Effect of bottom trawling on the health of macro benthic community: a graphical technique approach

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An attempt was made to study the health assessment of marine environment through graphical technique. Experimental trawling was carried out with the help of a commercial trawler during the study period of one year from January to December 2009. Maximum density of benthic organisms was recorded at 25m & 35m depth. Samples of ‘before and after’ trawling to ascertain whether, they are subjected to any form of disturbances or not, and the results are shown graphically. In these plots, it clearly revealed that the trend observed in ABC plots were on positive side, indicating undisturbed nature of benthic macro fauna. The values on the negative side indicating moderately disturbed. Cluster and MDS also group forming before and after trawling in both the regions.

[Keywords: Polychaete, Trawling, ABC plot, Cluster, MDS]

Introduction

The conventional system of fisheries management is intended to promote the landings of economically important species. But in the long run, the main aim to optimize the catch resulted in the decrease of the targeted species. At the same time, the fishing operations contributing to deterioration of marine ecosystem are towed fishing gears like trawling and dredging, which, over the years, have emerged as the most important fishing methods in the world. Major impact vary from gear to gear that include otter trawls, beam trawls, scallop dredge to even the rapid trawl, a kind of beam trawl operated in the northern Adriatic Sea.

Bottom trawling causes physical and biological damages that are irreversible, extensive and abiding. By-catch and discards are ample evidences of impact of bottom trawling. Bottom trawling inflicts impact on environmental parameters, sediment geochemistry, epifaunal, and infaunal macro and meiobenthos and this kind of bottom trawling is one of the most disruptive and wide-spread human induced physical disturbance that impacted the seabed communities with global environmental concern.

Macro fauna are small-bodied invertebrate organisms living in or on the sediments. They are retained in the sieve having the mesh size between 0.5 mm and 1 mm. 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 predators. Macro fauna, being sedentary 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 macro faunal 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. Considering the role of benthos, the present investigation was made to bring out the possible effect of bottom trawling on the benthic communities of inshore waters off Parangipettai and Cuddalore, India. This study also forms the first attempt to document the macrofaunal species related to bottom trawling of the study area.
Materials and Methods

The region along the coastline encompassing off Parangipettai (Lat. 11°29’N; Long. 79°46’E) and off-Cuddalore (Lat. 11°44’N; Long. 79°47’E) coastal waters of Parangipettai and Cuddalore, Tamilnadu, India was selected for conducting the bottom trawling survey (Fig. 1). Experimental trawling was carried out with the help of a commercial trawler (Meyammai 50ft OAL) using a standard bottom trawl gear during the study. The study area was divided into four depth zones (5 m, 15 m, 25 m and 35 m) using GPS (Global Positioning System). Thus, a total of eight samples each were taken in every month in Parangipettai and Cuddalore. Samples collected before trawling have been designated as BT (5 m, 15 m, 25 m and 35 m) and after trawling as AT (5 m, 15 m, 25 m and 35 m).

Three replicate samples were collected every month in four stations each before and after trawling, using a long-armed van Veen grab which covered an area of 0.1 m² for a period of one year from January to December 2009. For the sake of interpretation of data, the monthly data were pooled for seasons and analysed with various methods, a calendar year was divided into 4 distinct seasons viz., (i) Postmonsoon (January to March) (ii) Summer (April to June) (iii) Premonsoon (July to September) (iv) Monsoon (October to December). Procedure adopted for sampling was following the method of Mackie. After collecting samples, they were emptied into a plastic tray. Larger organisms were handpicked immediately from the sediments and then sieved through 0.5mm mesh screen. Organisms retained by the sieve were placed in a labeled container and fixed in 5% formalin. Subsequently, the organisms were stained with Rose Bengal solution (0.1g in 100ml of distilled water) for greater visibility during sorting. All the species were sorted, enumerated and identified to the advanced level possible with the consultation of available literature. The works of Fauvel and Lyla et al. for crustaceans; Subba Rao et al. and Ramakrishna for molluscs. Data were treated with various statistical methods namely graphical (ABC-plot, cluster & MDS) analyses using the statistical software PRIMER - Ver.6.0. Results

With respect to population density, in Parangipettai waters, the population density varied from 558 to 30,140 nos. m⁻² with minimum during monsoon (November) and maximum during summer and pre-monsoon seasons (June & July) in the samples collected before trawling (Fig. 2) while in the samples collected after trawling, it varied from 239 to 12,669 nos. m⁻² with minimum during monsoon (December) and maximum during summer (June) (Fig. 3).

In Cuddalore waters, the population density varied from 598 to 29,412 nos. m⁻² in the samples of before trawling (Fig. 4) with minimum during monsoon (November) and maximum during summer (June) while in the samples of after trawling, it varied from 518 to 14,622 nos. m⁻² with minimum during monsoon (December) and maximum during premonsoon (July) (Fig. 5).
Fig. 3-Seasonal variation of population density of benthic faunal groups recorded in the samples collected after trawling at Parangipettai coastal waters

Comparing two regions, the maximum density of benthic organisms was recorded at 25m & 35m depth in Parangipettai during premonsoon (July) and minimum at 5m depth during monsoon (October) in both the regions. Similarly, maximum density of benthic organisms was recorded in the samples collected before trawling and minimum in the samples of after trawling in both the regions.

