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Impact of bottom trawling on water and sediment characteristics of Cuddalore and Parangipettai coastal waters

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The present study was carried out to understand the impact of bottom trawling on the hydrographic, nutrient and sediment characteristics of Cuddalore and Parangipettai coastal waters during April 2014–March 2015. The present study addressed the impact of trawling on the sediment re-suspension, biochemical composition and bioavailability of organic matter in two coastal waters off Bay of Bengal. Sampling was carried out in four depth stations at 10, 20, 30, 40 m. Water and sediment samples were collected before and after trawling. The variations in total organic carbon and sediment nutrients were prominent in relation to stations and seasons. Pronounced changes were observed in water nutrients before and after trawling, while there was a minor effect on dissolved oxygen, total organic carbon and sediment nutrients. Conforming to the results, the PCA plot drawn for both the regions also revealed similar trend by the fact that the water nutrients had positive correlation with samples collected after trawling in all the stations, while dissolved oxygen, soil nutrients and total organic carbon showed negative correlation with the samples collected before trawling in all the stations.

[**Keywords**: Trawling; Physico-chemical parameters; PCA; Coastal waters]

Introduction

The impact of trawling on the seafloor, which depends upon the speed of towing, the size and weight of the net, type of seabed and strength of currents and tides, may remain a transitory phenomenon in shallow waters affected by strong tides or persists for several years in deeper areas with less disturbance[1]. Trawling activities may affect the sediment community function, carbon mineralization and bio-geochemical fluxes because the physical effects of trawling are equivalent to those of an extreme bioturbator[2]. The impact of physical contact [illegible] significant aftermath: it releases clouds of suspended sediment[3]; re-suspend and bury biologically recyclable organic material[4]; and for releases nutrients to the overlying water column[5]. Most studies of the physical processes related to towed fishing gears have focused on the hydrodynamic forces acting on the gears and the related netting/gear deformation[6], while studies of this kind are very limited. Among the different types of fishing practices that are in vogue in the fisheries sector on a global scale, bottom trawling is one of the most destructive methods. It is a source of chronic and widespread disturbance in shallow shelf seas and modifies the diversity, community structure, trophic structure and Kaiser and Groot[7] have reported productivity of the macro benthic invertebrate communities as earlier.

Biogeochemistry links the processes that control the fate of sediments, nutrients and organic matter, as well as trace metals and organic contaminants. Thus, this discipline requires an integrated perspective associated with the input, transport and either accumulation or export of materials that largely control the primary productivity. Trawling causes a number of direct and indirect changes in the [illegible] the fish population and in the benthos can occur and the water column receives organic and inorganic nutrients that may cause significant changes in the nutrient level besides oxygen budget[8]. Indirectly, bottom trawls affect marine animals and their associated habitat by re-suspending the sediments and nutrients into the water column by removing stones, turning over of boulders, scraping and ploughing 1–30 cm deep into the seafloor[9,10].

Taking into consideration the facts stated above, the present investigation was made to assess the impact of bottom trawling on the sediment resuspension by studying (i) Seasonal changes in the internal loadings of physico-chemical characteristics in the sample collected before/after trawling (ii) Changes in the oxygen level in the water column (iii) Changes in the sediment nutrients such as total nitrogen, total phosphorous and total organic carbon in the samples collected before and after trawling.

Materials and Methods

Study area

The region along the coastline encompassing off-Parangipettai (PP) (Lat. 11º 29'N; Long. 79º 46'E) and off-Cuddalore (CU) (Lat. 11º 44' N; Long. 79º 47'E) waters were selected for conducting bottom trawl survey. The experimental trawling was carried out with the help of commercial trawler (30-40 ft OAL) using a standard bottom trawl gear during the study. The study area was divided into four depth zones i.e. 0-10 m, 11-20 m, 21-30 m and 31-40 m. Sampling was carried out more or less at the mid depth of these zones (e.g. 5, 15, 25 and 35 m) using GPS reading. Three replicate samples were collected from each zone. Thus, 24 samples each in Parangipettai and Cuddalore were collected (Fig. 1).

