

Marine ecological habitat: A case study on projected thermal power plant around Dharamtar creek, India

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Abstract

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Estuaries and tidal creeks, harboring mangroves particularly, face tremendous anthropogenic pressures. Expansion of mega cities and the thermal power plants are generally proposed in the vicinity of estuaries and creek, due to the feasibility of intake and discharge of water for cooling. Discharges from such developments remain constant threat of increasing thermal pollution and affecting the quality of environment. The baseline information on prevailing quality of aquatic environment comes handy for understanding alterations due to such activities. Principle component analysis (PCA) revealed that temperature, pH, salinity, suspended solids, DO, BOD and phaeophytins are major parameters influencing the creek system. Heated effluents may have direct and adverse impacts on these parameters, altering biotic constituents. Hence, periodic and detailed observations are necessary to estimate exact response of biotic communities to changing environment. The present paper is based on case study, projecting a power plant in the vicinity of major mangrove habitats of Dharamtar creek

Key words

Case study, Marine habitat, Thermal pollution, Mangroves, Dharamtar creek, PCA

Introduction

Marine backwaters including creeks and estuaries have long been over exploited and ill-treated for disposal of domestic, agricultural and industrial wastes. These water bodies possess capacity of self-purification through diurnal tidal cycle and constant ecological interactions. However, excessive and growing industrialization and urbanization in their vicinity remain a constant threat, degrading habitats of ecological and socio-economic values. The tidal influenced water bodies, particularly, close to mega-cities reported to be beyond their carrying capacity (Kulkarni *et al.*, 2009).

Thermal pollution, one of the major byproduct of modern industries, especially of power plants forms a major ecological concern. Thermal discharges cause significant caefaction of water bodies (Kennish, 1992), affecting biological communities by inducing sublethal damage, adversely impacting regeneration process in native biota (Efimova, 1977; Langford, 1990; Thorhaug *et al.*, 1973), and often altering primary and secondary production (Dell and Swatzman, 1984; Hoffmeyer *et al.*, 2005; Kennish, 1998). Chlorine used in coastal power plants as antifouling agents of condenser tubes affect non target organisms (Fox and Moyer, 1975; Hall *et al.*, 1979).

Numerous fish and macro-invertebrates get impinge on intake water screening devices of power plants, culminating in sizable mortalities (Schubel *et al.*, 1977).

Estuaries and tidal creeks harboring mangrove habitats in the tropics, particularly from India, face tremendous anthropogenic pressures. Development of twin Mumbai city (Maharashtra) has proposed to the southeast of Mumbai. It demands a great amount of electricity and hence, a number of additional thermal power plants too. Generally, such developments are proposed on the banks of estuaries and creeks for convenience of intake and discharge of water.

The baseline data on prevailing quality of environment form the basis for understanding impacts of a particular anthropogenic stress. Mangrove dominated Dharamtar creek targeted for various developments, was evaluated for its biological and relevant environmental characteristics, and likely impacts of thermal power plant. Data discussed would help in understanding ecological changes and formulation of effective management strategies for ecologically sensitive marine habitats.

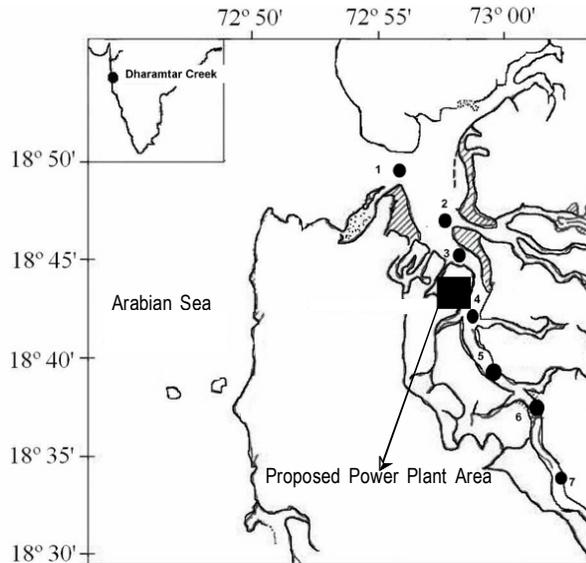


Fig. 1: Map of the study area

Materials and Methods

Study area: Dharamtar creek falls within 18°48' N 72°58' E to 18° 41' N 73°01' E, along the central west coast of India (Fig. 1). It is ~8 km wide and 9-10 m deep near its mouth measuring ~32 km. Main channel remains 1 km wide and accessible by small boats during high tide. Creek substantially crisscrossed with many sub-creeks and channels, sustaining luxuriant growth of mangroves in mid intertidal zone.

