Environmental impact of trawling on the continental shelf of Bay of Bengal

Mahua Das

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Abstract
Entire West Bengal offshore and estuaries along the Indian continental shelf of Bay of Bengal exhibits excellent breeding ground of uncountable marine species presenting the great marine ecosystem shared by World’s largest mangrove food web famously ‘Sundarbans’ (World Heritage Site 1989). With increasing population demanding fish as most preferred food, fishing trawlers are increasing day by day. Shankarpur–Digha fishing zone has intensively been studied where modern bull trawlers drag bigger trawl nets through ocean bottom. This non-selective fishing gear is very likely to have destroyed undersea habitat of uncountable baseline component species of the complex marine food chain posing threat to all top consumers. Resultantly, sustenance of the whole sea-food-dependent coastal fisherfolk at the apex is suspected to be at stake inviting total collapse to entire marine food pyramid. Unfortunately, most local trawlers practice fishing in shallower offshore water with maximum growth of benthic biodiversity damaging the submarine ecosystem maximum. Trawl-induced biodiversity loss along with chemical disturbances in submarine soil and water is statistically quantified here with suggested effective Environmental Management Plan for conservative use of marine resources for a sustainable marine ecosystem.

Keywords Offshore ecosystem in West Bengal · Largest mangrove food web · Commercial trawl netting · Affected benthic environment · Sustainable development

Introduction
In the unique bio-climatic littoral and infra-littoral zone of West Bengal, estuarine and marine ecosystem including Sundarban’s mangrove food web (Fig. 1) (Protect Sundarbans 1994) exists with huge reserve of microscopic phyto-planktons forming the extensively broad baseline of marine food chain and mangrove food web with other marine species occupying different higher trophic levels. It is well understood that if any of these baseline components is found missing or damaged by any sort of human intervention, entire marine food pyramid must be collapsed in long run and pose a great threat to all top consumers (Das 2002). Modern bull trawlers use to drag bigger trawl nets through ocean bottom while chasing bottom-dweller target species of fish (Fig. 2a). As a mobile non-selective fishing gear, the bottom trawl net (Fig. 2b) collects every organism in its path and the incidental capture of non-target species—by-catch—has become a major concern allied to trawling (Kumar and Deepthi 2006). This dragging action is very likely to have destroyed undersea habitat of benthic and non-benthic species as essential primary and secondary consumers. This malpractice through years seems to have shortened the broad base of marine food pyramid supplying much lesser amount of energy accordingly to the tertiary and top consumers (Das 2010) endangering their lives for future. As an outcome, this will pose a great threat to the sustenance of all dependant marine species occupying higher trophic levels. Increasing contribution of trawlers to the total catch of fish observed in the coastal West Bengal during the last few decades clearly indicates much severe destruction of the habitats of bottom-dweller juvenile species. Target species are only the highly demanded commercially profitable, i.e., Rahu, Bhola, Bhekti, Parse, Hilsa, Lalbhola, Katla, tiger prawn, etc., caught at the cost of destruction of huge number of ecologically important non-target species (trash fishes) as by-catch (Fig. 3b) by non-selective bottom trawl net. Loss of these species at different specific trophic positions of the
marine food chain has obviously damaged the existence of their predators occupying all the higher trophic levels. Figure 3b has shown how the extensive trawl routes have already scooped out the benthic biodiversity at Louisiana. Ultimately, this will endanger the existence of all the coastal humans, too as the apex species of the food pyramid, absolutely dependent on marine stuffs as major food supply and on fishing as their primary occupation. Even if this malpractice is left untreated through years, vast global tropic marine ecosystem will start affected in long run. This paper presents an intensive field study of West Bengal offshore trawl fishing zones that remains totally unrevealed and deserves extra attention for intrinsic national and international values of the ‘Sundarbans’, largest mangrove ecosystem (World Heritage Site). This destructive trawling impact gradually leading towards an irreparable loss to entire marine ecosystem has been tested with a proper environmental management plan suggested for a sustainable marine environment.