Samples were collected at monthly intervals by adopting the standard protocol[11]. Water samples were collected using Teflon-coated Niskin water sampler. Dissolved oxygen (DO) was measured in the site itself and the remaining parameters such as nitrite (NO_2), nitrate (NO_3) and ammonia (NH_3) was analyzed by adopting the standard methods of Stickland and Parsons[12]. The inorganic phosphate (IP) was analyzed following the standard methods of Murphy and Riley[13]. For the sediment analysis, a known quantity (250 g of sediment) of sample was taken from each grab sample in each station. The sample was dried at 55 °C for one hour and the homogenized sediments were analyzed for nutrient parameters. Total phosphorous (TP) was determined using the method of Menzel and Corwin[14]; total nitrogen (TN) using Stickland and Parsons[12] and total organic carbon (TOC) by following El-Wakeel and Riley[15] method. For the sake of data analysis, the monthly data were amalgamated to various seasons, namely, summer, pre-monsoon, monsoon and post-monsoon. The results are given season-wise.

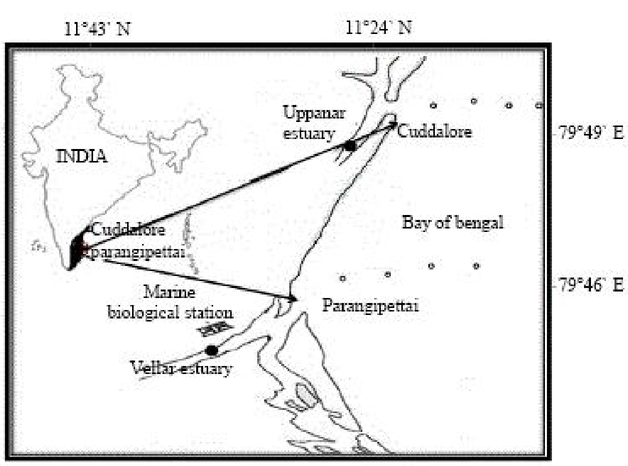

Fig.1 — Map showing the sampling stations

Results

The DO concentrations varied from 3.08 to 5.96 mg/l with maximum value (5.96 mg/l) at station PP-1 (after trawling) during monsoon season and minimum value (3.08 mg/l) at station PP-2 (before trawling) during summer season. The concentration of nutrients in seawater samples collected before and after trawling at the study area was analyzed with a view to study the immediate effect of trawling on the nutrient parameters. The nitrate values ranged from 2.02 to 5.89µmol/l with the maximum value observed at station PP-3 in the sample collected after trawling during monsoon season and the minimum value at station CU-1 in the sample collected before trawling during pre-monsoon season. The minimum nitrite concentration (0.22µmol/l) was recorded in the sample collected before trawling at station CU-2 during pre-monsoon season and the maximum (1.58 µmol/l) observed in the sample collected after trawling at station PP-1 during monsoon season. The ammonia values were from 0.012 to 0.176µmol/l. The higher value (0.176µmol/l) was observed in the sample of after trawling during monsoon season at station PP-3 and lower values (0.012µmol/l) in the samples collected before trawling during summer season at station CU-2. The level of inorganic phosphate ranged from 0.27 to 1.73µmol/l with the minimum value at CU-2 in the sample of before trawling during pre-monsoon season and the maximum at station PP-2 in the sample collected after trawling during monsoon season.