Atmospheric temperature varies from 12-38°C with minimum and maximum in the month of January and May, respectively (IMD, 2007). Humidity ranges from 65-85% with average rainfall is of 2200 mm of which 90% occurs during July and August (monsoon). Tidal fluctuation in the creek ranges from 0.1-4.0 m (Anon, 2006).

Projected 4000 MW power plant comprised of 2800 MW gas based and 1200 MW coal based thermal power plant, may require ~9.11 km² of area which could be acquired by reclaiming agricultural land. The plant may utilize 177000 m³ of fresh water day⁻¹, out of which 20,000 m³ day⁻¹ will be released at suitable point in creek. Fresh water will be supplied through a dam situated ~20 km away from plant. Heated effluent may carry 900 mg l⁻¹ of total dissolved solids and 100 mg l⁻¹ of suspended solids.

Table - 1: Mangrove community structure from Dharamtar creek

Station	Dominant species	%FO	H	DBH	SD
1	<i>A. marina</i>	100	0.5 – 1	< 2.5	900 - 1200
2	<i>A. marina</i> , <i>A. alba</i>	100	0.5 – 1	< 2.5	900 - 1400
3	<i>A. marina</i> , <i>A. alba</i>	80	1.5 – 2	3 – 8	200 – 250
4	<i>A. alba</i> , <i>S. apetala</i>	80	2.5 – 3	10 – 15	30 – 65
5	<i>A. alba</i> , <i>S. apetala</i>	70	2.5 – 3	10 – 15	40 – 150
6	<i>S. apetala</i>	66.66	4 – 5	25 – 35	20 – 35
7	<i>S. apetala</i> , <i>E. agallocha</i>	60.33	3 – 3.5	25 – 30	35 – 60

FO= Frequency occurrence, H= Height (m), DBH= Diameter at breast height (cm), SD= Seedling density (no m⁻²)

Mangrove evaluation: Fixed transects of width ~50 m were laid down from low tide level to high tide mark, perpendicular to the shore, at stations 1-7 (Fig. 1). The length of transect varied from ~ 50 to 1500 m at different stations. Mangroves were evaluated for their community structures (area, distribution, density, height, DBH, species composition, % frequency etc.) at each station by standard line transect and quadrant method (DOD, 1998).

Data on hydrological and biological (phytoplankton, zooplankton and benthos) properties of creek were obtained from earlier reports (Anon, 2009).

Statistical analysis: Mangrove community structures were assessed by estimating Margalef's, Shannon's and Simpson's indices and Evenness (Clarke and Warwick, 2001). Abundance Biomass Comparison (ABC) method was applied for the detection of disturbances in zooplankton and benthos populations (Lambshed et al., 1983; Warwick, 1986). Draftsman plot was constructed to assess correlation between phytoplankton, zooplankton and benthos abundances and zooplankton and benthos biomasses. Principle Component Analysis (PCA) was performed to identify and assess the sources affecting water quality. The main concern of PCA was to understand the mode of action of ecosystem components (Peterson et al., 2001; Bangraine and Marhaba, 2003). The statistica 6.0 software have been used for box whisker plots and PCA, while primer 6.0 software have been used for diversity indices, Draftsman plot and ABC curve method.

Results and Discussion

Hydrological properties: Box and Whisker plots were examined for nine water quality parameters during three seasons (Fig. 2), to assess temporal variations in water quality.

Biological parameters: Mangroves occurred in fringes as well as in large patches, along Dharamtar creek. The large patches of *Avicenia marina* (% FO > 90) in the downstream intertidal zones, though dense, were observed to be dwarf (0.5-1 m), particularly along west bank creek (Table 1). However, *A. alba* was the most dominant (% FO = 80) along the east bank. In general, taller mangroves occurred from the seaward to the upstream region along the east bank, while, the west bank sustained mainly dwarf *A. marina* formations. The *Sonneratia apetala* was observed to be more common and taller in the downstream region, indicating more freshwater influence.

