

## BIOLOGICAL AND ENVIRONMENTAL CHARACTERISTICS OF MANGROVE HABITATS FROM MANORI CREEK, WEST COAST, INDIA

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### ABSTRACT

Mumbai, a megacity of India and its adjacent marine environment, though heavily stressed from various anthropogenic interferences, harbors ~146 km<sup>2</sup> of mangrove cover. Manori creek, in the close vicinity of Mumbai, sustains relatively better mangrove formations. A Creek habitat had been evaluated for its biological and environmental characteristics, and is compared with similar but relatively lesser stressed Mandovi estuary (~ 475 km south of Mumbai). Several evidences of deteriorating environment of Manori creek have been described with respect to Water Quality Index and various biotic community structures. Water Quality Index of < 55 indicated unacceptable aquatic conditions of Manori creek. Dominance of *A. marina* and poor abundance and diversity of mangrove and associated biological features indicate highly stressed environment. Dominance of stress tolerant phytoplankton spp. such as *Skeletonema costatum* and benthic fauna such as Polychaeta further supported the view. The data presented in the present document would help in developing rational approach towards conservation, protection and sustainable development of mangrove dominated creek and estuarine wetlands.

**Key Words:** Mangroves; Community Structure; Environment; Creek; Estuary; Management.

## INTRODUCTION

Mangroves, predominant habitats in the tropics have been reported to be of immense ecological and socioeconomic values, and hence categorized under ecologically sensitive zones. Central West Coast (CWC) of India sustains relatively better mangrove formation, measuring ~235 km<sup>2</sup> of mangrove area (Jagtap et al. 1994). The Mumbai and adjacent marine environment, though intensely polluted and heavily pressurized from various anthropogenic interference, harbors > 60% out of total mangrove cover along the CWC (Jagtap et al. 1994).

Manori creek, though one of the highly stressed creek sustain better mangrove formations in close vicinity of Mumbai (Anon 2007). However, it is intensively targeted for dumping garbage and disposal of sewage as well as over exploited for salt industries, fishing, navigation and recreational activities. A large number of developments are also proposed in the vicinity, raise constant threat to creek habitat. Considering the deteriorating environmental conditions in and around, it is necessary to account for natural habitats while planning development. In view of the above, the Manori creek was evaluated for its biological communities and ambient environment. The similar data from Mandovi estuary of Goa (~ 475 km south of Manori creek), which is relatively subjected to less pollution and anthropogenic pressures (Anon 2004), have been compared with the prevailing environment of Manori by adopting standard methods which were essential to built baseline data for understanding prevailing quality of environment and monitoring changes in future.

Several evidences have been discussed of deterioration of marine habitats influenced by Manori creek, with respect to physicochemical properties, collectively grouped as Water Quality Index (WQI), diversity indices of mangrove community, species diversity of phytoplankton composition, different aspects of zooplankton and macrobenthic community structure (diversity and abundance of major taxa). In view of the fact that development is an ever continuing process, deteriorating the prevailing environment, the data presented in the present document could certainly be of a great use in developing rational approach to management strategies, in conservation, protection and sustainable development of mangrove dominated habitat.

### Description of study area:

The Manori creek lies between 19° 11'N 72° 47'E and 19° 15'N 72° 50'E and runs for ~ 10.6 km in the state of Maharashtra (Fig. 1). The seaward channel of creek, ~1 km wide and shallow (0.8 to 4m) is substantially connected with many narrow criss-cross channels towards midstream and upstream zone of creek which sustain luxuriant growth of mangroves.

Climate of the region remains equable (IMD 2007) with atmospheric temperature varying from 19° to 33° C with minimum and maximum in January and May, respectively. Average humidity ranges between 75 – 89%, with peak values during June to September. Average rainfall of 2470 mm has been estimated of which 90% occurs during the monsoon (July and August). The tidal column fluctuates in the range of 0.32 m to 5.10 m (Anon 2006). During last three decades the particular region is heavily pressurized from various anthropogenic activities degrading and constantly increasing stress on the environment (Khadilkar 1989; Anon 1989 and Anon 2000).