In Parangipettai waters, the biomass of polychaetes varied from 23.528 to 78.431g/m². The biomass of crustaceans ranged from 22.364 to 437g/m². The bivalves biomass ranged between 1083.17 and 2256.53g/m² and the biomass of the gastropods fluctuated from 326.221g/m². Crustacean biomass varied between 20.568 and 326g/m². Estimated biomass of bivalves fluctuated between 1012.57 and 2256.53g/m². Biomass of gastropods varied from 616.43 to 1573.22g/m². In the samples collected after trawling, polychaete biomass fluctuated between 19.052 and 68.25g/m². Crustacean biomass varied between 18.432 and 210g/m². Biomass of bivalves varied from 914.42 to 1863.81g/m². Biomass of gastropods ranged between 610 and 1432.21g/m².

In general, the minimum values were recorded during monsoon and premonsoon season of after trawling and the maximum values during summer and postmonsoon season of before trawling in both regions. Among the various groups, bivalves which were recorded in all the stations (depths) showed maximum biomass followed by gastropods, crustaceans, and polychaetes.

In Cuddalore, in the samples of before trawling, the biomass of polychaetes varied from 21.263 to 76.221g/m². Crustacean biomass varied between 20.568 and 326g/m². Estimated biomass of bivalves fluctuated between 1012.57 and 2256.53g/m². Biomass of gastropods varied from 616.43 to 1573.22g/m². In the samples collected after trawling, polychaete biomass fluctuated between 19.052 and 68.25g/m². Crustacean biomass varied between 18.432 and 210g/m². Biomass of bivalves varied from 914.42 to 1863.81g/m². Biomass of gastropods ranged between 610 and 1432.21g/m².

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In the present study, the data pertaining to species abundance and biomass were allowed to draw ABC- curve for all the stations (depths) in the samples of before and after trawling to ascertain whether, they are subjected to any form of disturbances or not, and the results are shown graphically.

In Parangipettai, at 5m depth, the ABC-curves drawn for the samples collected before and after trawling showed that the biomass curve to lie above the abundance curve for the entire length (Figure 6a and b), indicating the pristine nature due to the fact that dominance of conservative species. Similarly in Cuddalore coastal waters also the biomass curve was found to lie above the abundance, showing undisturbed nature (Fig. 6c & d).
Fig. 6-ABC-curves drawn for the total macrofauna collected in 5-35m depth of samples collected before and after trawling in Parangipettai and Cuddalore coastal waters

Fig. 7-'W' statistic values recorded in different depths of samples collected before and after trawling in Parangipettai and Cuddalore coastal waters
(Note: BT - Before Trawling; AT – After Trawling; P- Parangipettai; C- Cuddalore)
With respect to 15m depth, in Parangipettai, ABC-curves drawn for the samples of before trawling showed that the biomass curve was found to lie entirely over the abundance curve, while after trawling, abundance and biomass curves were intersecting each other indicating moderately disturbed nature of the area (Fig. 6a & b). Same trend was observed in 15m depth of Cuddalore coastal waters as well (Fig. 6c & d). At 25m depth, in Parangipettai, ABC-curves drawn for the samples of before trawling showed that the biomass curve was found to lie over the abundance curve throughout, while in the case of samples of after trawling the biomass and abundance curves were intersecting each other showing moderately disturbed (Figure 8a and b). The same trend was also noticed in 25m depth of Cuddalore coastal waters (Fig. 6c & d).

In Parangipettai, at 35m depth, ABC-curves drawn for the samples of before trawling showed the biomass curve was found to lie entirely over the abundance curve, whereas samples collected after trawling showed that the abundance curve is to lie above the biomass curve indicating disturbed nature (Figure 6a and b). The same trend was also observed in Cuddalore coastal waters (Fig. 6c & d).

In the present study, the ‘W’ values were overlying on the ABC - curves, were plotted for the samples collected before and after trawling and shown in Fig. 7. In Parangipettai, the samples collected before trawling, the values were 0.175, 0.055, 0.177 and 0.083 whereas after trawling 0.083, -0.053, 0.007 & -0.165 in 5, 15, 25 & 35m depth respectively. In Cuddalore, the samples collected before trawling the values were 0.234, 0.175, 0.137 & 0.094 while after trawling 0.094, -0.02, -0.054 & 0.127 in 5, 15, 25 & 35m depth respectively.

The plots clearly revealed the trend observed in ABC plots that the values were on positive side, indicating undisturbed nature of benthic macro-fauna and the values on the negative side indicating moderately or grossly disturbed.

In the present study, cluster analysis & MDS methods were performed to ascertain the similarity between stations (depths) in the samples collected before and after trawling. The cluster analysis drawn showed that the samples collected at various stations in Parangipettai and Cuddalore formed separate groupings of samples collected before and after trawling. This fact was further confirmed through MDS, which was also revealed the same pattern of groupings as recognized in cluster analysis (Figs. 8-11).