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Materials and methods

Area studied

Entire Bay of Bengal offshore on the south of the State of West Bengal in India enjoys many commercial fishing zones of which Shankarpur–Digha, the present study area is demarcated by the State of West Bengal on the North, Bay of Bengal on the South, Bangladesh on the East, and State of Orissa on the West (Fig. 4). All modern bull trawlers...
Fig. 4 Location of coastal West Bengal

Source: NATMO, 1998, Dept. of Sc. & Tech., Govt. of India.
usually start their trip from Digha–Shankarpur zone (Fig. 5) round the year only excluding 2–3 months of pre-monsoon or summer. The latitudinal and longitudinal positions of the sampling fishing points are mentioned in Table 1 with starting and ending distances of each cruise.

Objectives

Objective of this study is (1) to determine the quantity of discards which otherwise form the non-target group and assess the loss of biodiversity with distance and depth of trawling, (2) to study the impact of biodiversity loss on the marine food chain, (3) to determine seasonal chemical changes in benthic environment and trace out trawl–induced chemical disturbances, and (4) to chalk out an environmental management plan ensuring sustainable marine environment. Outcome of the project was meant for a sure help in undertaking a proper Ocean Environment Management Plan suggesting the best conservative use of tropical marine biodiversity for sustainable development.

Methodology

To fulfill the specific objectives, methodological steps followed were:

(a) To determine trawl impact during the post-monsoon and winter of 2012–2013, experimental sampling of benthic fauna was done by eight trawl survey trips named Maa Damayanti, Safina Baija, Bijli 2, Maa Ganga, FB Ganga, FB Alakananda, Ma Bhabatarini, and FB Joy Ma Padma-bati at Shankarpui-g-Digha fishing zone on 2.02.2010, 24.02.2010, 28.01.2011, 9.02.2011, 19.12.12, 11.01.13, 8.02.13, and 12.2.13. at different offshore locations from varying depths of 30–35 feet between 2.5 and 3 km off Shankarpur, 23.4–26.3 feet between 9 and 14 km off Digha, 26.9–28.2 feet between 8 and 10 miles off Digha, and 28.8 to 34.6 feet between 12 and 15 km off Shankarpur.

(b) To determine trawl impact during the post-monsoon and winter of 2013–2014, experimental sampling of benthic fauna was done by seven survey cruises arranged on 6.11.13, 7.11.13, and 10.11.13 from Shankarpur by the trawlers named F.B. Saksheegopal, Joyma Padmabati, and F.B Dadar Kirti; on 9.11.13 and 20.11.13 from Petua by Maa Mansa; on 9.12.13 from Namkhana by F.B Brahmanmoyee; on 9.02.14 from Digha by F.B Safina Tul Bahar at different depths of 7.13 mt, 6.757 mt, and 5.486 mt at distance of 4.63 km, 6.044 km, and 5.486 km off Shankarpur, at depth of 14.24 and 9.14 mt at distance of 5 and 15 km off Petua, at depth of 9.14 mt at distance of 4 km off Namkhana, and at depth of 9.144 mt at distance of 10 km off Digha.

(c) Samples of all trawl discards (biotic species) have been taken at every trawl cruise (Fig. 6) and discarded species have been identified and analysed by Zoological Survey of India, Kolkata and S.D Marine Biological Research Institute, Sagar Island, India.

(d) In every cruise, sample bottom soil at every trawling depth was manually collected from the trawl net itself immediately after the trawl operation was over. Sample sea
Surface water was also manually collected twice from two spots, i.e., once at the starting point and other at the ending point of trawl netting.

(e) Sea water and soil parameters have been first determined, mainly according to the research objective of proving trawl-induced marine environmental degradation. Salinity and organic carbon of marine soil have been tested as those carry the impact of ‘on-boat destruction of huge trawl discards. Heavy metals in soil, specially lead, cadmium, and copper, have been tested as those denote the petro-chemical pollution of sea soil by extracts from diesel engines of huge number of the trawlers, constant washing, cleaning, painting, and maintenance of those. Sea surface water salinity and temperature have also been tested as those imply the presence of pollutants and also the seasonal changes in the off-shore bio-climatic environment of West Bengal.

