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Investigations on selected ecological parameters of Tuticorin Bay, Gulf of Mannar, south-east coast of India with emphasis on suitability for mariculture

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ABSTRACT

A study was conducted for a period of two years from 2017 to 2018 to assess the health of Tuticorin Bay, south-east coast of India. Water and sediment quality parameters, total clam density, heavy metal content in the sediment and clam tissue samples from four sites were used as the criteria for health assessment. High values of parameters like salinity (38.3±5.04 ppt) and ammonia (0.09±0.04 mg l^{-1}) were observed at the station close to the thermal power station and high nitrite (0.688±0.13 µg l^{-1}) and total suspended solids (380.3±0.04 mgl^{-1}) were observed at the station close to Koramballam freshwater creek. Most of the water quality variables were within the standard limit prescribed for aquaculture activities. The organic matter content in the sediment of the bay ranged from 0.26 to 5.17%. Comparatively low heavy metal concentration was observed both in the sediment and clam tissue samples. The metals were found accumulated in the order of Fe>Mn> Pb>Cu>Ni>Cd in the sediment samples and in the order Fe>Pb>Mn>Cu>Cd>Ni in clam tissue samples. The estimated levels were also within the permissible limits for most of the metals. The study indicated that Tuticorin Bay is suitable for mariculture activities.

Keywords: Clam density, Heavy metal concentration, Tuticorin Bay, Water and sediment quality parameters

Introduction

Tuticorin Bay (08º46'20"N; 78º10'46"E) enclosing a water area of 56 sq km, is situated in the Gulf of Mannar, in Tamil Nadu, south-east coast of India. Hare Island forms the eastern boundary of the Bay and the Tuticorin landmass is on its western side. The southern point of Tuticorin Bay extends to a creek with a wide mangrove area, which is under the influence of the Tuticorin Thermal Power Plant (TTPP) (Mohamed, 1998). Tuticorin Thermal Power Station (TTPS) was commissioned in 1978, with an area of about 160 ha. It produces 1050 MW electricity per day utilising 18,000 t per day of coal and causes severe pollution of air, water and land environment (Selvin *et al.*, 2010). TTPS discharged fly ash into the Bay until the CRZ notification by the Ministry of Environment and Forests in 1991. Clara and Sugritha (2013; 2016a) have reported-about the chemical changes that occurred due to fly ash released from TTPS, especially the trace element content when in contact with seawater. Heavy metals like arsenic, lead, nickel, cobalt, chromium, boron and antimony that leached from the fly ash were found to be hazardous for living organisms (Clara and Sugritha, 2016b). Leaching of metals from fly ash into the surrounding environment has been reported from different parts of India (Tripathi *et al.,* 2002; Dwivedi *et al.,* 2007; Rajarshi *et al.,* 2009). Ganesan and Kannan (1995) reported a higher concentration of Fe and Mn in the seawater, sediment and algae in the vicinity of Tuticorin Port. Palanichamy and Rajendran (2000) indicated a high concentration of Cd and Pb in the bottom waters than the surface waters off the Tuticorin coast. Asha *et al.* (2010) reported a high concentration of heavy metals in the seawater, sediment and bivalves of Tuticorin coastal waters within the vicinity of TTPS.

Besides this, the TTPP discharges hot water effluent with temperature ranging between 40 and 44^{o}C into the adjacent water body at a rate of 115 x 10^{6} l day^{-1} (Kailasam and Sivakami, 2004). The neutralisation of temperature has been noticed up to 2 km from the Bay (Easterson *et al.,* 2000). The influence of hot water effluents on the hydrography has been studied in various locations of the Bay (Asha, 2002; Shelarpiyusha *et al.,* 2017). Fish mortality due to high ammonia concentrations has been reported from Tuticorin Bay (Asha *et al.,* 2009). Irrespective of all these health hazards, the Bay serves as a significant source of livelihood for the local villagers for its clam and polychaete worm resources

(Kripa *et al.*, 2012; Asha and Diwakar, 2019). Considering the rich fishery potential, monitoring the health of the Bay is a prerequisite to maintain the sustainability of the resources. No information is available on the health of the bay, especially the region surrounding the seawater intake point of the marine hatchery system of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) and the present work is aimed at addressing the knowledge gap in this line and confirming the suitability of the bay for mariculture activities.

Materials and methods

The study was carried out during the period 2017-2018. Four stations were fixed in the bay *viz.,* Station-1 (St.1) at the northern side near Roche Park, (08^{0}47’.068’N; 078^{0}09’.625’E); Station-2 (St.2) 200 m away from St.1 nearer to the Koramballam freshwater creek (08^{0}46’.990’N; 078^{0}09’.589’E); Station-3 (St.3) (08^{0}46’.826’N; 078^{0}09’.642’E) 40 m away from St.2 on the southern side of the bay nearer to the seawater intake point of ICAR-CMFRI marine hatchery and Station 4 (St.4) (08^{0}46’.719’N; 078^{0}09’.699’E), 100 m away from St.3, towards the south, nearer to the TTPS plant (Fig. 1).

Seawater and sediment samples were collected from the four stations during four different seasons *viz.,* summer, pre-monsoon, monsoon and post-monsoon. Water quality parameters such as dissolved oxygen (DO), carbon dioxide, biochemical oxygen demand (BOD), pH, salinity, chlorophyll, gross primary productivity