## **METHODOLOGY**

### **Sampling:**

Three stations MC1 (19° 11'59'' N, 72° 47'44'' E), MC2 (19° 13'44'' N, 72° 48'57'' E) and MC3 (19° 14'38'' N, 72° 49'17'' E) were selected for biological and hydrological samplings across salinity gradient of manori creek (Figure 1). The geographical coordinates were determined using Garmin 12 GPS. Fixed transects of width ~50m were laid down from mid channel up to high tide mark, perpendicular to the shore, at each station. Biological samplings and observations were carried out seasonally during premonsoon (February – May), monsoon (June – September) and postmonsoon (October – January) periods of 2007, along these transects as described below.

### **Biological Characteristics:**

Mangroves were evaluated for their community structures (distribution, density, height, DBH, species composition, % frequency etc) at each station by standard line transect and quadrant method (DOD 1998). Ten quadrants of 100 m<sup>2</sup> at the intervals of ~ 50 – 150 m were laid down along each transect randomly, from mid tide to high tide mark. Bottom water samples were collected for phytoplankton from mid channel at each station using Niskin water sampler with closing mechanism, while surface

water samples were collected with bucket. Samples immediately after collection were fixed in Lugol's Iodine solution and stored. Cells counts were made using Sedgewick Rafter and total abundance was estimated as number of cells  $l^{-1}$ .

Zooplankton samples were collected using a Heron Tranter net (mesh size 0.3 mm; mouth area  $0.25 m^2$ ) with an attached flow meter (DOD 1998). An oblique haul of 5 min duration was taken from all stations at the speed of  $2 km hr^{-1}$ . Samples immediately after collection were preserved in 5% buffered formaldehyde. Total population was estimated as number  $m^{-3}$  volume.

Sediments from subtidal (mid channel) and intertidal (low tide, mid tide and high tide levels) were collected with Van veen grab (area  $0.05 m^2$ ) and quadrant (area  $0.01 m^2$ ), respectively. Sediments were sieved through 0.5 mm sieve and residues obtained were preserved in 5% buffered Rose Bengal formalin. Residues were sorted for benthic fauna and total population was estimated as number  $m^{-2}$  area. All samples of phytoplankton, zooplankton and macrobenthos were collected in triplicates on each sampling.

### **Statistical Analysis:**

Water quality indices (WQI) of Manori and Mandovi were derived from standard formula (CCME 2003).

Mangrove community structures were assessed by estimating Simpson's and Shannon's indices,  $e^H$  and Evenness (Clarke and Warwick 2001). Kolmogorov – Smirnov test was carried out to determine goodness of fit (Cartner et al. 1981). Phytoplankton, zooplankton and macrobenthos data were analyzed to estimate correlation among them.

Species diversity of phytoplankton and number of zooplankton and macrobenthos taxa were subjected to analysis of variance. Two Way ANOVA (Station X Season) was performed for phytoplankton and zooplankton.

## **RESULTS**

Mangroves were confined to the mid and upper intertidal belt varying from ~ 50 – 1500 m and mostly were of dwarf nature, dominated by *Avicennia marina* (Table 1). Phytoplankton population ranged from  $0.026 - 0.066 \times 10^5 l^{-1}$  with, *Thalassionema nitzschioides*, *Skeletonema costatum* and *Thallasiosira*

*eccentrica* as dominant species (Table 2). The zooplankton were dominated by Copepoda, Amphipoda, Gastropoda and Polychaeta and density ranged from 17.83 – 82.27 no m<sup>-3</sup> (Table 2). Polychaeta (184 – 904 no m<sup>-2</sup>) dominated the macrobenthos community.

#### Statistical Analysis:

The WQI is widely used for monitoring water quality from different aquatic habitats (House and Ellis 1987). It is determined based on various parameters like dissolved oxygen (DO), biological oxygen demand (BOD), pH, water temperature, total phosphate, nitrate, turbidity, total solids and fecal coliforms. Manori creek exhibited WQI to be 53.51 while it was 76.13 for Mandovi estuary (Table 3).