(f) Laboratory analysis of some physico-chemical parameters was completed on the samples of benthic soil and sea water collected during trawl cruises. Soil parameters, i.e., texture, organic carbon, salinity, lead, cadmium and copper, and sea water parameters, i.e., salinity, pH, lead, cadmium, and copper were tested in the laboratory of Envirocheck, Kolkata, India. The analysis methods are soil salinity: APHA 22nd Edition, 2520B/2520C; sea water salinity: APHA 22nd Edition, 2520B/2520C; organic carbon: IS 2720 (Part-XXII) 2002; lead: EPA 3050 B: 1996; cadmium: EPA 3050 B: 1996; copper: EPA 3050 B: 1996.

12. Resultant relative position of the graphs is good enough to analyse and understand the suitability of marine environment for biodiversity growth as well as trawl-induced chemical disturbances that deter the growth of biodiversity.

(g) Loss of discards has been graphically plotted with trawling distance and depth. Based on this, a detailed statistical assessment of the impact of biodiversity loss on the marine food chain has been completed.

(h) Environmental Management Plan has been drafted suggesting some essential remedial steps towards conservative use of these marine resources.

Results and discussion

A single passage of beam trawl has been reported to kill 5–65% of the resident fauna and mix the top few centimeters of sediment (Duplisea et al. 2001). The non-target species may have key roles in the marine food webs that fortify ecosystem processes and functioning, which in turn determines the productivity of marine capture fisheries (Auster and Langton 1999). Habitat impacts and by-catches affect stocks of commercially valuable species, the natural biodiversity, and ecological services provided (McAllister and Spiller 1994). This research resultantly reflects severe trawl-induced damage of marine biodiversity in West Bengal offshore through chemical analysis of bottom soil and sea water as well as scan (identification, total weight, lost quantity) of trawl discards. Table 1
contains the detailed reports on the chemical analysis of all collected samples of marine water and benthic soil from different trawl cruises. These data has been graphically plotted in Figs. 7, 8, 9, 10, 11, and 12. Figure 7 and Table 2 show the loss of marine biodiversity in relation to the ‘depth of trawling’ and ‘starting distance of trawling’. Figures 8, 9 depict the benthic (undersea) soil texture and organic carbon. Figures 10, 11 depict soil salinity and sea water salinity. Figure 12 depicts the presence of heavy metals, i.e., lead, cadmium, and copper in the soil. Data analysis with graphical presentation shows implicative seasonal and trawl-induced negative changes in the chemical composition of bottom soil and sea water that highly damages the offshore marine ecosystem in West Bengal.

**Discards identified**

Figure 3a shows some of the identified discards specially noted for their high ecological significance and important role played in Sundarbans mangrove food web as well as in the greater marine ecosystem. All varieties of these destroyed discards (Table 2) or non-target species were collected as samples and identified by Zoological Survey of India and S.D Marine Biological Research Institute, Sagar Island, India. First cruise destroyed non-target species like sting ray (*Himantura imbricata*), catfish, flatfish (flounders and soles, i.e., *Solea ovata*), silver belly, clupid fish, gastropod (*Babylonia spirata*), sepia (two species, i.e., *Sepia scubata* and *Sepia inermis*), loligo (two species, i.e., *Loligo sp.*).

**Fig. 7** Seasonal marine biodiversity loss by trawling with ‘distance’ and ‘depth’, 2010–2014

**Fig. 8** Presence of benthic sand, silt, and clay since 2010–2013
and *Loliolus investigatoris*, mud octopus (*Octopus macro-pus*), nudibranch, sea urchin (*Tenebrio treumaticus*), sea anemone, squilla (mantis shrimp), and portunus crab. Second, third, and fourth cruises destroyed sting ray (*Himan-tura imbricata*), catfish, flatfish (flounders and soles, i.e., *Solea ovata*), clupid fish, sepia (two species, i.e., *Sepia scubata* and *Sepia inermis*), loligo (two species, i.e., *Loligo sp.* and *Loliolus investigatoris*), sea anemone, squilla (mantis shrimp) shark, skate (*Raja.sp*), halibut (*Psettas erumei*), a precious commercial fish in West Bengal coast, benthic crab (*Doclea ovis*) very uncommon in this coast, gobid fish, or mud skipper (*Parachaetrichthyes polynema*), and squids (*Loligo sp.*). Fifth, sixth, seventh, and eight cruises destroyed cattle fish, sting ray (*Himantura imbricata*), catfish, flatfish (halibut and *Silago sihama*), silver belly, clupid fish, sepia (two species, i.e., *Sepia scubata* and *Sepia inermis*), loligo (two species, i.e., *Loligo sp.* and *Loliolus investigatoris*), anchovy (*Coilla dussumierii*), gobid fish, sea anemone, squilla (mantis shrimp), and crab (three species, i.e., *Matuta plenipes*, *Matuta victor*, and *Charybdis feriatus*). Eight-to-fifteenth cruises experienced more or less same species as the others, i.e., sting ray (*Himantura imbricata*), catfish, flatfish (flounders and soles, i.e., *Solea ovata*), silver belly, clupid fish, gastropod (*Babylonia spirata*), sepia (two species, i.e., *Sepia scubata* and *Sepia inermis*), loligo (two species, i.e., *Loligo sp.* and *Loliolus investigatoris*), mud octopus.
Octopus macropus), nudibranch, sea urchin (Temnopleurus toreumaticus), sea anemone, and squilla (mantis shrimp).