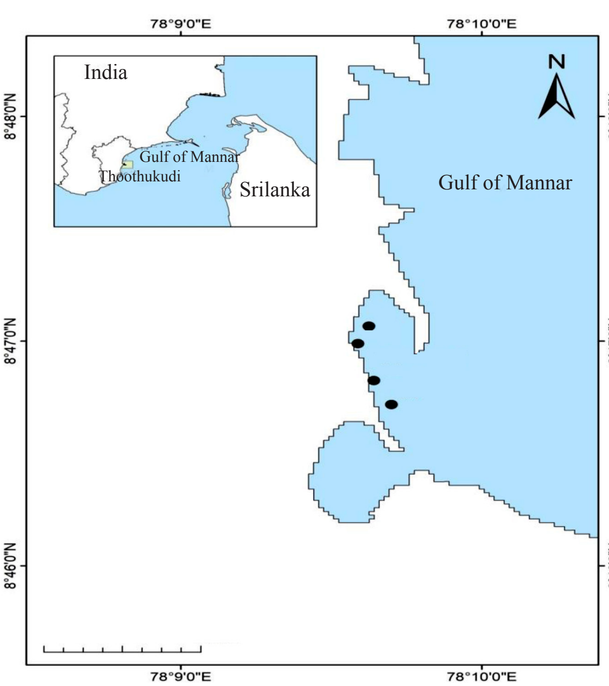

Fig. 1. Map showing the sampling locations in Tuticorin Bay

(GPP), net primary productivity (NPP), ammonia, total suspended solids (TSS), total dissolved solids (TDS), alkalinity, carbon dioxide and nutrients like nitrite (NO_2), nitrate (NO_3), phosphate (PO_4) and silicate (SiO_3) were assessed by standard methods. *In situ* measurements of early morning air and sea surface water temperatures (AT and SST) were made using a high precision thermometer. Salinity was determined by Mohr’s titration method (Grasshoff, 1983). Dissolved oxygen and BOD were estimated by the modified Winkler’s method (Strickland and Parsons, 1972). Ammonia was estimated by the phenol hypochlorite method (Solarzano, 1969) and the nutrients were determined using spectrophotometer (Genesis 10 model) following the procedure given by Grasshoff *et al.* (1999)**.** Primary production was estimated by the dark and light bottle method and Winkler’s method was employed for the estimation of oxygen. The same was converted into carbon equivalent using a PQ of 1.25 for obtaining the gross production. Total chlorophyll was estimated according to Parsons *et al.* (1984). Total suspended and dissolved solids were estimated by filtration technique and alkalinity by titration method (APHA, 2005). Carbon dioxide concentration was quantified by the acid-base titrimetry method (Dickson, 1998).

Core sampler of 20 cm length and 3 cm lumen diameter was used to collect subsurface sediment samples from the four stations. The samples were dried, pulverised and sieved for estimation of sediment quality parameters. Sediment texture was analysed by the pipette method (Lewis, 1984). Organic carbon, organic matter and nitrogen of the bottom sediments were estimated by Walkley-Black (1934) method. The benthic productivity of the bay was analysed in terms of clam biomass and density. For the clam productivity estimation, a quadrat (0.0625 m^{-2}) was placed at random in triplicates at the four stations and all the bivalves found in the quadrat were collected, washed thoroughly, counted and weighed. The mean of three quadrat samplings was considered to get the density and biomass per square meter. Different species of clams *viz., Meretrix casta, Marcia opima, Gafrarium pectinatum* and *Protapes gallus* (=*.Paphia malabarica*) (10-35 nos.) collected from each station were washed and kept in filtered seawater to empty the gut. Whole-body tissue of animals was removed and washed in distilled water. The sediment and clam tissue samples were dried in an oven at 80±2^{o}C. One gram of finely ground representative fraction of each sample was digested using HNO_3 HCl; 1:3 v/v and 6 ml of HF which was kept in a hot water bath for 3 h and then the digested precipitate was made up to 100 ml (Dalziel and Baker, 1984). The concentration of metals like Cd, Cu, Fe, Mn, Ni, Zn and Pb were estimated by an Inductively Coupled Plasma Optical Emission Spectrometer (Perkin Elmar Optima 5300 DV ICP-OES).

One-way analysis of variance (ANOVA) and correlation between all possible combinations were performed to test the significant seasonal and station-wise differences between parameters. Statistical analysis was performed using SPSS software ver. 20 (Chicago, USA).

Results and discussion

Water quality conditions of the bay

An apparent seasonal variation was noticed in the air as well as sea surface temperatures between stations. At all the stations it was lowest during post-monsoon and highest during summer, however not much variation was noticed between stations. The air temperature ranged between 25.5 and 35°C and water temperature between 26 and 33.5°C. The highest mean value of air temperature (31.3±1.9°C) was recorded at St.3 and St.4 and water temperature (29.8±1.4°C) at St.4 (Fig. 2a). Kailasam and Sivakami (2004) and Shelarpiyusha *et al.* (2017) have reported a more or less similar range (27.7-33.7°C) of water temperature in the bay away from the hot water discharge point. The estimated mean sea surface temperature at all the stations was within the range of 25-32°C prescribed for mariculture (FAO, 2006). The seasonal variation was statistically significant for air and water temperatures at all the stations ($p<0.001$). A high positive correlation was also noticed between the two temperatures ($p<0.01$). The salinity was exceptionally high during the monsoon season at St.2 and St.4. The unexpected higher salinity might be due to runoff from the neighbouring salt pans during the monsoon season. High salinity in Tuticorin Bay due to the neritic water dominance has been reported earlier (Clara and Sugritha, 2015). The most elevated salinity of 53.4 ppt and the maximum mean value of 38.3±5.04 ppt were noticed at St.4 nearer to the TTPS (Fig. 2a). Kailasam and Sivakami (2004) reported a lower range of salinity (31.6-36.3 ppt) within the vicinity of power plant stations. Shelarpiyusha *et al.* (2017) also reported a higher salinity range of 36.2-39.9 ppt in the bay. The pH was comparatively higher at all the stations during the pre-monsoon season and varied between 7.65 at St.1 to 8.46 at St.3 (Table 1). The present work reported a more or less similar range of pH (7.5-8.5) as reported by Clara and Sugirtha (2015) and Shelarpiyusha *et al.* (2017) and a higher range of pH (8.08-8.35) than the values reported by Kailasam and Sivakami (2004). The usual range of pH noticed at all the study sites also indicated the low influence of alkaline fly ash from the TTPS (Clara and Sugritha, 2016). All the stations reported a mean pH within the permissible range of 7-8.5 prescribed for marine hatchery works (Boyd, 2003). The seasonal variation was significant for all the stations ($p<0.001$). The mean value was highest (8.15 ±0.1) at St.4 (Fig. 2b).