With respect to soil nutrients, the soil nitrogen values ranged from 2.51 to 15.17ppm with maximum value at station PP-1 (5M) in the sample collected before trawling during monsoon season and the minimum value at station PP-4 (35M) in the sample collected after trawling during post-monsoon season. Similarly, the soil phosphorus values ranged between 0.91 and 5.88 µg/g. The minimum was observed at station PP-4 (35M) in the sample collected after trawling during post-monsoon season and the maximum collected recorded at station CU-1(5M) in the sample collected before trawling during monsoon season. TOC showed minimum 2.10 mgC/g in the sample collected after trawling at station PP-4 (35M) during monsoon season and the maximum of 12.41mgC/g in the sample collected before trawling at station PP-1 (5M) during summer season. As stated earlier, the mean with standard deviation values for each station for both water and soil parameters are given in the Tables 1-4.

Principal Component Analysis (PCA)

To find out the inter-relation among the parameters, PCA was drawn for both the regions. The results

Table 1 — Station-wise variations in water and sediment nutrients recorded in the samples collected before and after trawling in Cuddalore and Parangipettai coastal waters during summer 2014

Parameters		0-5M		5-15M		15-25M		25-35M	
		BT	AT	BT	AT	BT	AT	BT	AT
DO (mg/l)	**CU**	4.67±0.33	4.04±0.58	5.09±0.67	3.08±0.21	5.12±0.28	4.26±0.32	5.00±0.37	4.03±0.41
	PP	4.71±0.74	4.28±0.42	4.05±0.51	4.04±0.46	5.61±0.52	3.23±0.36	5.23±0.63	4.21±0.44
NO_3 (µmol/l)	**CU**	3.08±0.26	4.18±0.31	2.83±0.17	4.52±0.46	2.53±0.37	4.56±0.57	3.01±0.35	5.08±0.44
	PP	3.37±0.57	5.18±0.45	4.38±0.40	5.73±0.57	4.58±0.63	4.90±0.57	3.14±0.48	4.07±0.33
NO_2 (µmol/l)	**CU**	0.41±0.05	0.65±0.11	0.52±0.67	0.83±0.10	0.42±0.09	0.65±0.04	0.39±0.06	0.93±0.11
	PP	0.32±0.18	1.07±0.21	0.56±0.09	0.92±0.29	0.41±0.15	0.87±0.21	0.65±0.12	1.00±0.08
NH_3 (µmol/l)	**CU**	0.036±0.012	0.053±0.015	0.012±0.021	0.080±0.017	0.058±0.010	0.086±0.022	0.037±0.007	0.053±0.015
	PP	0.071±0.026	0.099±031	0.017±0.004	0.049±0.007	0.049±0.13	0.084±0.034	0.042±0.018	0.084±0.022
IP (µmol/l)	**CU**	0.69±0.07	0.83±0.13	0.62±0.17	0.73±0.19	0.62±0.12	0.70±0.20	0.70±0.14	0.97±0.21
	PP	0.64±0.08	0.90±0.22	0.68±0.21	1.23±0.14	0.99±0.11	1.44±0.16	0.99±0.19	1.48±0.16
Soil nitrogen (ppm)	**CU**	6.76±1.23	6.22±1.15	5.71±1.87	5.01±1.51	7.12±3.20	5.87±1.97	4.86±1.34	3.63±1.03
	PP	7.75±4.16	7.02±3.08	6.63±2.78	5.65±2.19	4.11±1.27	5.87±1.65	4.88±2.00	3.78±1.21
Soil phosphorus (µg/g)	**CU**	4.96±1.73	3.32±0.92	3.31±1,32	2.88±0.95	2.94±0.85	1.68±1.21	2.31±1.08	1.41±0.63
	PP	2.72±0.78	2.63±0.57	2.28±1.29	1.92±1.56	1.91±2.09	1.52±0.87	1.49±1.23	1.32±0.72
Soil TOC (mgC/g)	**CU**	12.12±2.34	9.45±1.35	10.57±1.90	8.12±1.67	9.65±1.82	7.97±1.78	8.48±1.45	6.14±1.32
	PP	12.41±2.01	9.44±1.82	11.36±1.72	6.62±1.21	10.65±1.65	5.84±1.07	10.72±1.54	4.69±1.09