Assessment of the trawling impact

Assessment of the marine biological impact of trawling

Marine biodiversity loss is recorded as the most severe impact of commercial trawl fishing. In first marine cruise, 33.33% (approx) discards was destroyed from 35 feet out of 2.6 miles (7.4–10 miles) of trawling from Shankarpur. In second marine cruise, 21.42% (approx) discards were destroyed from 38 feet out of 1.5 miles (6–8.5 miles) of trawling from Digha. Comparing two results, richness of benthic biodiversity is proved higher (loss of 21.42%) on the continental shelf closer to the coast off Digha and much lesser (loss of 19.25%) on the continental shelf far from the coast off Shankarpur. Benthic biodiversity higher near coast thinning away from the coast has proved biodiversity richness inversely related to the offshore distance. Biogeographically, huge nutrients continuously washed off the land by numerous rivers of Bhagirathi-Hooghly delta to be thickly deposited onto the continental shelf of Bay of Bengal gets thinner away from the coast. Moreover, Trawl depth of continuous 35 feet off Shankarpur has proved a shallower continental shelf with natural ecological viability for richer benthic biodiversity. In contrast, increasing trawl depth of 29–38 feet off Digha has proved more gradient continental
Table 1  Report of chemical analysis of the soil and sea water samples

| Years of sampling | Date of marine cruise | Seasons | Number of marine cruises | Soil salinity (ds/m) | Sand (%) | Silt (%) | Clay (%) | Soil organic carbon (mg/kg) | Lead (ppm) | Cadmium (ppm) | Copper (ppm) | Sea water Temp (°c) | Sea water salinity (ppt) |
|-------------------|-----------------------|---------|--------------------------|---------------------|----------|----------|----------|----------------------------|------------|-----------------|--------------|-------------------|--------------------------|
| 2010              | 2.2.10                | Pre-monsoon | 1st                     | 15                  | 36       | 49       | 3400     | –                          | –          | –               | –            | –                 | –                        |
| 2010              | 24.2.10               | Pre-monsoon | 2nd                     | 5.0                 | –        | –        | –        | 3340                       | –          | –               | –            | –                 | –                        |
| 2011              | 28.1.11               | Winter    | 3rd                     | 5.8                 | 45       | 33       | 22       | 8310                       | –          | –               | –            | –                 | 32.0                     |
| 2011              | 9.02.11               | Pre-monsoon | 4th                     | 4.5                 | 15       | 30       | 55       | 3500                       | –          | –               | –            | –                 | 30.0                     |
| 2012              | 19.12.12              | Winter    | 5th                     | 6.24                | 30.4     | 36       | 33.6     | 280                         | 19.5       | 1.62            | 19.2         | 22–23 °C         | 6.5                      |
| 2013              | 11.1.13               | Winter    | 6th                     | 2.96                | 58.4     | 16.0     | 25.6     | 240                         | 16.4       | 1.09            | 19.05        | 20–21 °C         | 6.3                      |
| 2013              | 8.2.13                | Pre-monsoon | 7th                     | 3.28                | 50.0     | 12.0     | 27.6     | 386                         | BDL        | BDL             | BDL          | 21.7              | 5.8                      |
| 2013              | 12.2.13               | Pre-monsoon | 8th                     | 4.5                 | 25.0     | 28.0     | 52.0     | 3500                        | 24         | BDL             | BDL          | 22.3 °C           | 1.6                      |
| 2013              | 6.11.13               | Post-monsoon | 9th                     | 3.6                 | 40       | 30       | 30       | 491.4                       | 10.0       | BDL             | 12.85        | 29.5 °C           | 15.0                     |
| 2013              | 7.11.13               | Post-monsoon | 10th                    | –                   | –        | –        | –        | 1965.6                      | 34.5       | BDL             | 27.9         | 29.5 °C           | 16.2                     |
| 2013              | 9.11.13               | Post-monsoon | 11th                    | 12.3                | 42.4     | 27.2     | 30.4     | 2784.4                      | 32.5       | BDL             | 31.25        | 29.0 °C           | 18.8                     |
| 2013              | 10.11.13              | Post-monsoon | 12th                    | 5.2                 | 10.1     | 25       | 34.9     | 3030.3                      | 27.5       | BDL             | 28.3         | 29.4 °C           | 18.1                     |
| 2013              | 20.11.13              | Winter     | 13th                    | –                   | –        | –        | –        | 1474.2                      | 27.0       | BDL             | 27.35        | 20.4 °C           | 10.0                     |
| 2013              | 9.12.13               | Winter     | 14th                    | –                   | –        | –        | –        | 4633.2                      | 25.5       | BDL             | 32.7         | 21.0 °C           | 8.8                      |
| 2014              | 9.2.14                | Pre-monsoon | 15th                    | –                   | –        | –        | –        | –                          | –          | –               | –            | 22.8 °C           | –                        |