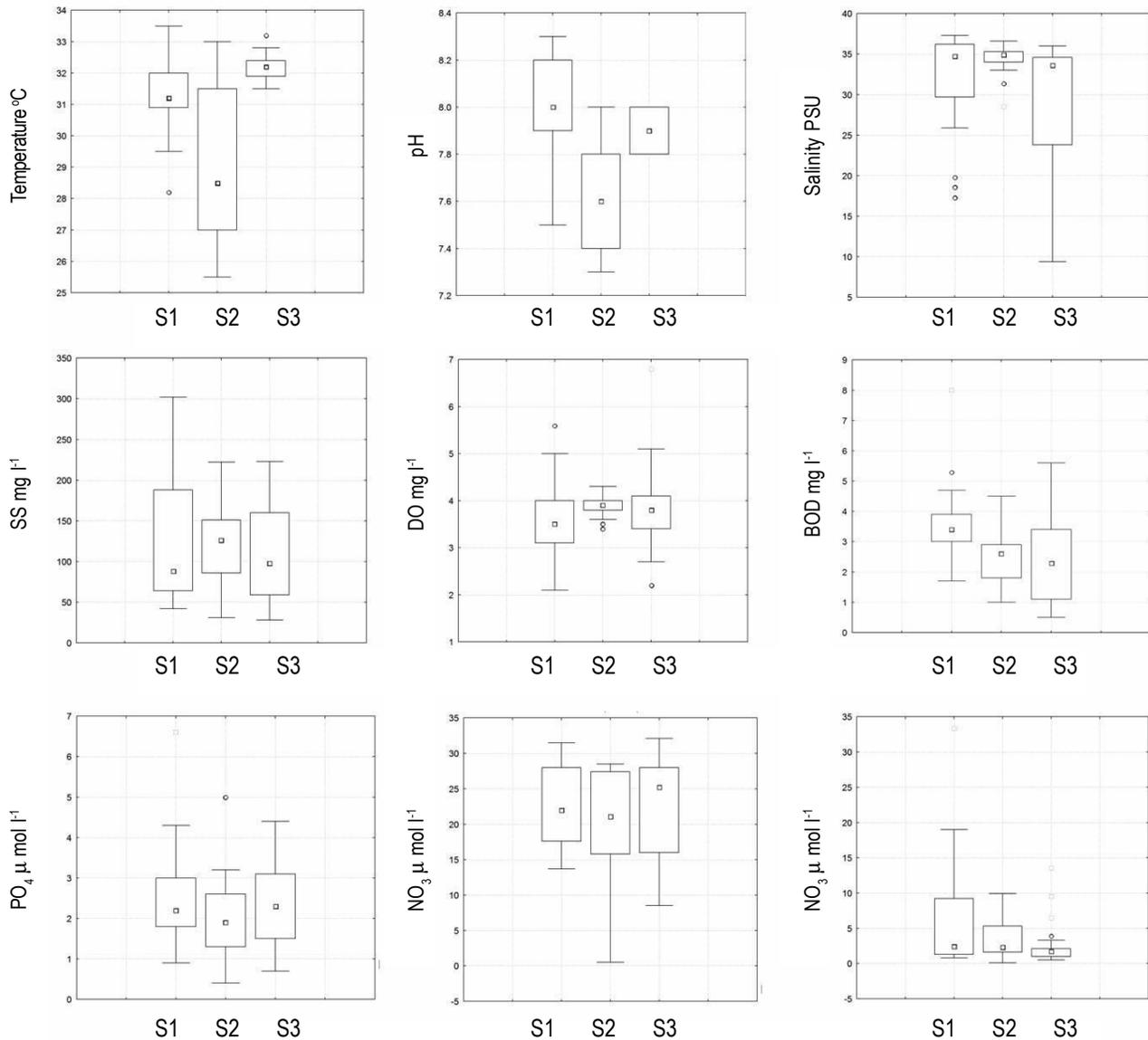


Fig. 2: Temporal variations in water quality S1 (Premonsoon), S2 (Monsoon) and S3 (Postmonsoon)

Phytoplankton exhibited maximum population in post monsoon season ($52.9-64.8 \text{ no} \times 10^3 \text{ l}^{-1}$) with dominance of *Pleurosigma angulatum* and *Biddulphia sinensis* (Table 2). While, *Skeletonema*, *Nitzschia* and *Thalassiosira* were dominant in monsoon, however, abundance was minimum ($4.2-18.6 \text{ no} \times 10^3 \text{ l}^{-1}$).