The DO concentration ranged between 2.5 to 8.2 ml l^{-1}. The mean value was lowest (4.52±0.82 ml l^{-1}) at St.2 and highest (5.76 ±0.27 ml l^{-1}) at St.4 (Fig. 2b). Shelarpiyusha *et al.* (2017) also reported higher DO (8.14 ml l^{-1}) in the Tuticorin Bay and Kailasam and Sivakami (2004) reported more or less similar variations (3.55 to 5.7 ml l^{-1}) of DO within the vicinity of TTPS. The GPP was comparatively higher at St.4 with the highest mean value of 9.2±4.2 mg cm^{-3} day^{-1}. Carbon dioxide was absent at all the stations.

The ammonia concentration was comparatively higher at St.4 nearer to TTPS and the mean value was highest (0.09±0.04 mg l^{-1}) at St.4 (Fig. 2c). Except for the highest value of 0.197 mgl $^{-1}$ recorded at St.4, the ammonia concentration was well below the toxic limit of 0.1 mgl^{-1} suitable for mariculture (Boyd, 2003) at all the stations. The ammonia concentration reported in the present study is more or less similar to the values reported by Selvin *et al.* (2010) and is comparatively lesser than the values reported by Shelarpiyusha *et al.* (2017). In general, the rain has positively influenced the nutrients like PO_4 and SiO_2, hence comparatively higher values were noticed during the post-monsoon season (Table. 1). The mean values were highest for NO_2 (0.688±0.13 µg l^{-1}) at St.2., for NO_3 (0.292±0.19 µg l^{-1}) at St.4., for PO_4 (1.06±0.51 µg l^{-1}) at St.1 and for SiO_2 (2.8±0.3 µg l^{-1}) at St.3 (Fig. 2c and d). The NO_2, NO_3 and PO_4 reported in the present study are more or less similar to the observation of Clara and Sugritha (2015). Significant seasonal variations were also noticed for PO_4, NO_3 and SiO_3 between stations ($p<0.001$). Higher PO_4 values were seen during the post-monsoon season at St.2, which might be due to the river runoff from the Koramballam creek as observed by Selvin *et al.* (2010). The PO_4 content was negatively correlated with SiO_2 ($p<0.05$). The estimated range of total inorganic nitrogen (0.008-0.012 mg l^{-1}) and inorganic phosphate (0.018-0.033 mg l^{-1}) at all the stations were also within the permissible range of 0.5-4.5 and 0.05-0.50 mg l^{-1} for total N_2 and total phosphate respectively prescribed for aquaculture (FAO, 2006). Suspended solids (TSS) were relatively lower during the pre-monsoon season at all the stations. In general, TSS was higher at St.2, due to the influence of Koramballam creek and varied between 208 and 573 mg l^{-1} (Fig. 2e). Seasonal variation was also significant at all the stations ($p<0.001$). The chlorophyll concentration was relatively better at St.1. The highest mean value of (1.415±0.525) mg m^{-3} was recorded at St.1 (Fig. 2f). There was a significant seasonal variation in chlorophyll content at all the stations ($p<.001$).

The BOD was nil at St.1 and comparatively higher at St.2 and St.4, with the highest mean of 1.63±0.23 mg l^{-1}

Table 1. Seasonal variation in water quality parameters of four stations in Tuticorin Bay

Parameters	Pre-monsoon				Monsoon				Post-monsoon				Summer				p<0.05
	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	
AT (°C)	33.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	26.0	26.5	26.0	26.0	33.5	33.0	35.0	25.0	0.000
SST (°C)	29.0	28.0	27.0	27.6	30.0	30.5	31.0	30.0	25.5	26.0	27.5	28.0	32.0	31.0	33.5	33.5	0.000
Salinity	37.0	37.8	35.8	34.2	35.8	42.2	35.2	53.4	36.0	32.9	36.2	31.6	36.9	36.6	34.1	34.1	0.148
pH	8.2	8.3	8.3	8.3	7.7	7.8	7.8	8.0	7.7	7.7	7.9	8.0	8.2	8.1	8.5	8.3	0.000
DO (mll $^{-1}$)	4.7	4.9	5.6	5.4	3.2	4.3	4.5	5.4	6.3	6.4	4.1	6.5	5.8	2.5	8.2	5.7	0.497
GPP (mg cm-^{3} day^{-1})	15.1	0.0	0.0	18.9	8.7	17.3	0.0	13.0	0.0	0.0	0.0	0.0	3.0	0.0	5.0	5.0	0.156
NH_3 (µgl^{-1})	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.502
TSS (mg l^{-1})	426.0	573.0	494.0	440.0	418.0	488.0	483.0	433	252.0	227.0	208.0	218.0	220.0	233.0	232.0	224.0	0.000
Chlorophyll (mg m^{-3})	0.0	0.2	0.2	0.2	0.5	0.0	0.0	0.0	4.6	0.6	0.9	0.5	0.5	0.4	1.0	0.6	0.158
NO_2 (µgl^{-1})	0.5	0.9	0.0	0.9	0.6	0.6	0.2	0.1	0.4	1.0	0.8	0.7	0.3	0.4	0.4	0.4	0.220
NO_3 (µgl^{-1})	0.1	0.0	0.0	0.0	0.2	0.1	0.4	0.8	0.2	0.1	0.5	0.4	0.0	0.0	0.0	0.0	0.000
PO_4 (µgl^{-1})	0.3	0.5	0.2	0.2	0.4	0.3	0.6	0.8	2.5	1.3	2.0	1.5	1.0	0.3	0.3	1.2	0.020
SiO_3 (µgl^{-1})	3.0	2.3	3.0	1.6	2.6	2.0	2.2	2.4	3.0	3.5	3.6	3.1	2.4	2.9	2.4	2.4	0.036
BOD (mgl^{-1})	0.0	0.0	1.0	2.1	0.0	1.9	1.0	1.9	0.0	2.6	1.3	1.3	0.0	3.5	0.0	1.2	0.932
Alkalinity (mgl^{-1})	86.4	91.3	90.6	93.4	126.0	116.0	121.0	116.0	77.9	76.4	74.9	116.8	109.2	107.3	107.3	100.2	0.003