Reports of chemical analysis by Envirocheck, Kolkata, India
shelf with natural possibility of supporting lesser benthic biodiversity. However, study has proved lesser biodiversity loss (19.23%) in Shankarpur offshore than that (21.42%) in Digha despite more ecologically viable continental shelf. Though more gradient than that of Shankarpur, Digha offshore enjoys higher nutrient deposition and higher biodiversity loss as it is about 1.5 miles closer to the coast than Shankarpur. It has proved benthic nutrients deposition as well as growth of biodiversity getting thinner with increasing offshore distance, Comparing third and fourth cruises, 58.33% loss of benthic biodiversity at 20.5 feet between 3 and 3.7 miles is much higher than 15% loss of benthic biodiversity at 47–50.6 feet between 6.72 and 9.47 km in the same offshore. It corroborates higher loss of benthic biodiversity at shallower continental shelf closer to the coast because of maximum benthic nutrient deposition at near coast submarine zone and vice versa. Fifth cruise proves that 62.5% discards were destroyed from 35 feet out of 0.5 km of trawling at Shankarpur offshore. Sixth marine cruise caught 94.4% loss of biodiversity (2.4% absolute discards and 92% for dry-fishing) from 26.3 feet out of 5 km of trawling from Digha. Seventh cruise shows 98.7% loss of benthic biodiversity (6.7% absolute discards and 92% discards for dry fish) at 28.2 feet out of 3.17 km of trawling off Digha. Eighth cruise recorded 20% loss of benthic biodiversity at 34.6 feet out of 3 km of trawling off Shankarpur. Comparing the results of fifth and eighth marine cruises held at Shankarpur offshore, loss of marine biodiversity is recorded at higher rate.