Zooplankton population exhibited maximum density during post monsoon season ($281-554 \text{ no} \text{ m}^{-3}$), though, only Copepods and Chaetognaths were dominant round the year (Table 2). Macrobenthos population varied in the range of $375-1425 \text{ no} \text{ m}^{-2}$, while, Polychaetes and Crustaceans were observed to be dominant (Table 2).

Diversity indices, ABC method and draftsman plot: Shannon index value (H') indicated poor diversity among mangroves and zooplankton, since the value lied below one (Table 3), whereas diversity of benthos was fair with index value 1.08. Phytoplankton

exhibited very good diversity as the index value was greater than two. Similarly Simpson index values of mangroves, zooplankton and benthos were very low, indicating poor diversity. Phytoplankton ($J' = 0.8067$) very good diversity. Margalef index value of mangroves was observed to be 0.7625, while that of phytoplankton; zooplankton and benthos were 6.32, 2.451 and 3.438, respectively. However, Evenness values (J') of all four parameters were less than one hence no even distribution of species was observed within any parameter. In the ABC method of zooplankton and benthos, biomass curves were observed below the abundance curves (Fig. 3). Draftsman plot of five biological variables (Fig. 4) exhibited right skewness between zooplankton biomass with benthos population and benthos biomass. For rest of the parameters, log transformation of data was found to be inappropriate, since no co-linearity was observed between any parameter.

Table - 2: Biotic parameters associated with mangrove habitats from Dharamtar creek (Source: Anon, 2009)

Parameters		Pre-monsoon	Monsoon	Post-monsoon
Phytoplankton	Abundance (no x 10 ³ l ⁻¹)	30.8-51.5	4.2-18.6	52.9-64.8
	Dominant Species	<i>Skeletonema costatum</i> <i>Thalassiosira nitzscoides</i>	<i>Skeletonema costatum</i> , <i>Nitzschia longissima</i>	<i>Pleurosigma angulatum</i> <i>Biddulphia sinensis</i>
Zooplankton	Abundance (nox10 ³ 100 m ⁻³)	24.4-44.3	3.1-49.5	28.1-55.4
	Dominant Group	Copepods, Chaetognaths, Decapod larvae	Copepods, Lucifer, Chaetognaths	Copepods, Medusae, Chaetognaths
Benthos	Abundance (no m ²)	500-1425	375-575	425-1175
	Dominant Group	Polychaetes, Crustaceans	Polychaetes, Molluscs	Polychaetes, Crustaceans