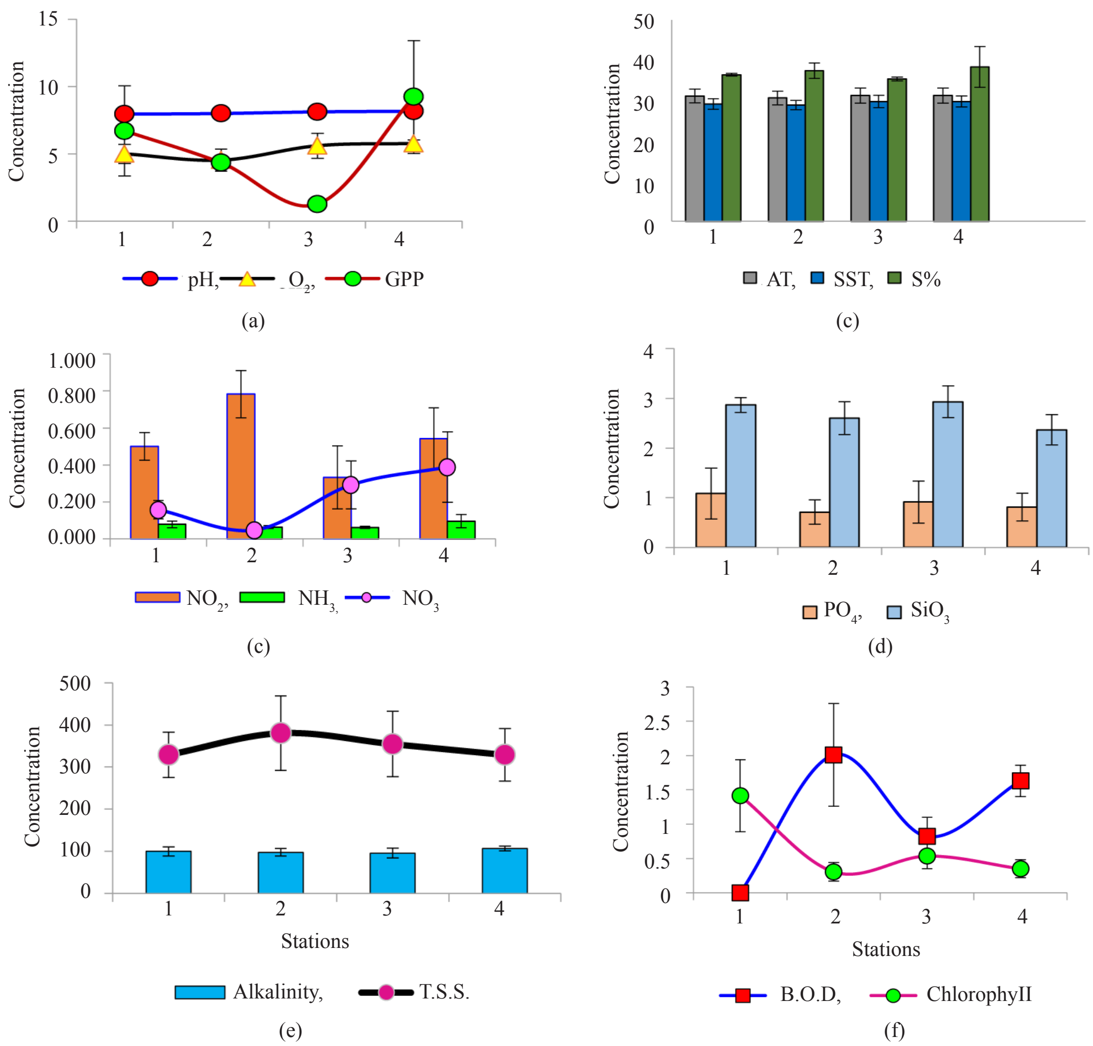

Fig. 2. Variations in the mean values of water quality parameters (a) pH, DO and GPP; (b) AT, SST and salinity; (c) NO_2, NO_3 and NH_3; (d) PO_4 and SiO_3; (e). Alkalinity and TSS; (f) BOD and chlorophyll, at four stations of Tuticorin Bay

noticed at St.4 (Fig. 2f). The BOD observed in the present study was relatively lower than the values reported by Selvin *et al.* (2010) and Shelarpiyusha *et al.* (2017) in the coolant water influenced areas of Tuticorin Bay. The estimated BOD values were also within the permissible limit of <15 mg l^{-1} prescribed for hatchery work (FAO, 2006). The total alkalinity was higher at all the stations during the monsoon season and ranged between 74.9 to 126 mg l^{-1} (Fig. 2e). The estimated alkalinitywas found below the permissible limit of 600 mgl^{-1}. The seasonal variation in alkalinity was significant at all the stations ($p<0.001$).

Sediment quality conditions of the bay

The seasonal variation in sediment quality parameters and clam population parameters are given in Table 2. Coarse sand constituted a significant portion of sediment at St.1, St.3 and St.4 which formed the highest share in the sediment at all the stations - 23.4±9.9% at St.1, 27.6±5.8% at St.2, 25.5±6.9% at St.3 and 27.9±8.4% at St.4 (Fig. 3b). Relatively higher composition of silt was noticed only in the sediment at St.1 (16.05±13.9%), whereas in other stations, silt contributed only a meager percentage (Fig. 3b). Clay and fine sand were positively correlated at all the stations ($p<0.05$). Fine sand was the second dominant constituent at all the stations. The sediment constituents significantly varied seasonally at all the stations ($p<0.001$). Kailasam and Sivakami (2004) also indicated the dominance of sand particles in the sediment of Tuticorin Bay. The percentage of organic matter, organic carbon and nitrogen were comparatively higher at St.1. The organic matter ranged from a minimum of 0.259 at St.4 to a maximum of 5.17% at St.1. The highest mean values of organic carbon (1.59±0.49), organic matter (2.75±0.86) and nitrogen (0.137±0.06) were reported at St.1 (Fig. 3a). The organic carbon content noted at all the stations was lower (4.894%) than those indicated from the fly ash dumpsite of TTPS (Clara and Sugritha, 2016), which might be due to the low clay fraction of the bottom soil. This also indicated the low influence of organic matter rich fly ash in the study area. There was a significant seasonal variation noticed at all the stations ($p<0.001$). A significant positive correlation was seen between clay and organic matter content and between fine sand and organic matter content of the sediment samples ($p<0.01$). In contrast, a significant negative correlation was observed between coarse sand and organic matter content. The mean density and biomass of total clam were highest (52.7±16.3 nos. m^{-2} and 765.6±148.9 g m^{-2}) at St.1 and lowest at St.4 (Fig. 4). The range of clam density and biomass estimated in the present study was more or less similar to the estimates made by Kripa *et al.* (2012) and Kavitha (pers. comm).