### Table 2: Seasonal marine biodiversity loss by trawling with ‘distance’ and ‘depth’ during 2010–2014

| No. of marine cruises | Date and season       | Starting distance of trawling (km.) and latitude, longitude | Total catch and total by-catch (kg) | Ending distance of trawling(km) | Total trawling mileage (in km.) | Average depth of trawling (in m) | Total loss of biodiversity (in %) | Loss of biodiversity in first 1.5 km (in %) |
|-----------------------|-----------------------|-------------------------------------------------------------|-----------------------------------|---------------------------------|---------------------------------|-------------------------------|----------------------------------|----------------------------------------|
| 1st                   | 2.02.2010 (pre-monsoon) | 11.8 (21°38’490N and 87°50.1E)                               | 90, 30                            | 16.1                             | 4.2                             | 10.7                          | 33.33                            | 11.9                                   |
| 2nd                   | 24.02.2010 (pre-monsoon) | 9.7 (21°45 N and 87°52.2'E)                                  | 70, 15                            | 13.7                             | 4                               | 10.2                          | 21.42                            | 8.03                                   |
| 3rd                   | 28.01.2011 (winter)     | 4.8 (21°47.80 N and 87°34.10'E)                               | 12, 07                            | 6                               | 1.2                             | 6.23                          | 58.33                            | 72.91                                  |
| 4th                   | 9.02.2011 (pre-monsoon) | 10.8 (21°37’N and 87°33'E)                                   | 40, 06                            | 15.24                            | 4.44                            | 15                            | 15                               | 5.07                                   |
| 5th                   | 19.12.12 (winter)       | 2.5 (21°38’Nand 87°34'E)                                     | 08, 05                            | 3                               | 0.5                             | 2                             | 62.5                             | 62.5                                   |
| 6th                   | 11.01.13 (winter)       | 9 (21°38.480N and 87°34'E)                                   | 125, 118                          | 14                              | 5                               | 7.6                           | 94.4                             | 28.32                                  |
| 7th                   | 8.02.13 (pre-monsoon)   | 13 (21°38.480N and 87°34'E)                                  | 150, 40                           | 16.2                             | 3.2                             | 8.4                           | 46.66                            | 21.87                                  |
| 8th                   | 12.02.13 (pre-monsoon)  | 12 (21°38.503N and 87°34.17'E)                                | 50,10                             | 15                              | 3                               | 9.7                           | 20                               | 10                                     |
| 9th                   | 6.11.13 (post-monsoon)  | 3.7 (21°38.48’N and 87°34'E)                                 | 10, 05                            | 4.63                             | 0.93                            | 7.13                          | 33.33                            | 53.76                                  |
| 10th                  | 7.11.13 (post-monsoon)  | 5.56 (21°38.35'Nand 87°34.2'E)                                | 40, 05, 35, 1.5                    | 6.48                             | 0.92                            | 6.04                          | 11.11                            | 18.12                                  |
| 11th                  | 9.11.13 (post-monsoon)  | 10 (21°47.81’N and 87°52.8'E)                                 | 75, 15                            | 15                              | 5                               | 13.34                         | 30                               | 9                                      |
| 12th                  | 10.11.13 (post-monsoon)| 5 (21°38.39’N and 87°34.18'E)                                | 4.5, –                            | 8                               | 3                               | 5.05                          | 16.67                            | 8.34                                   |
| 13th                  | 20.11.13 (winter)       | 3.64 (21°47.81’N and 87°52.84'E)                              | 01, 1.5                           | 5                               | 1.36                            | 8.23                          | –                               | –                                      |
| 14th                  | 9.12.13 (winter)        | 3.5 (21°45.24’N and 88°12.67'E)                               | 20, 40                            | 4                               | 0.5                             | 7.62                          | 60                               | 25.71                                  |
| 15th                  | 9.02.14 (pre-monsoon)   | 6 (21°38.269’Nand 87°32.796'E)                                | 10                               | 4                               | 7.62                            | 66.66                         | 25                               | –                                      |

Data retrieved from all the experimental trawl cruises.
(62.5%) in near offshore (2.5–3.00 km), whereas much lower (20%) in far offshore. Moreover, Digha offshore is proved as much shallower (26.3 feet at 14 km and 28.2 feet at 16.0 km) with higher loss of benthic biodiversity (94.4 and 98.7%). However, Shankarpur offshore is found steeper (35 feet at 3 km and 34.6 feet at 15 km) with lesser loss of benthic biodiversity (62.5 and 20%). It has proved higher loss of benthic biodiversity at shallower continental shelf closer to the coast because of more benthic nutrient deposition here. This loss is very clearly proved in the data set (Table 2) and also graphically in Fig. 6, and shows the loss of marine biodiversity in relation to the ‘depth of trawling’ and ‘starting distance of trawling’. This too proves that trawling at higher depth as well as far from the coast causes lesser marine biodiversity loss than that performed in shallow water at lower depth near the coast. Unfortunately, most of the commercial trawlers in West Bengal offshore practice fishing invariably in the biodiversity-enriched shallower water closer to the coast to ensure highest catch with maximum profit at the cost of maximum damage to submarine ecosystem.