Shannon's indices derived from mangrove data pertaining to Manori and Mandovi were found to be 0.9225 and 2.1697, respectively (Table 3). Simpson's index calculated from Manori was found to be 0.5465. While that of Mandovi was 0.8629.

The Kolmogorov – Smirnov test quantifies the distance between empirical distribution function of the two samples. This test is one of the most useful and a general nonparametric method for comparing two samples, as it is sensitive to differences in locations of the two samples. Test was performed considering null hypothesis (Phoenix 1997).

$D_{crit}$  value obtained by the formula:

$D_{crit}: K \propto \sqrt{(N_1+N_2) / N_1N_2}$  (Table 4).

Where:  $\propto = 0.05$  and  $0.01$ . Therefore  $D_{crit} (0.05) = 1.3581$  and  $D_{crit} (0.01) = 0.0739$ . Maximum cumulative difference ( $D_{max}$ ) was found to be 0.7019. Since there is significant difference between  $D_{crit}$  and  $D_{max}$  value, the diversities for each site do differ significantly at  $P = 0.05$ .

Dominance plot computes abundance of each taxon (Clarke and Warwick 2001). Mandovi site is richer; as its curve does not reach 100% until rank 12, whereas Manori site reaches 100% at rank 6. Also, the sharper the “knee” of the Manori community plot suggested the lower diversity (Fig. 2).

Positive correlation was observed between all mangrove associated plankton and benthic communities. Phytoplankton showed positive but insignificant correlation with zooplankton ( $R = 0.0282$ ) and benthos

( $R = 0.08$ ). However, zooplankton and benthos ( $R = 0.8376$ ) too were found to be significantly correlated (Fig. 3).

Analysis of variance showed significant ( $p < 0.05$ ) seasonal variations in for phytoplankton as well as zooplankton diversity. Macrobenthos however, did not yield significant results, since the diversity was observed to be very poor. Two Way ANOVA performed on six of most dominant phytoplankton species and five of most dominant zooplankton taxa (Table 5). The population of *Navicula halophila* and *Thalassionema nitzschioides* found to be significantly governed by salinity gradient. *Biddulphia biddulphiana*, *Amphora turgida*, *Navicula halophila*, *Thalassionema nitzschioides* and *Thalassiosira eccentrica* were the five species characterized by significant season effect. Among zooplankton, two taxa were characterized by significant station effect and three taxa were characterized by significant season effect. *Navicula halophila* ( $p = 0.03$ ) and Copepoda ( $p = 0.02$ ) were the only taxa where a significant interaction between station and season existed.

## DISCUSSIONS

Conservation, restoration and sustainable utilization of mangrove habitats are issues of global concern. In spite of having intensive anthropogenic pressures, Manori creek harbour dense mangrove habitats. Salinity levels  $> 30$  ppt indicates influence of high land run off from salt pans within upper reaches of creek. Effluents from urban areas are mainly responsible for high levels of nutrients in Manori creek (Zingade and Govindan 2000). Percolation of pollutants from neighboring dumping grounds remains the prime cause of low amount of DO and higher BOD values. Average DO values in Manori creek water were reported to be  $5.1 \text{ ml l}^{-1}$  in 1982 and  $3.6 \text{ ml l}^{-1}$  in 2000, then declined to  $1.6 \text{ ml l}^{-1}$  in 2007 (Anon 2000; Anon 2007) below acceptable limits (Hargreaves and Tucker 2002; Ingole and Kadam 2003). Salinity values of creek water were also reported to be widely fluctuated during 1982 (Khadilkar 1989) however, later remained higher ( $> 31$  ppt) and constant round the year (Anon 2000 and Anon 2007), which could be attributed to reduced inflow of land run off, as well as salt production in the upstream zone of the creek. Similarly considerable hike was observed in nutrient levels of creek water, in past 25 years (Table 6). Rise in the concentrations of heavy metals also indicates intense pollution in the Manori creek (Table 7), as it receives raw sewage, industrial and municipal wastes; concentration of heavy metals is constantly increasing (Sahu and Bhosale 1991; Singh et al 2007). Activities like washing oil

drums and barrels, boat manufacturing plants discharging unauthorized hazardous waste also contribute substantially towards intensive pollution (Zingade and Desai, 1980).