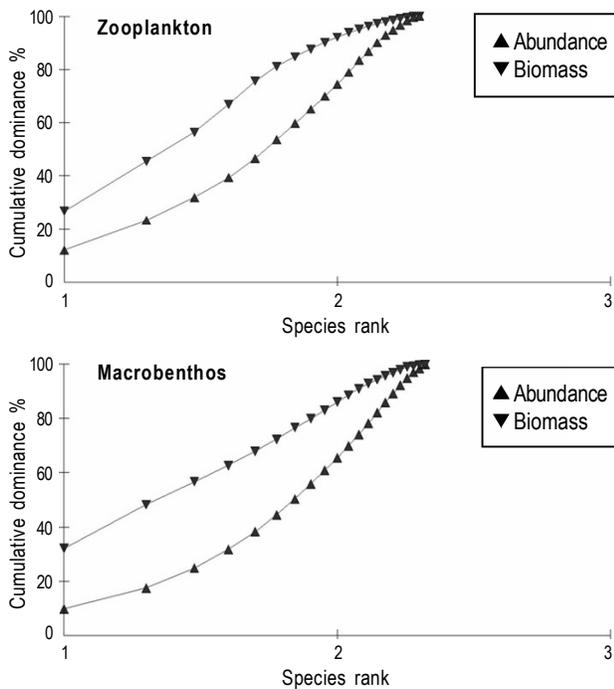


Fig. 3: ABC curves for detection in disturbance of zooplankton and benthos

Principal component analysis (PCA): Analysis on 14 parameters yielded five Principle Components (PCs) explaining sample variance of ~68% (Table 4). The first PC (Score 1) that explains ~21% of total variance has significant loadings (>0.4) on pH and petroleum hydrocarbons (Fig. 5). High loadings on petroleum hydrocarbons could be due to intensive navigation activities in the creek. The second PC revealed that 18% of total variance correlates to salinity and phenolic compounds. Higher salinity in upstream regions during pre-monsoon season (February-May) is attributed to the reduced freshwater inflow. Within the part of variance described by third PC, suspended solids and PO₄ have an opposite significance in comparison with NO₃. The fourth PC found to be negatively correlated with pH and phaeophytin with positive loadings on temperature, dissolved oxygen and NO₃. Significant negative loadings were

exhibited in fifth PC on BOD and phaeophytin, mainly due to heavy water turbulence during monsoon season.

Dharamtar creek harboring healthy mangrove ecosystem, is likely to be under intensive anthropogenic pressures as the region is identified for various developments in near future. It is being developed as a twin megacity of Mumbai, would demand a number of additional power plants. The projected power plant in the present investigation would discharge 20000 m³ day⁻¹ of heated effluent in the creek, leading to adverse impacts on prevailing hydrological and biological features of creek system. Moreover, the relevant infrastructure developments may require reclamation of ~0.11 km² of existing mangrove area, particularly along the criss – cross network of water, as well as loss of potential flats for mangrove regeneration.

Creek biota such as phytoplankton, zooplankton and macrobenthos exhibited healthy abundance; however, Shannon and Margalef indices as well as evenness values indicated very poor diversity (Margalef, 1972). ABC plots of zooplankton and benthos perceived that habitat is non polluted (Lambshed et al., 1983), since biomass curve rested above abundance curve for both parameters (Fig. 3). However, Draftsman plot revealed that no correlation exist between any biotic parameter (Fig. 4), indicating high vulnerability of creek environment (Clarke and Einworth, 1993; Saintilan, 2004). Hence, mangrove habitat in the creek region though appears to be healthy, any sudden and drastic changes in ambience may lead to adverse and irreversible impacts on mangrove habitats, altering native and endemic biota.

The PCA revealed that temperature, pH, salinity, suspended solids, dissolved oxygen, BOD and phaeophytins are major parameters influencing the water body (Fig. 6), particularly in the downstream region where heated discharge will adversely impact, altering temperature, salinity and suspended solid regime of the creek. Increased temperature of water would consequently result in decreased DO and increased BOD and pH (Majewski and Miller, 1979).