Damage to the marine ecosystem This malpractice ultimately causes an irreparable loss not only to the Sundarbans mangrove food web existing in the Indian offshore. However, the entire tropical oceanic food chain is going to be affected in long run and ultimately the worldwide marine ecosystem will also feel shortfall due to the absence of these base level marine species. Immediate biological damages caused by trawling action are as follows:

(a) Loss of sea anemons and sea urchins must put their predators, i.e., sea snails, sea spiders, grey sea slugs, sea stars, and large demarsal fishes into crisis of survival, (b) destruction of sepia and loligo creates severe food crisis for commercial fish species, cuttlefish, pelagic finfish, ocean pike, sting ray, eel, dolphin, seal, and marine (diving) birds, (c) skates are also destroyed putting their predators, i.e., shark and sting rays in danger, (d) Regular loss of shark, sepia, loligo, flat fish (flounders and soles), squid, and halibut as indispensable food is ultimately causing food crisis for coastal population as the top consumers of marine food chain, (e) destruction of cuttlefish as major food for dolphins, sharks, seals causes crisis of their survival, (f) flatfishes (Sillago sihama, Cinoglosus sp.) and anchovy (Coila dussumieri) destroyed largely by trawling create lack of food for bony-fishes and fin fishes, (g) marine benthic crabs namely Matuta plenipes and Matuta victor are totally destroyed putting flatfishes in danger as their important food, (h) destruction of benthic crabs namely Charybdis feriatus and C. variegata create food crisis for finfish and bony-fishes, (i) destruction of eel, i.e., Uroconger lepturus creates food crisis for bass, lake trouts, fish-eating birds, and marine mammals, and (j) at random destruction of grooved rajor fish (Centriscus scutatus) puts seals in food crisis. Commercial trawling is, therefore, proved to cause not only short term or ready loss to the immediately upper trophic level species affecting only the local mangrove ecosystem in West Bengal offshore. However, this malpractice also has a far-reaching impact to cause ultimate long-term loss to all the higher order marine species dominating the greater global oceans. Even the large sea-food-dependent tropical coastal population of Asia, South-East Asia, Oceania, and Polynesia will also be at stake as the apex omnivores in the greater marine food chain. As all the oceanic ecosystems are ecologically interconnected, great global marine ecosystem must also be affected in common by such a malpractice. Thus, this apparently localized trawl-induced malpractice will very soon take shape of a global marine environmental disaster in near future. If this anthropogenic interference is left untreated for years, global marine ecosystem will start collapsing in long run. Thus trawl-based economic development in coastal West Bengal is gained at the cost of great ecological loss to the international coastal and marine environment.