Heavy metal concentrations in the sediment and clam tissues

The sediments of St.1 had the highest concentrations of heavy metals like Cd (0.17 mg kg^{-1}), Cu (0.172 mg kg^{-1}), Fe (63.8 mg kg^{-1}), Ni (0.078 mg kg^{-1}) and Pb (0.542 mg kg^{-1}).

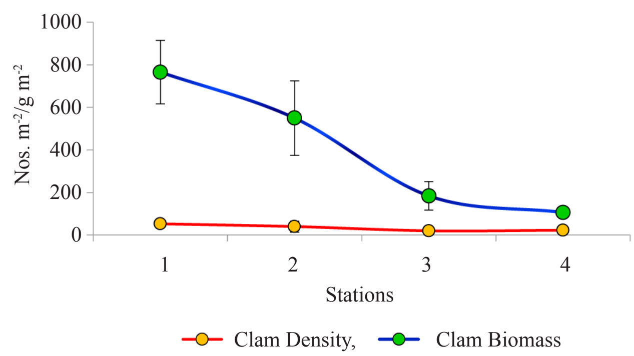

Fig. 4. Variation in the mean values of clam density and biomass at four stations of Tuticorin Bay

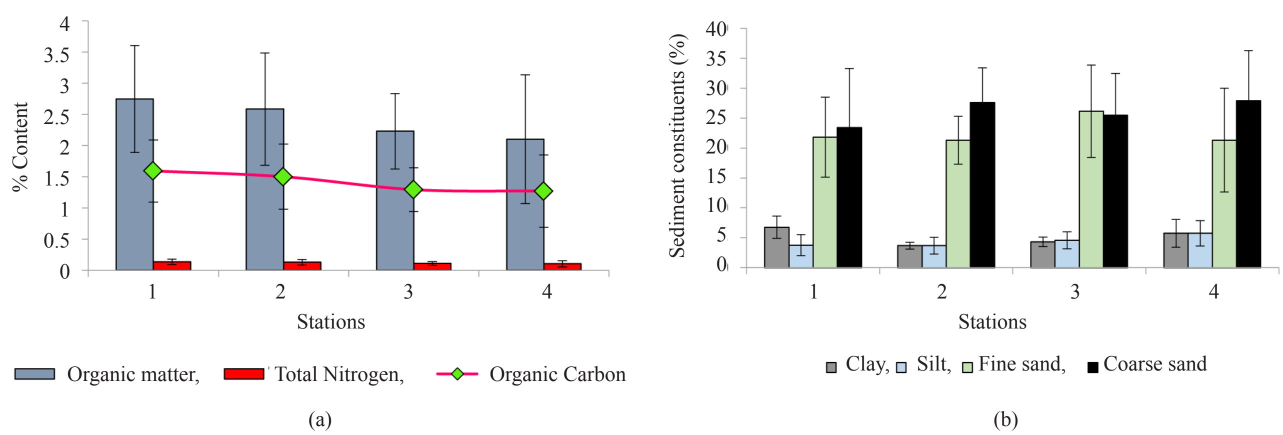

Fig. 3. Variation in the mean values of sediment quality parameters (a) Percentage of organic carbon, organic matter and nitrogen, (b) Percentage of sediment constituents, at four stations of Tuticorin Bay

Table 2. Seasonal variations in the sediment quality parameters and clam density of four stations at Tuticorin Bay

Parameters	Pre-monsoon				Monsoon				Post-monsoon				Summer				p<0.05
	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	
Organic carbon (%)	1.5	0.6	0.6	0.15	1.2	1.8	1.65	1.35	0.67	0.75	0.83	0.73	3	2.85	2.1	2.85	0.000
Organic matter (%)	2.58	1.03	1.03	0.25	2.06	3.1	2.84	2.32	1.16	1.29	1.42	0.9	5.17	4.91	3.62	4.91	0.000
Total nitrogen (%)	0.12	0.05	0.05	0.01	0.1	0.15	0.14	0.11	0.05	0.06	0.07	0.04	0.25	0.24	0.18	0.24	0.000
Clay (%)	7.9	4.4	4.8	4.6	1.8	4.3	2	1.9	6.8	2	4.8	4	10.6	4	5.6	12.5	0.430
Silt (%)	8.7	1.3	7.2	4.6	0.4	1.3	0.6	0.4	2.8	5.6	5.6	8	3.2	6.5	4.9	10.0	0.370
Fine sand (%)	23.5	31.5	34.9	13.1	10.7	12.6	9.1	10	13	18.3	17.9	15	40	22.8	42.8	47.2	0.000
Coarse sand (%)	6.7	37.8	17.6	31.4	18.8	15.5	23.4	21.5	52.1	37.2	45.8	49.2	16	19.9	15.2	9.6	0.001
Clam density (nos. m^{-2})	0	0	0	0	20	12	24	12	68	16	16	28	70	92	20	28	0.179
Clam biomass (g m^{-2})	0	0	0	0	151.9	52	157.8	90.2	784.9	97	311	123	1360	1500	84	164	0.187