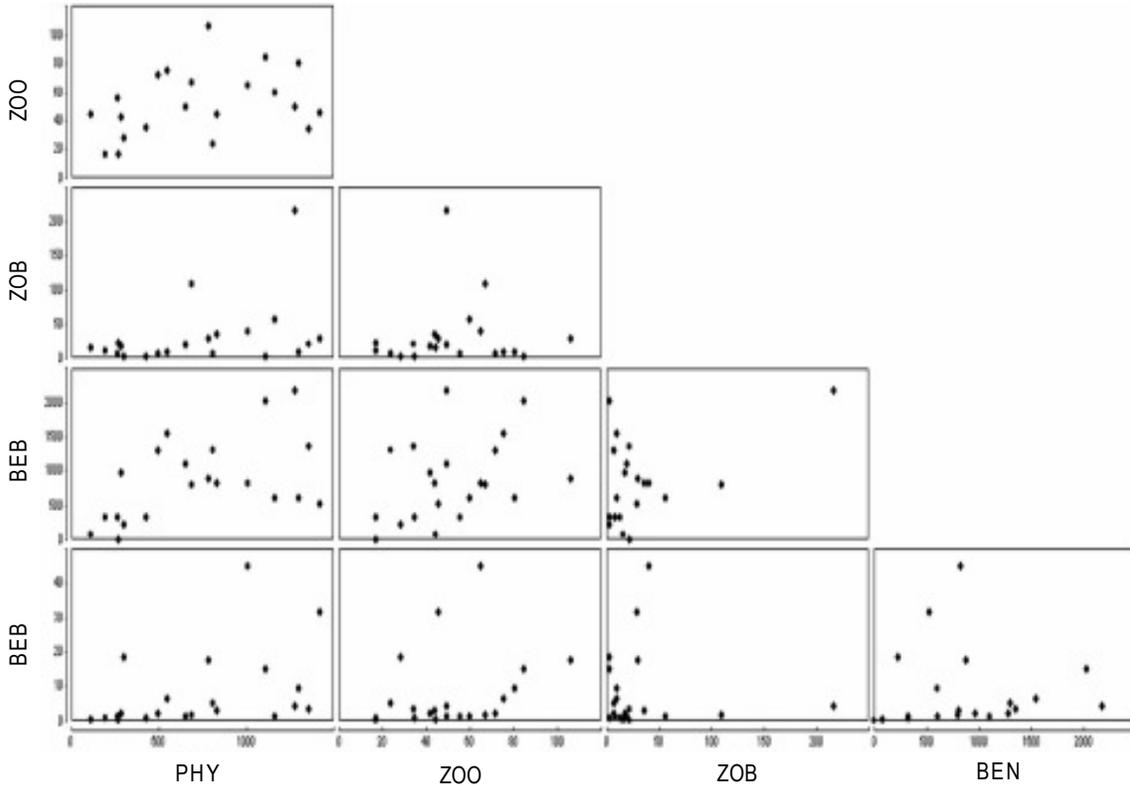


Fig. 4: Draftsman plot to assess abundance and biomass.

PHY= Phytoplankton abundance, ZOO = Zooplankton abundance, BEN = Benthos abundance, ZOB = Zooplankton biomass, BEB = Benthos biomass

Table - 3: Diversity indices of biological parameters from dharamtar creek

Parameters	Species richness (S)	Margalef's index (d)	Shannon index (H')	Evenness (J')	Simpson's index
Mangroves	8	0.7625	0.9225	0.5148	0.3072
Phytoplankton	29	6.32	2.148	0.638	0.8067
Zooplankton	13	2.451	0.988	0.3852	0.4277
Benthos	17	3.438	1.08	0.3812	0.4141

Table - 4: Eigenvalues and percentage of variance explained by principal components analysis

PC	Eigenvalues	% Variation	Cumulative % Variation
1	2.92	20.8	20.8
2	2.60	18.5	39.4
3	1.50	10.7	50.1
4	1.31	9.3	59.4
5	1.22	8.7	68.1

The ambience around close vicinity of the discharge may exhibit sharp decrease in overall zooplankton abundance due to the raised temperature. Experimental data revealed that temperature affects the grazing of zooplankton (Capuzzo, 1980). Total mortality values of zooplankton were observed to be four times higher at water discharge site than the intake (Hoffmeyer *et al.*, 2005).

Thermal discharge may result into the disturbance in physicochemical constituents of water body, affecting species composition. Phytoplankton and other marine macrophytes may show increase in vegetation period and cell size, consequently resulting in

increased productivity (Beznosov and Suzdaleva, 2004). It would also cause destruction of *Porteresia* beds (pioneer for mangrove formation) and show diminished photosynthesis in mangroves (Lacerda, 2002; Tomlinson, 1995).

Similarly, temperature change will affect spawning period of benthic macrofauna. Benthic organisms being sedentary animals associated with sediment bed provide an understanding of integrated effects of stress, and hence serve as good bioindicators of early warning of potential damage (Grey *et al.*, 1990).

The wastewater inflow and tidal exchange modulates the salinity regime of marine aquatic environments. Phytoplankton assemblages will be significantly altered if salinity fluctuates in the range of 2-6 PSU, indicating major change in chlorophyll contents and phytoplankton diversity (Ahel *et al.*, 1996). Mangrove flora may show transition with respect to change in water salinity (Montague and Ley, 1993). It has been observed that tree species are more vulnerable to climatic changes than shrubs and herbs (Pandey, 1983). It is therefore, tree species of high salinity tolerance such as