Assessment of the marine chemical impact

Next alarming impact of trawling found is marine chemical changes. According to the chemical analysis of benthic soil (Table 1, Fig. 8), decreasing percentage of sand with increasing silt and clay towards the land in shallower continental slope proves the presence of very nutritious subma- rine bed formed of thick deposition of fresh silt by various distributaries of river Hooghly near the estuarine mouth supporting rich growth of benthic biodiversity in entire Bay of Bengal offshore. Sand increases obviously with decreasing silt and clay away from the land in deeper sea slope. As a support to this fact, organic carbon (mg/kg) in the benthic soil is also found decreasing away from the land in deeper sea slope with an increase landward in shallower benthic zone (Table 1; Fig. 9). Moreover, electrical conductivity or salinity of the benthic soil (Table 1; Fig. 10) and total phosphate (Table 1) are also found increasing landward with a decrease away from the land. Salinity of sea water (Table 1; Fig. 11) interestingly shows a marked relation with daily tidal times and also with change of seasons. After the end of monsoonal rain, sea water salinity starts increasing slowly during winter period and attains maximum uprising during entire pre-monsoon till the on break of next monsoon. All these physico-chemical parameters recorded in the benthic soil as well as sea water all along the trawl survey routes have together contributed to highly rich growth of benthic biodiversity all along the broad continental shelf area adjacent to the deltaic West Bengal. Therefore, a huge loss of benthic biodiversity can be easily assumed due to continuous commercial trawl netting in this offshore zone that needs to be immediately taken care of.
Damage to the marine chemical environment  Trawling as an extreme bioturbator highly affects undersea sediment function, carbon mineralization, and biogeochemical cycles. The macro-benthos of the sea bottom is important carbon consumers and their presence reduces the magnitude of available fluxes. Model studies by Duplisea et al. (2001) showed that in soft sediment systems, where the level of physical disturbance due to waves and tides is low, intensive trawling disturbance could cause large fluctuations in benthic chemical fluxes and storage. The dragging of trawl nets may decrease dissolved oxygen, which may be due to the mixing of reduced products such as methane and hydrogen sulphide or the re-suspended bacteria attached to sediments exerting an increase in oxygen demand in the water column (Riemann and Hoffman 1991). Formation of sediment clouds in the sea bottom may affect natural balance between physico-chemical parameters in the ocean, further depleting the availability of oxygen (Main and Sanger 1990). Trawling was also found to flush out nutrients and contaminants (Messiah et al. 1991) and there are possibilities of rise in lethal gases such as ammonia, methane, and hydrogen sulphide, affecting the life of organisms in water (Churchill et al. 1998). As a leading busy industrial zone of India, ‘Hooghly Industrial Belt’ occupies both sides of the river Hooghly, its estuarine mouth covering entire West Bengal offshore is subjected to heavy chemical pollution. The most crowded city of Kolkata is also very close to this coastal belt draining out huge effluents into the ocean through this estuarine mouth polluting entire West Bengal offshore. However, continuous oil spilling and lethal water washed out of huge number of mechanized diesel operated trawlers are also additionally responsible for severe marine water and benthic soil pollution in this offshore. None of these trawlers rather mechanized boats have marine pollution control measures. Many of these do not have authentic registration obtained from the Government. As per the composition of ejection of huge toxic effluents, lead, cadmium, and copper are considered the most lethal benthic soil and water polluting agents having a profound impact on the coastal and marine ecosystem. Table 1 and Fig. 12 show a glimpse of benthic soil pollution in West Bengal offshore and estuarine area and seasonal changes in three parameters, i.e., lead, cadmium, and copper recorded along the eight trawl survey routes. As monsoonal rain dilutes down the degree of lethality, percentage of lead and copper shows a marked increase during post-monsoon or winter and becomes higher during pre-monsoon or summer till the onset of the next monsoon shower.

Conclusion and recommendation

Intensive field survey into West Bengal offshore has revealed a profound negative impact of random destruction of non-target species on the littoral and infra-littoral habitat ecology. It proved how an apparently local marine environmental hazard is getting a big global concern day by day. To get rid of this situation, conservative use of marine resources is the only solve left. Here, lies the urgent need for a proper Environmental Management Plan (E.M.P) to ensure scientific pattern of commercial fish collection, so that marine ecology will neither be polluted nor destroyed but utilised conservatively. An effective oceanic management system should be incorporated in this problem-stricken West Bengal offshore area where E.M.P (Fig. 13) must highlight the following checks on trawling: (a) preventive measures: (i) trawl netting must be strictly banned and legal penalty should be imposed in case of violation of order, (ii) night trawl should specifically be banned forever as it is the resting period of fish naturally increases the percentage of damage of non-target species, (iii) monsoon trawl should also be banned forever as the spawning and maturity period for larvae and their juveniles before being caught during the next fishing season, and (iv) trammel nets must be introduced instead of...
trawl, because trawl as a dragging device destroys benthic habitats on sea floor. However, trammel as a floating gear floats just above seafloor to catch fish without damaging the benthic species and their undersea habitats. (b) Curative measures: (i) free of cost training on scientific fish collection techniques is essential for the local fishermen. They must be trained in restoring caught non-target species alive in specific containers on boat during commercial catch and releasing those all instantly into the ocean, (ii) strict rules on ‘on-boat restoration of caught non-target species alive and instant release those into ocean’ must be imposed on all trawlers and related fishermen working in West Bengal offshore, and (iii) village administrative They will monitor scientific operation of the existing trawlers to restore non-target species and also stop further registration of new trawlers in all fishing zones off West Bengal.

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