The Mn concentration (3.042 mg kg^{-1}) was highest in the sediment of St.4 (Fig. 5b). Concentration of metals *viz.,* Cd, Ni and Pb were second-highest in the sediments of St.4 (Fig. 5c). Sediments of St.2 contained the second-highest concentration of Cu and Fe (Fig. 5c and a). Baskaran *et al.* (2002) and Clara and Sugritha (2015) also reported the dominance of metals like Cu, Fe, Pb and Cd in and around 5 km of ash slurry discharge point of the power plant. However, the present work reported comparatively lower values of metals like Cu, Fe, Pb and Cd than those reported by Srikanth *et al*. (2014) and Clara and Sugritha (2015). The clams of St.1 were found to contain the maximum concentration of Cd (37 mg kg^{-1}), Fe (7.58 mg kg^{-1}), Ni (0.064 mg kg^{-1}) and Pb (8.254 mg kg^{-1}). The Mn (3.042 mg kg^{-1}) (Fig. 6a) and Cu (0.366 mg kg^{-1}) (Fig. 6c) concentrations were highest in the clam tissues of St.3. Compared to all other elements, the lead concentration was found to be exceptionally higher in the clam tissues of St.1 (Fig. 6b). The present study reported comparatively lower levels of metals like Cd, Cu, Fe, Mn and Ni in both the sediment and bivalve tissue samples of fly ash-laden dyke of TTPS, as seen in a previous study by Asha *et al.* (2010), which confirmed the lower influence of fly ash in the study area and also confirmed a decrease in the impact of fly ash with an increase in the distance from the dumpsite (Khanra *et al.,* 1998; Clara and Sugritha 2016). Scanning electron microscope (SEM) with energy-dispersive X-ray

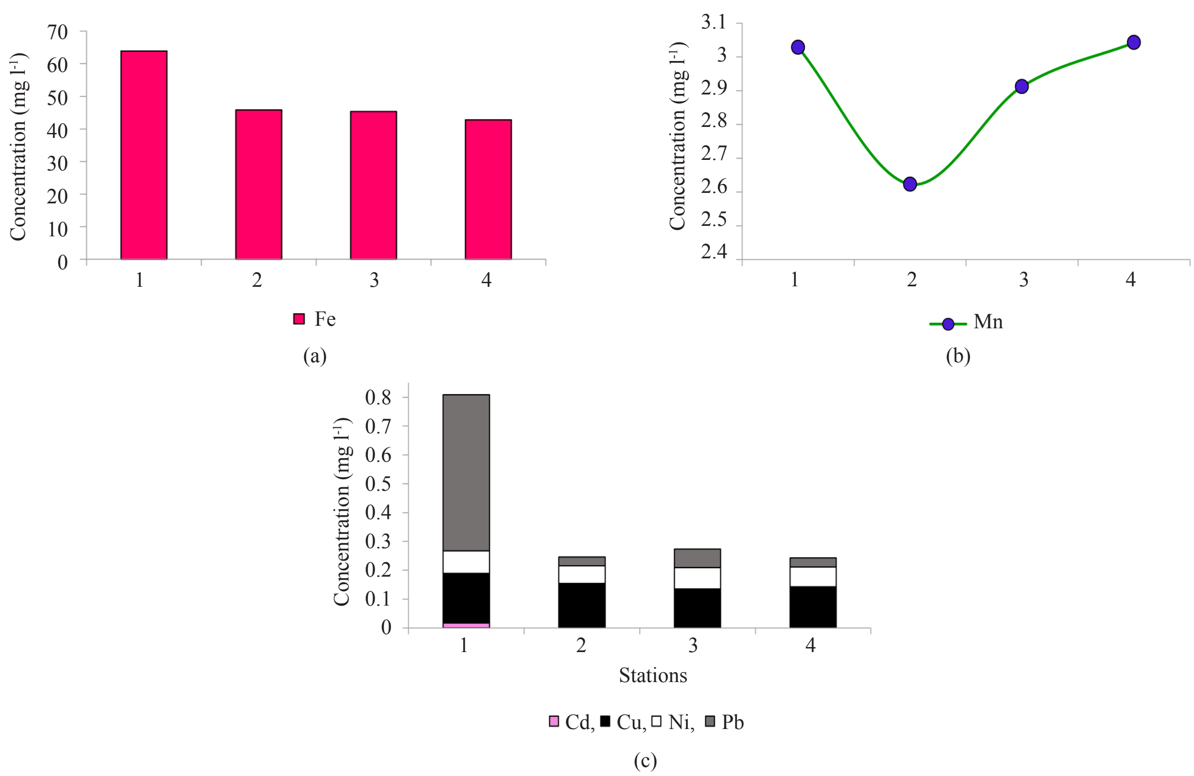

Fig. 5. Variations in the heavy metal concentrations (a) Fe; (b) Mn; (c) Cd, Cu, Ni and Pb, in the sediments at four stations of Tuticorin Bay