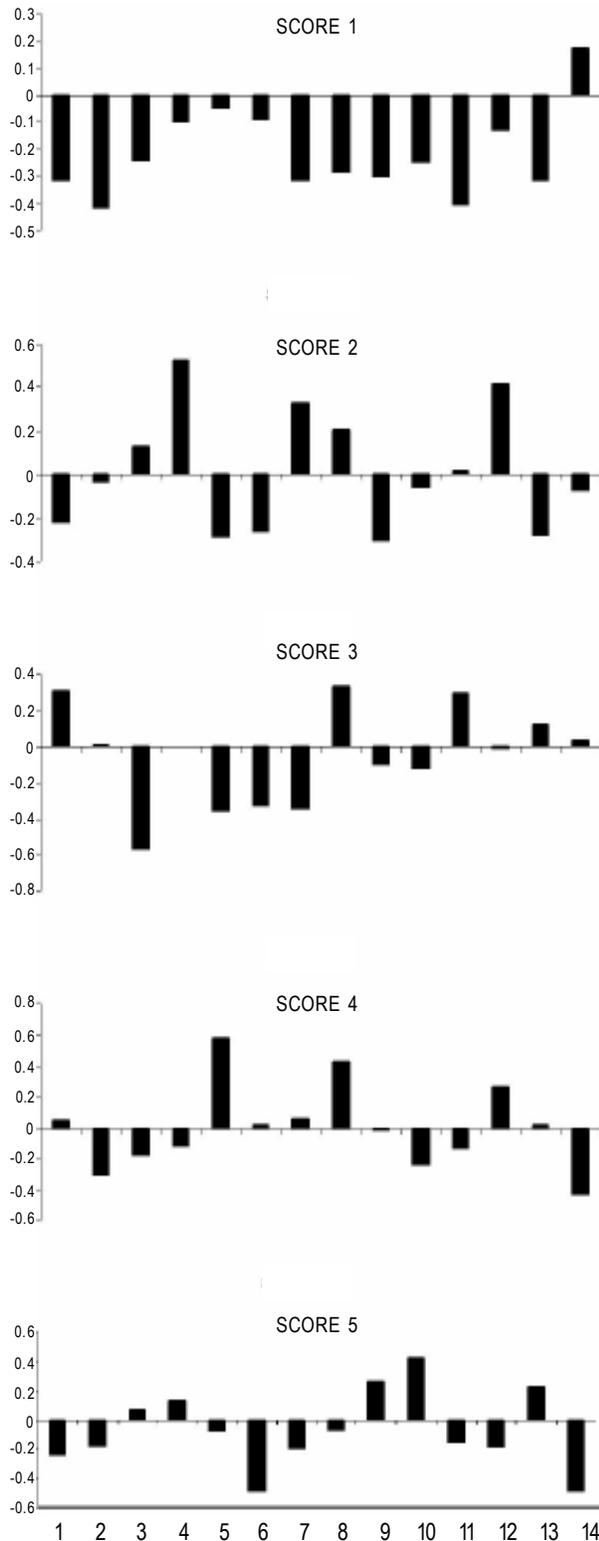


Fig. 5: Factor loadings from PCA on 14 water quality parameters from Dharamtar creek

1: Temperature, 2: pH, 3: Suspended solids, 4: Salinity, 5: DO, 6: BOD, 7: PO_4 , 8: NO_3 , 9: NO_2 , 10: NH_4 , 11: PHc, 12: Phenols, 13: chl-a, 14: Phaeo-pigments

A. marina may get replaced by less salt tolerant forms like *A. officinalis* or *S. alba*. Mangrove fern, *Achrostichum aureum*, which is generally found in upstream zones of low salinity, might invade the downstream zone.

A number of industrial plants are operational in the study region and are likely to expand by many folds in the near future, generating adequate amount of energy and employment. However, raising power plants exert major stress on estuarine habitat including mangroves and agricultural land. Long term utilization of colossal quantity of fresh water and reclamation of agricultural land may lead to water and food crisis. Depending upon the nature and intensity of utilization of fresh water and thermal effluents, the ecosystem may either reestablish the previous equilibrium or establish a new one, or it may remain in prolonged disequilibrium. In view of the above, periodic observations are necessary to estimate exact response of biotic communities to changing salinity, suspended load and temperature, enabling retaining better quality of creek and associated mangrove habitats.

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