Mean ± S.D. CU – Cuddalore, PP – Parangipettai, BT – Before trawling, AT – After trawling

Table 2 — Station-wise variations in water and sediment nutrients recorded in the samples collected before and after trawling in Cuddalore and Parangipettai coastal waters during pre-monsoon 2014

Parameters		0-5M		5-15M		15-25M		25-35M	
		BT	AT	BT	AT	BT	AT	BT	AT
DO (mg/l)	**CU**	4.52±0.42	3.41±0.23	5.24±0.43	3.53±0.37	4.67±0.18	3.81±0.41	5.34±0.46	3.98±0.25
	PP	4.94±0.34	3.23±0.46	5.82±0.42	4.27±0.45	4.74±0.58	3.47±0.34	5.06±0.41	3.59±0.34
NO_3 (µmol/l)	**CU**	2.02±0.36	4.22±0.47	2.50±0.31	4.86±0.39	2.46±0.29	5.08±0.43	2.55±0.30	5.08±0.45
	PP	2.45±0.34	3.70±0.45	3.51±0.47	4.66±0.32	2.15±0.31	3.18±0.28	2.52±0.37	3.01±0.33
NO_2 (µmol/l)	**CU**	0.25±0.09	1.14±0.17	0.22±0.04	0.69±0.14	0.22±0.07	0.71±0.19	0.34±0.11	0.59±0.18
	PP	0.57±0.16	1.28±0.19	0.31±0.08	1.38±0.13	0.37±0.03	1.47±0.11	0.56±0.08	1.32±0.09
NH_3 (µmol/l)	**CU**	0.045±0.017	0.068±0.012	0.035±0.005	0.064±0.018	0.044±0.009	0.062±0.023	0.075±0.026	0.100±0.019
	PP	0.055±0.024	0.090±0.042	0.105±0.051	0.079±0.023	0.103±0.052	0.173±0.041	0.048±0.008	0.116±0.02`
IP (µmol/l)	**CU**	0.44±0.54	0.93±0.89	0.27±0.14	0.73±0.45	0.57±0.32	1.21±0.88	0.60±0.52	0.82±0.79
	PP	0.56±0.19	1.20±0.25	0.78±0.31	0.90±0.31	0.89±0.18	0.80±0.21	0.75±0.11	1.09±0.32
Soil nitrogen (ppm)	**CU**	9.75±2.09	8.77±1.73	8.09±2.34	7.53±2.13	7.48±2.41	5.65±1.44	4.56±1.14	5.19±1.06
	PP	12.12±2.78	11.24±3.12	10.25±2.15	9.92±2.36	7.52±2.00	7.32±2.08	4.87±1.03	3.34±0.86
Soil phosphorus (µg/g)	**CU**	5.14±2.01	4.21±1.90	4.66±1.73	3.73±1.94	1.95±0.88	1.21±0.56	1.81±0.68	0.93±1.02
	PP	4.78±1.45	3.32±1.34	3.81±0.94	2.63±1.13	2.74±1.43	1.45±0.45	2.92±1.23	1.28±0.44
Soil TOC (mgC/g)	**CU**	9.41±1.34	8.81±2.16	7.45±1.12	6.65±1.06	4.65±0.87	3.79±1.35	3.94±059	2.11±1.20
	PP	8.21 ±0.48	7.99±1.23	7.84±0.52	6.01±1.11	6.42±0.87	5.74±0.97	6.20±1.18	3.21±0.65

Mean ± S.D. CU – Cuddalore, PP – Parangipettai, BT – Before trawling, AT – After trawling.