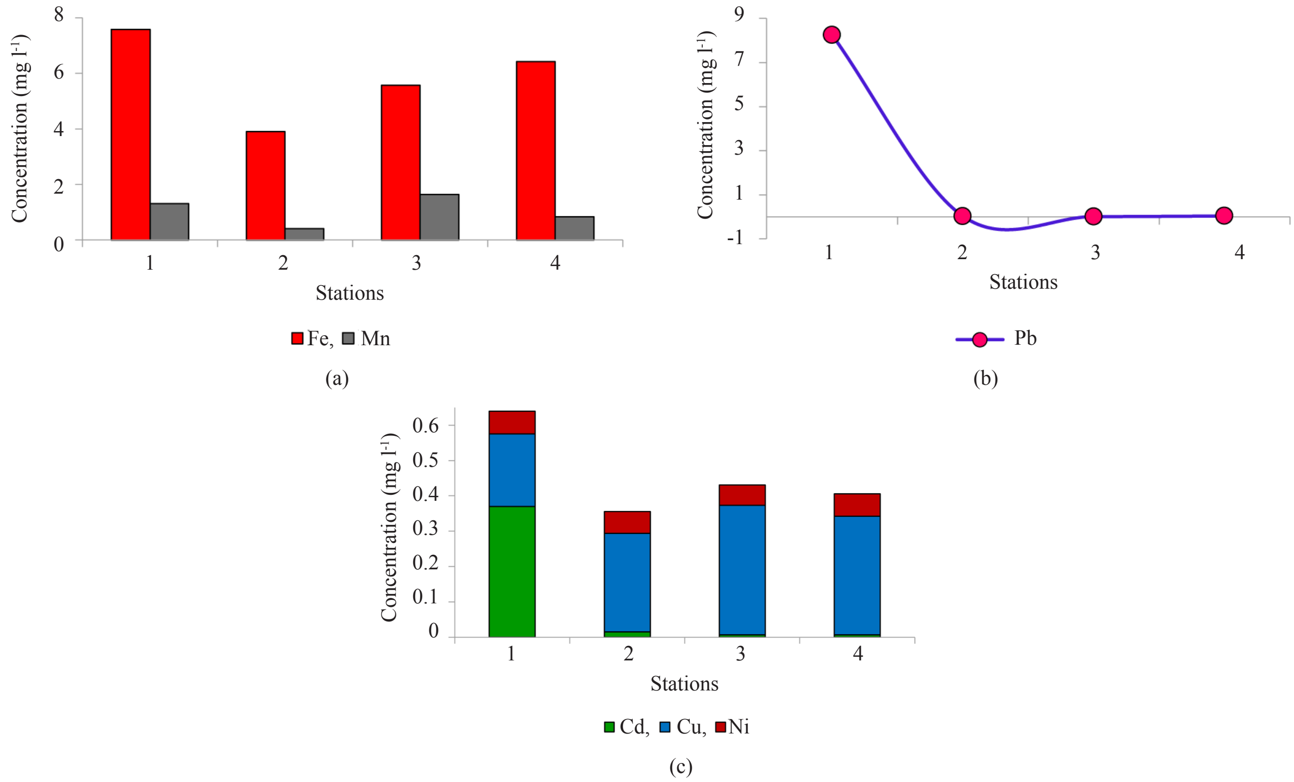

Fig. 6. Variations in the heavy metal concentrations (a) Fe, Mn; (b) Pb; (c) Cd, Cu and Ni in the clam tissues at four stations of Tuticorin Bay

spectroscopy (EDXS) studies by Clara and Sugritha (2013) had indicated that the impact of fly ash was only within a few kilometres surrounding the dumpsite. The heavy metals were found to be accumulated in the order of Fe>Mn> Pb>Cu>Ni>Cd in the sediments and Fe>Pb> Mn>Cu>Cd>Ni within the bivalve tissue samples, which conforms to the earlier findings of Asha *et al.* (2010) in the surrounding areas of TTPS. Except for the concentration of Mn in the bivalve-tissue samples of St.1 and St.3, all the other metals recorded in sediment and clam tissues were found to be below the permissible limit prescribed by European Union countries.

The purpose of the study was to assess the suitability of the bay water for mariculture activities including marine hatchery work of ICAR-CMFRI, Tuticorin Regional Station, since the area of seawater intake point is influenced by both, the effluent discharge from TTPS and the freshwater influx of Koramballam creek. The analysis of different quality parameters from four selected locations of the bay, including the intake area, indicated that neither TTPS nor the Koramballam creek significantly impacted the bay's water and sediment quality conditions. However, a profound seasonal influence from precipitation and condensation phenomena of the monsoon and summer seasons was noticed among stations, as widely reported from various parts of the sea off Tuticorin. No significant difference was detected in the variations in water quality parameters between stations ($p>0.01$). Most of the water quality parameters, especially the seawater temperature, salinity, pH, BOD, ammonia, total N_2 and total PO_4, were within the standard limits prescribed for aquaculture activities (Boyd, 2003; FAO, 2006). Water quality indexing yielded a good quality standard for all the stations, confirming the same trend throughout the bay. Comparatively lower concentrations of toxic metals were noticed in the sediment and bivalves of the bay water at the sampling locations in the study. The estimated levels were also within the permissible limit for most of the metals. This observation confirms the minimal mobilisation of any fly ash constituents and low metal enrichment from the previously dumped fly ash into the current locations. The study thus proved the suitability of Tuticorin Bay for mariculture activities. However, it recommends the need for constant monitoring and the introduction of management strategies and practices for enhancing the bay water acceptability for mariculture purposes.

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References

APHA 2005. *Standard methods for the examination of water and wastewater*. American Public Health Association, Washington DC, USA.

Asha, P. S. 2002. Impact of effluent discharge from Tuticorin thermal power plant, Tuticorin on the hydrological conditions of Tuticorin Bay. *Proceedings of the DAE BRANS National Seminar on Thermal Ecology,* p. 150-156.

Asha, P. S. and Diwakar, K. 2019. Observation on the fishing of polychaete worm in the intertidal region of Tuticorin Bay. *Mar. Fish. Infor. Serv. T&E Ser.*, 235: 14-15.

Asha, P. S., Joshi, K. K. and Diwakar, K. 2009. Incidence of fish mortality in Tuticorin Bay, Gulf of Mannar. *J. Mar. Biol. Ass. India,* 51(2): 173-177.

Asha, P. S., Krishnakumar, P. K., Kaladharan, P., Prema, D., Diwakar, K., Valsala, K. K. and Bhat, G. S. 2010. Heavy metal concentration in seawater, sediment and bivalves off Tuticorin. *J. Mar. Biol. Ass. India*, 52(1): 48-54.

Baskaran, M., Ramadhas, V. and Santhanam, R. 2002. Metal pollution in Tuticorin coastal waters due to fly ash of thermal power plant. *Proceedigns of the National Seminar on Marine and coastal ecosystems. Coral and mangrove - Problems and management strategies*. *SDMRI Res. Publ.,* 2: 190 -193.

Boyd, C. E. 2003. Guidelines for aquaculture effluent management at farm-level. *Aquaculture,* 226: 101-112. doi:10.1016/S0044-8486(03)00471-X.