**Discussion**

As regards biological entities, the maximum faunal density was recorded in the samples collected before trawling and minimum in the samples collected after trawling in both the regions. Similar dwindling of benthic population was observed earlier by Jennings *et al.* who reported dramatic reduction in the numerical abundance of epifauna and infauna in the benthic samples due to trawling. Likewise, Althaus *et al.* also reported reduction in diversity of deep sea corals owing to bottom trawling.
The reduction in habitat heterogeneity is a major deterrent in the survival and recruitment of countless marine organisms, including many species that are commercially important. Impact of trawling on the seafloor depends upon the speed of towing, the size and weight of the net, type of seabed and strength of currents and tides, may remain as a transitory phenomenon in shallow waters affected by strong tides or persists for several years in deeper areas with lesser disturbance7,23. Polychaetes showed higher abundance in the samples collected before trawling in an experiment conducted by Bergman and Hup24. Most of the polychaetes observed throughout the present study were small in size and this was due to the fact that communities become dominated by juvenile stages where in extensive and repeated fishing disturbance are prevalent. These organisms do not get the opportunity to grow into larger size because of the continuous trawling disturbance at the bottom. Similar findings were reported earlier by Sainsbury25, Eleftheriou and Robertson26.

Several organisms that occur in the path of the net killed as a result of direct contact with the gear and exposure to predators24. Impacts are more severe with beam trawl because of its deeper penetration; even the low impact of trawling may significantly affect the sensitive infaunal and epifaunal species inhabiting the upper zones of the sea bed27.

Bottom-trawl nets can plough deep furrows in the seafloor, remove rock and coral, stir up sediments that smothering benthic organisms, and smooth out natural topography, thus resulting in the reduction of structural heterogeneity – an important factor contributing to the abundance of biodiversity at the sea bottom28.

Many studies conducted in the west and east coasts of India especially along the shelf waters reported the dominance of polychaetes in the infaunal macrofauna 29,30. Parulekar and Ansari31 also reported that polychaetes were the most important group (70%) in the macrobenthic assemblage in the Andaman Sea. In the present observation, high abundance of polychaete was noticed at the sandy stations, which also corroborate to the findings of Harkantra et al.30 and Sunil Kumar32. Bottom layers of sand with a mixture of silt or clay form ideal substrates for polychaete and bivalves33.

In the present study, highest abundance and biomass was recorded during summer, postmonsoon and premonsoon periods followed by premonsoon and monsoon. Harkantra and Parulekar34 reported the replenishment of benthic fauna with high species diversity after southwest monsoon; however, a second peak was observed in July, during the trawl ban period along the Kerala coast imposed by the Govt. of Kerala. The present findings paralleled views of the above referred study. It appears that the polychaetes get an opportunity for their recoupment and regeneration as the sea bottom is totally free from any sort of disturbance due to the imposition of ban for bottom trawlers.

ABC- curve and W- statistic done for the total macrofauna revealed two situations namely slightly and moderately disturbed environs. The communities in the most strongly trawled areas showed a moderately disturbed pattern (abundance curve lie above the biomass curve) and a disturbed pattern with intersecting curves. The ABC method is
based on the assumption that increasing disturbance shifts communities from dominance by large-bodied species with low turnover rates towards dominance by small bodied species with high turnover rates.

In the present study, to ascertain the impact of bottom trawling on macrofaunal assemblage in Parangipettai and Cuddalore coastal waters, the ABC plot was drawn. In an environment, the long term effects will be evident through moderately stressed fauna in ABC curves which the short term effect will be indicated through biodiversity indices. Usha et al. stated that to know the trawling impacts, appropriate untrawled control sites are very much necessary for comparative assessment. Eco-friendly 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.

In the present study ABC curves drawn for 5m depth in both the regions indicated that the biomass curve to lie above abundance curve indicating undisturbed nature of the samples collected before and after trawling. At 15 & 25m depths, the biomass curves were found to lie above the abundance curves signalling the pristine nature for the samples collected before trawling, whereas after trawling both the curves were intersecting each other indicating slight disturbance. At 35m depth, in both the regions, the biomass curves were seen to lie above the abundance curve in the samples collected before trawling whereas samples collected after trawling showed that the abundance curve is to lie above the biomass curve indicating disturbed nature. This might be due to the impact of trawling since the trawling will be more intensive in higher depths.

The cluster analysis showed unequivocally that the distinct variation in species abundance before and after trawling by the fact that the species recorded before and after trawling got grouped themselves indicating numerical abundance of the species. This was further confirmed through MDS plot. Groupings recognized in dendrogram were evident here as well. Similar grouping of stations due to trawling was observed earlier by; Usha et al. (2012) and Muthuvelu et al.

To conclude, the results of the present study is only part of a larger exercise and it clearly indicated that the impact is severe with increasing depth. Therefore, in order to lessen this, some regulatory measures to be implemented and the ban period may also be increased.

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References


