0.65	5.65 ±0.20	5.55 ± 0.19	13.87 ± 0.99	15.29 ± 1.14

T_iD_j indicate trawling mode and water depth value. i = 1 for before and 2 for after trawling. j = 1,2,3,4 and 5 for stations at the five discrete water depths from 15 to 40 m at 5 m interval. a. T^2 is significantly different from T^1 ($P<0.05$)

different before and after trawling ($P<0.05$). At D_3, D_4 and D_5, only the number (N) was significantly different ($P<0.05$). All other indices were not significantly different before and after trawling at these depths ($P>0.05$). It may be concluded that the biodiversity indices were significantly different before and after trawling at D_1 and D_2. Variation was not observed at other water depths studied. This may be due to the fact that the stress on biodiversity was evident in lightly trawled areas while masked in heavily trawled areas. The stations plotted at D_1 and D_2 are lightly trawled due to the intermittent rocky nature of sea bottom and prevalence of traditional fishing practices like gillnetting. Due to intense trawling by commercial vessels, the impact may have been masked at stations D_3, D_4 and D_5. Immediately after the trawling disturbance, the number of species, species abundance and diversity decreased in the trawled area in comparison to the reference area (Mc Conkey and Watling, 2001). Van Dolah *et al*. (1991) on studying trawling impacts along South Carolina opined that there were no significant differences between trawled and non-trawled sites with regard to biodiversity indices and species abundance.

The ABC Curve and W-statistic of the total macrofauna showed that the fauna of the area studied were moderately or grossly stressed (Fig. 3). A paired t-test showed no significant difference between before and after trawling w- statistic value for each water depth. It may be assumed that as bottom trawling is prevalent in the area since 1960's, the fauna is already stressed Moderately or grossly stressed fauna may be indicative of long-term stress. The communities in the most strongly trawled areas showed a disturbed pattern (abundance curve above the biomass curve) and a moderately disturbed pattern with intersecting curves (Blanchard *et al*., 2004). The ABC method is based on the assumption that increasing disturbance shifts communities from dominance by large-bodied species with low turnover rates toward dominance by small-bodied species with high turnover rates. In contrast with the theory that underlies the ABC method, along Bay of Biscay, France, higher trawl efforts do not shift benthic macrofaunal communities toward increasing domination by small-bodied opportunistic species. The dominant species in disturbed conditions were large-bodied organisms (Vergnon and Blanchard,2006).

MDS plots were constructed using the entire set of macrofaunal samples collected over the course of the study. A definite stretching was observed between before and after trawling clusters (Fig.4). The variation in species and abundance may be the cause for the stretching observed before and after trawling clusters. According to Thomas *et al*. (2006), the wide distance between before and after trawling clusters indicates variations in the abundance and biomass of the polychaetes due to bottom trawling. Mc Conkey and Watling (2001) studied the impact of bottom trawling in Penobscot Bay in Maine. In their study, the MDS plot revealed that sensitive species of bivalves decreased in abundance at the post-trawl station while carnivorous nemerteans increased in abundance. Duplisea *et al*. (2002) studied the impacts of bottom trawling along the central North Sea. In this study, MDS plot showed that the size structure of the infaunal communities was influenced by trawling disturbance. The sites subject to higher levels of disturbance was clearly separated from those sites where trawling disturbance was low.

The direct mortality due to trawling occurs in the case of gastropods, starfishes, crustaceans, annelids and bivalves in the trawl track (Bergman and van Santbrink, 2000). McConnaughey *et al*. (2000) examined the impacts of bottom trawling in a shallow, soft-bottom area of the Bering Sea and reported higher densities and diversity of macrofauna in historically unfished areas. They observed drastic variations (both positive and negative) in the abundance of several macrobenthic species between heavily fished and unfished areas. Small-bodied opportunistic organisms such as polychaetes dominated in heavily fished areas (Simboura *et al*., 1998; Kaiser *et al*., 2002).

The present study ascertains the impact of bottom trawling on macrofaunal assemblage off Veraval coast. The impact of bottom trawling differs with species and locations. The long-term effects were indicated by moderately or grossly stressed fauna in ABC curves. The short-term effect were indicated by damage to molluscan shells, polychaete tubes, presence of broken arms of brittle stars, damage to sessile structures and stress to biodiversity indices. The excess number of bottom trawlers operated in the study area has to be controlled. Continuous monitoring of macrofauna for a long period will also enable to build a database on changes in macrofaunal assemblage. The species composition of macrofauna indicates the 'health' of a community. Hence taxonomic studies on macrobenthos of fishing grounds have to be promoted. Whether the increase in numerical density of macrofauna after trawling is increasing the food resource for the commercially important fish species has to be investigated. To conduct studies on trawling impacts, appropriate untrawled control sites are very much necessary for comparative assessment. Ecofriendly trawls with light rigging have to be promoted to minimize physical disturbance to the benthic fauna. Semi-pelagic trawls have to be popularized for off-bottom resources. To protect the biodiversity and ecosystem health, the imminent need is to survey and make catalog, identify indicator species and update the new data generated. This will enable to adopt suitable management strategies for the conservation of macrofauna.

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