Clara, J. J. and Sugirtha, P. K. 2013. Study of SEM/EDXS and FTIR for fly ash to determine the chemical changes of ash in marine environment. *Int. J. Sci. Res.,* 5(7): 1688-1692.

Clara, J. J. and Sugirtha, P. K. 2015. Trace metals and environmental impact of fly ash on marine sediment in Tuticorin coastal area, Tuticorin, Tamil Nadu, India. *Res. J. Chem. Sci.,* 5(6): 15-19.

Clara, J. J. and Sugirtha, P. K. 2016a. Chemical changes of fly ash in contact with seawater and their impact on marine environment. *Int. J. Sci. Res.,* 7(7): 12502-12505.

Clara, J. J. and Sugirtha, P. K. 2016b. Evaluation of trace metal concentrations in Tuticorin coastal water near thermal power plant. *Int. J. Sci. Res*., 5(6): 2117-2121.

Dalziel, J. and Baker, C. 1984. Analytical methods for measuring metals by atomic absorption spectrophotometry. *FAO Fisheries Technical Paper 212*, Food and Agriculture Organisation of the United Nations, Rome, Italy, p. 14-20.

Dickson, A. G. 1998. Reference materials for oceanic carbon dioxide measurement. *CDIAC Communication,* 25: 1-16.

Dwivedi, S., Srivastava, S., Mishra, S., Dixit, B., Kumar, A. and Tripathi, R. D. 2007. Screening of native plants and algae growing on fly ash affected areas near National Thermal Power Corporation, Tanda, Uttar Pradesh for accumulation of toxic heavy metals. *J. Hazard. Mater.,* 158: 359-365. doi: 10.1016/j.jhazmat.2008.01.081.

Easterson, D. C. V., Asha, P. S. and Selvaraj, M. 2000. Effect of thermal power plant effluents on hydrobiological conditions in the Tuticorin Bay. *J. Mar. Bio. Ass. India,* 42(1&2): 135-138.

FAO 2006. State of world aquaculture 2006. *FAO Fisheries Technical paper 500.* Food and Agriculture Organisation of the United Nations, Rome, Italy,

Ganesan, M. and Kannan, L. 1995. Iron and manganese concentrations in seawater, sediment and marine algae of Tuticorin coast, south-east coast of India. *Indian J. Mar. Sci*., 24: 236-237.

Grasshoff, K. 1983. Determination of salinity. In: Grasshoff, K., Elxhardt, M. and Kremling, K. (Eds.), *Methods of seawater analysis,* 3rd edn. Wiley-WCH, Weinheim, Germany, 634 pp.

Kailasam, M. and Sivakami, S. 2004. The effect of thermal effluent discharge on benthic fauna of Tuticorin Bay. *Indian J. Mar. Sci*., 25: 371-372.

Khanra, S. Mallick, Dutta, S. N. and Chaudhari, S. K. 1998. Studies on the phase mineralogy and leaching characteristics of coal fly ash. *Water Air Soil Pollut*., 107: 251.

Kripa, V., Chinnadurai, S., Padmanathan, Aathipandian, Sadhakatullah and Mohan Raj 2012. Restoration and natural revival of clam populations at Tuticorin Bay, Tamil Nadu after a mass mortality incident. *Mar. Fish. Infor. Serv. T & E Ser*., 211: 3-4.

Lewis, D. W. 1984. *Practical sedimentology*. Hutchinson Ross Publishing Company, UK, 229 pp.

Mohamed, G. 1998. *Studies on the effects of thermal effluents on the physiology of selected seaweeds*. Ph. D. Thesis, Cochin University of Science and Technology, Kochi, India.

Palanichamy, S. and Rajendran, A. 2000. Heavy metal concentrations in seawater and sediments of Gulf of Mannar and Palk Bay, Southeast coast of India. *Indian J. Mar. Sci*., 29: 116-119.

Parson, T., Maita, Y. and Lalli, C. A. 1984. *Manual of chemical and biological methods for seawater analysis.* Pergamon Press, New York, USA, 184 pp.

Rajarshi, C. and Anita, M. 2009. Mutagenicity and genotoxicity of coal fly ash water leachate. *Ecotoxicol. Environ. Saf*., 72: 838-842. doi: 10.1016/j.ecoenv.2008.09.023.

Selvin, P. J., Ananthan, G. and Sudhakar, M. 2010. Studies on the effect of coolant water effluent of Tuticorin Thermal Power Station on hydrobiological characteristics of Tuticorin coastal waters, south east coast of India. *Curr. Res. J. Biol. Sci.,* 2(2): 118-123.

Shelarpiyusha, S., Padmavathy, P., Srinivasan, A. and Karal Marx, K. 2017. Effect of thermal power plant effluent on the physico-chemical parameters of Thoothukudi coastal waters, South India. *Indian J. Fish.,* 64(Special Issue): 243-248.

Solarzano, L. 1969. Determination of ammonia in natural waters by the phenol hypochlorite method. *Limnol. Oceanogr.*, 14: 799-801. https://doi.org/10.4319/lo.1969.14.5.0799.

Srikanth, K. and Ahmad, Rao, J. V. 2014. Seasonal trend of potential toxic elements in seawater and sediments from Tuticorin coast. *Water Air Soil Pollut*., 225: 2069.

Strickland, J. D. H. and Parsons, T. R. 1972. A practical handbook of seawater analysis. *Fish. Res. Board Can. Bull.,* 167: 311.

Tripathi, R. D., Vajpayee, P., Singh, N., Rai, U. N., Kumar, A., Ali, M. B., Kumar, B. and Yunus, M. 2002. Efficacy of various amendments for amelioration of fly ash toxicity growth performance and metal composition of *Cassia siamea* Lamk. *Chemosphere*, 54: 1581-1588. DOI:10.1016/j.chemosphere.2003.09.043.

Walkley, A. and Black, T. A. 1934. An experimentation of the vegetative method for determining organic matter and proposed modification of chromic acid titration method. *Soil Sci.,* 37: 38-39.

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