Table 3 — Station-wise variations in water and sediment nutrients recorded in the samples collected before and after trawling in Cuddalore and Parangipettai coastal waters during monsoon 2014

Parameters		0-5M		5-15M		15-25M		25-35M	
		BT	AT	BT	AT	BT	AT	BT	AT
DO (mg/l)	CU	5.78±41	4.23±0.44	5.90±0.33	5.49±0.53	5.85±0.59	5.37±0.3	5.89±0.64	5.52±0.46
	PP	5.96±0.51	4.59±0.72	4.45±0.34	3.36±0.41	5.22±0.18	4.82±0.32	5.45±0.38	4.93±0.25
NO_3 (µmol/l)	CU	3.56±0.33	4.73±0.40	3.08±0.15	4.17±0.32	4.22±0.39	4.65±0.49	4.07±0.26	5.61±0.34
	PP	3.72±0.74	4.73±0.64	2.21±0..21	4.17±0.35	4.56±028	5.89±0.43	4.01±0.18	5.64±0.49
NO_2 (µmol/l)	CU	0.51±0.17	1.58±0.14	0.66±0.04	0.96±0.11	0.59±0.05	0.76±0.13	0.67±0.09	1.03±0.10
	PP	0.50±0.15	1.08±0.18	0.43±0.06	0.66±0.04	0.72±0.18	0.98±0.10	0.56±0.07	0.74±0.18
NH_3 (µmol/l)	CU	0.058±0.017	0.073±0.011	0.033±0.005	0.082±0.09	0.068±0.019	0.127±0.014	0.093±0.006	0.147±0.020
	PP	0.050±0.024	0.094±0.031	0.098±0.027	0.128±0.030	0.118±0.016	0.176±0.008	0.058±0.016	0.074±0.013
IP (µmol/l)	CU	0.71±0.09	1.27±0.15	0.70±0.05	1.02±0.08	0.73±0.05	1.07±0.13	0.70±0.11	1.08±0.16
	PP	0.43±0.11	1.35±0.03	0.37±0.05	1.73±0.15	0.96±0.12	1.48±0.20	0.77±0.16	1.19±0.11
Soil nitrogen (ppm)	CU	15.17±4.04	13.34±3.25	14.63±2.89	11.42±3.51	12.11±3.42	8.28±2.90	7.86±1.72	6.35±1.45
	PP	14.46±5.03	13.21±3.80	13.34±4.04	12.13±3.80	9.41±3.01	8.31±2.09	8.21±2.56	7.84±3.21
Soil phosphorus (µg/g)	CU	5.88±2.05	4.61±1.77	4.12±1.56	3.18±1.24	4.54±2.18	2.96±1.04	1.79±1.25	0.99±1.54
	PP	3.26±1.98	5.66±1.34	2.55±1.54	4.25±2.05	1.46±1.04	4.53±1.34	0.91±1.02	3.56±1.29
Soil TOC (mgC/g)	CU	6.12±1.78	4.26±1.14	7.3±1.78	5.12±1.45	6.74±1.23	4.3±1.34	5.97±1.15	2.31±1.03
	PP	6.11±1.56	5.61±1.33	6.20±1.00	4.31±1.31	5.68±1.32	3.41±1.56	5.34±1.48	2.10±1.20

Mean ± S.D. CU – Cuddalore, PP – Parangipettai, BT – Before trawling, AT – After trawling.

Table 4 — Station-wise variations in water and sediment nutrients recorded in the samples collected before and after trawling in Cuddalore and Parangipettai coastal waters during post-monsoon 2015

Parameters		0-5M		5-15M		15-25M		25-35M	
		BT	AT	BT	AT	BT	AT	BT	AT
DO (mg/l)	CU	5.45±0.50	5.26±0.64	5.89±0.46	4.57±0.39	4.23±0.12	4.04±0.48	5.00±0.40	4.70±0.28
	PP	4.38±0.34	4.03±0.17	4.53±0.12	4.10±0.31	4.71±0.19	4.03±0.25	4.23±0.24	4.29±0.36
NO_3 (µmol/l)	CU	3.06±0.68	4.73±064	3.07±0.56	5.26±0.50	3.06±0.44	5.54±0.51	3.21±0.49	4.40±0.51
	PP	4.35±0.34	5.80±0.67	4.10±0.54	5.29±0.51	3.01±0.39	4.93±0.37	4.59±0.29	5.49±0.42
NO_2 (µmol/l)	CU	0.44±0.22	0.68±0.27	0.53±0.31	0.60±0.36	0.37±0.25	0.75±0.22	0.51±0.18	0.58±0.28
	PP	0.42±0.34	0.80±0.33	0.73±0.25	1.26±0.16	0.32±0.28	1.35±0.31	0.44±0.34	1.29±0.22
NH_3 (µmol/l)	CU	0.023±0.005	0.068±0.023	0.024±0.009	0.076±0.021	0.015±0.025	0.073±0.034	0.014±0.016	0.082±0.023
	PP	0.055±0.018	0.092±0.012	0.042±0.007	0.061±0.009	0.060±0.015	0.132±0.011	0.034±0.005	0.096±0.010
IP (µmol/l)	CU	0.56±0.09	1.29±0.09	0.80±0.12	0.91±0.10	0.65±0.72	0.85±0.16	0.65±0.07	0.99±0.16
	PP	0.58±0.11	1.36±0.18	0.46±0.03	1.36±0.12	0.49±0.08	1.67±0.17	0.68±0.14	1.25±0.15
Soil nitrogen (ppm)	CU	7.96±2.45	7.16±2.18	6.5±2.67	5.86±3.04	5.14±3.87	4.32±1.09	4.83±1.23	3.74±1.32
	PP	8.58±4.98	7.01±3.34	6.29±2.54	5.96±2.76	6.18±3.23	5.25±2.88	3.83±1.90	2.51±1.56
Soil phosphorus (µg/g)	CU	4.69±1.34	3.76±1.13	5.54±1.98	2.96±0.89	3.21±1.23	1.56±0.32	1.88±0.34	0.94±0.11
	PP	4.63±1.05	3.26±0.90	3.84±1.34	2.55±0.89	2.5±0.98	1.46±0.55	2.18±0.23	0.91±1.34
Soil TOC (mgC/g)	CU	8.23±2.43	7.56±1.09	9.71±3.45	8.26±2.76	6.61±2.11	4.86±1.23	5.75±1.32	4.87±1.90
	PP	10.25±3.33	8.68±2.20	8.92±1.45	6.89±1.22	4.32±2.09	3.96±1.56	3.88±1.90	3.65±1.36

Mean ± S.D. CU – Cuddalore, PP – Parangipettai, BT – Before trawling, AT – After trawling.

are shown graphically in Fig. 2a & b. In Cuddalore coastal waters, parameters such as nitrite, nitrate, ammonia and inorganic phosphate were found to show positive correlation with the samples collected after trawling in all the stations, whereas dissolved oxygen, soil nitrogen, soil phosphorus and total organic carbon showed negative correlation with the samples collected before trawling (Fig. 2a). Similarly, in Parangipettai coastal waters, as seen in Cuddalore waters, parameters such as nitrite, nitrate, ammonia and inorganic phosphate of after trawling samples had positive correlation in all the stations, while dissolved oxygen, soil nutrients and total organic carbon showed negative correlation with samples collected before trawling in all the stations (Fig. 2b).

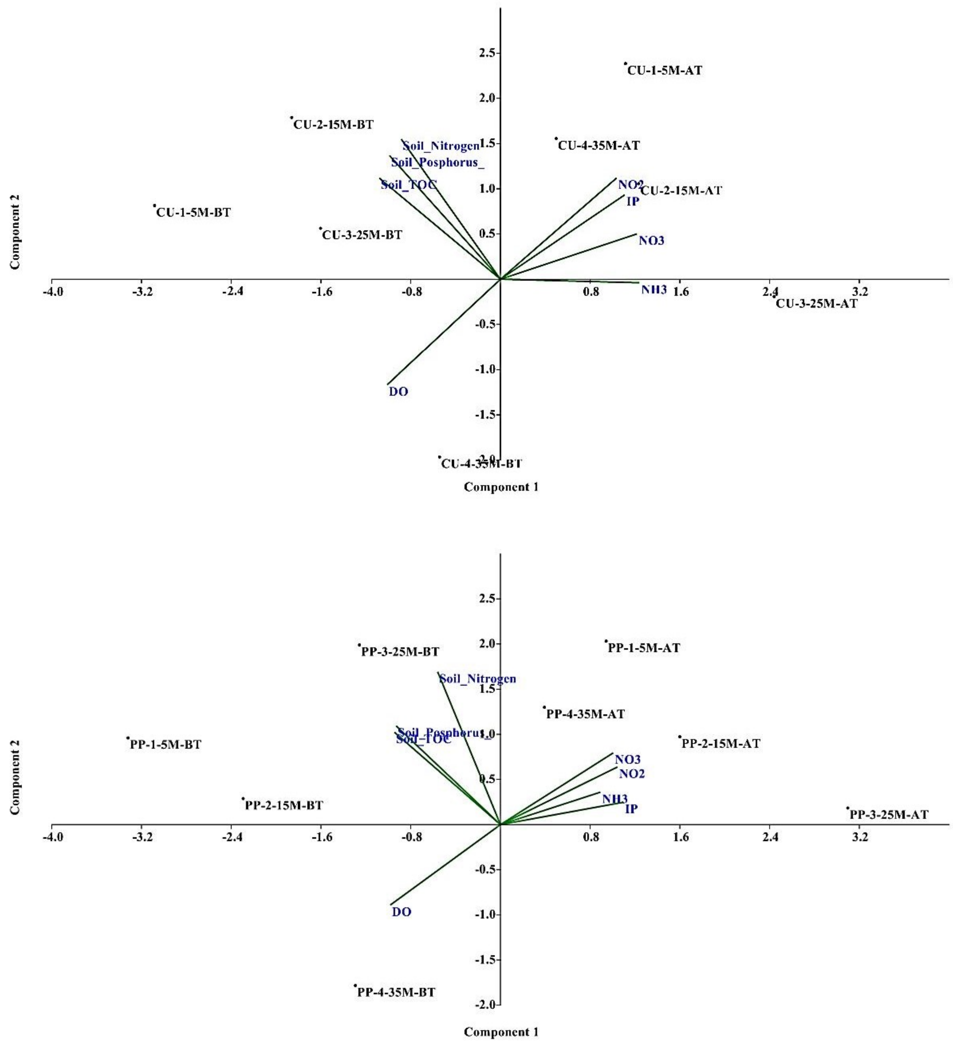

Fig. 2 — Principle component analysis – biplot of physico-chemical parameters of water and sediment (a) Cuddalore (b) Parangipettai coastal waters.

Discussion

The present study was made to quantify impact of bottom trawling on the structural attributes of fish habitat in unconsolidated sandy sediments on the continental shelf off Cuddalore and Parangipettai coastal waters. The physical effects of beam trawls are expected to be high due to its close contact with the seabed as reported by a researcher elsewhere[16].

The dissolved oxygen is one of the most indispensable parameters in determining water quality and the distribution and abundance of various groups[17]. The dissolved oxygen was found maximum during monsoon season and minimum during summer season. Higher dissolved oxygen concentration observed during monsoon season might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing[18]. The oxygen concentration in the surface as well as bottom waters showed decreasing trend after trawling and the decrease was more pronounced at all the stations. According to Warkern *et al.*[19], moderate and repeated trawling will result in removal of the upper oxygenated sediment layers and would create anoxic surface sediments and this might be the plausible reason for the decrease in DO content in the samples collected after trawling.

The nutrients showed asymmetric distribution in the tropical zones at different depth levels and are regulated by seasonally varying physical processes like thermocline elevation and zonal transport, the equatorial undercurrent and elevation of nutrient replete waters north of the equator and sinking of nutrients-poor water toward the equator driven by tropical instability waves[20]. Distinct seasonal variations were noticed in nitrite and phosphate concentration with maximum during monsoon season, while post-monsoon and pre-monsoon periods registered comparatively lower values. Nitrate, nitrite and phosphate values showed maximum during monsoon season and minimum during summer season. Subramanyan *et al.*[21] recorded high nitrite and phosphate values during monsoon in Kerala coast. The depletion of nutrients in the closing stage of post-monsoon season can be attributed to the planktonic productivity as reported earlier by Sankaranarayanan and Qasim[22]. Rittenberg *et al.*[23] opined that in marine condition, the major source of nutrients is the river run–off from terrestrial environs. Thomas *et al.*[24] reported an increase in the level of nitrate and phosphate content in seawater after trawling.

The higher ammonia concentration was observed during the monsoon season and the lower values were found during the summer season both before and after trawling. The higher concentration could be partially due to the death and subsequent decomposition of phytoplankton and also due to the excretion of ammonia by planktonic organisms[25]. Trawling was also known to flush out nutrients and contaminates[26] and there are possibilities of rise in lethal gases like ammonia, affecting the life of organisms in water[27]. Sediment nutrients are essential to life in the sea and among them nitrogen and phosphorus are the most important elements[28,29]. Distinct seasonal variations were noticed with high nitrogen and phosphorus concentrations in the monsoon period while post-monsoon and pre-monsoon periods showed comparatively lower values. Several researchers recently have reported that bottom trawling has the capacity to alter natural sedimentary environments[30,31]. Soil nitrogen and soil phosphorus in the samples collected before trawling was conspicuously high when compared to the samples collected after trawling. This might be due to trawling effect wherein the availability of sediment nutrients gets dispersed, which resulted in minimum value in the samples collected after trawling as clearly demonstrated by Sreedevi[32]. The interstitial water may also contribute to an increase in the nutrients content of seawater and decrease in the sediment[33]. German researchers noted a significant remobilization of nutrients from pore water as a result of disturbance to surface sediment layers. The higher TOC content in the sediment during summer season might be attributed to settling of decayed plant and animal wastes brought in through municipal waste and adjacent agricultural field since these are the potential source of TOC content in the sediment. The lower value recorded during monsoon might be due to incessant stirring up of the sediments releasing the organic carbon from the sediment to the water column. When the trawling is related, the maximum level of TOC was recorded in the samples collected before trawling and minimum in the sample collected after trawling in both the regions. Usha *et al*.[34] reported in Veraval coast, Gujarat that the experimental trawling considerably reduces the organic matter content at all depths and continued incessant trawling operation can cause even more drastic reduction. This observation holds good for the TOC values of the present study. Intensive trawling may cause sediment systems to become unstable sediment disturbance coupled with flux of nutrients from the sediment to the overlying water[35]. Water and sediment nutrients in relation to trawling at a low resolution, the patchy distribution will be averaged out with areas trawled less intensively. Hence, the estimate of the untrawled area increases with the level of resolution[36,37]. A resolution of about 1 min latitude by 1 min longitude as used in this study is considered to be appropriate as reported by various researchers elsewhere[38,39] as trawling is shown to be randomly distributed at this level of resolution[40].

Results of the present study highlighted the general trends on impact of bottom trawling on water and sediment characteristics of the trawling grounds. This kind of experimental trawling studies is needed to understand the marine environmental impact associated with commercial fishing operations. To conduct studies on trawling impacts, appropriate control sites are very much necessary. Under this circumstance, continuous monitoring of sediment characteristics for a long period will certainly reveal interesting and useful information in the chosen area.

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