The WQIs for the Manori creek and Mandovi estuary were primarily developed to reflect changes in physicochemical quality of surface waters, which could also be used as indicators of ecological change. WQI enables large amount of water quality data to be reduced to single index value, as it has been developed in accordance with recognized water quality standards and criteria. WQI of < 55 indicated unacceptable aquatic conditions of Manori creek.

Diversity index is intended to measure the biodiversity of an ecosystem. In general, such indices facilitate the understanding, conservation and utilization of living resources by creating a single annotated index of biological collections. In general Shannon's index falls in the range of 1.5 – 3.5 for a good diversified area and it is considered to be zero when there is no diversity (Margalef 1972). Shannon's index of Manori creek mangroves is below the normal range and closer to zero. Hence it is concluded that the diversity is very poor. Similarly all other indices (Table 3) obtained from Manori creek are much lower than that of Mandovi estuary.

Higher concentration of salts from tidal influenced zones is conducive for growth of highly salt tolerant species like *A. marina* and obligate halophytes like *Sesuvium portulacastrum*, *Sueda maritima* etc. *Avicennia marina* exhibit wide tolerance to salinity, however, dominates in highly saline region exhibiting stunted growth (Jagtap et al. 2003; Dahdouh-Guebas et al. 2004). In contrast to *Avicennia* spp., *Sonneratia caseolaris* has very poor tolerance to salinity (Jagtap 1985), and hence prefers low salinity regions. Absence of *S. caseolaris* in upper reaches of Manoi creek (Table 1) also suggests influence of high salinity. Increasing amount of pollution and stress might have affected composition of flora drastically in last 15 years. Absence of mangroves like *S. caseolaris* and *Kandelia rheedii*, indicative of low salinity also suggest increased tidal influence and reduced fresh water input in Manori creek.

Pollution implications may certainly alter the physicochemical properties of water and sediments, ultimately adversely impacting biological nature. Hence, investigations of ecosystem, and particularly of biological communities, constitute an important part of pollution monitoring studies. The basic process in an aquatic ecosystem is the production of organic carbon by photosynthesis. Phytoplankton and zooplankton are reflectors of *productivity* at primary and secondary levels (William et al. 2002; Peterson

et al. 1987). Poor quantum of phytoplankton (Table 2) in spite of nutrient rich ambience (Table 6) in Manori creek is suggestive of severely stressed environment resulting in low productivity (Ramaiah and Nair 1998). Seasonal occurrence of *N. halophila* at all stations showed significant ( $p < 0.05$ ) relation with increased temperature. Similar observations were reported earlier (Gallardo 2003).

Benthic organisms associated with particular habitat being sedentary provide information regarding the integrated effects of stress, and hence are good indicators of early warning of potential damage (Gray et al. 1990). Benthic productivity in the mangrove influenced regions of Manori creek was generally recorded to be very poor. The quantum of benthic faunal communities of the creek increased towards midstream and upstream regions, showing influence of dense mangroves (Parulekar et al. 1976; Varshney 1983). Polychaeta contributed major share in the benthic population while total absence of Bivalvia may be attributed to the higher salinity (Govindan et al. 1980). Abundance of Polychaetes in sediments from Manori, express their potential as bioindicators of stress environment (Jenderedjian et al. 2007). Increased salinity, temperature and heavy metal concentrations in Manori creek might support the dominance of polychaeta in study area (Lyster 1965; Grant et al. 1989; Kenny 1969).

Although the creek habitat is reflecting degraded conditions, a number of factors in ambience are still optimistic, particularly luxuriant growth of mangroves. Positive correlation between mangrove associated biota also suggests a balanced food chain in the creek components (Banse 1994). Hence, the prevailing status of Manori creek warrants immediate clean up action for improving biological and environmental qualities. The mangroves under regular flooding with mean tidal amplitude along major creeklets must be protected and be made denser by introducing species like *S. alba*, *S. apetala*, *R. mucronata* etc. which occurs very rarely along the creek side.

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Table 1: Comparative Status of Mangroves in Manori Creek and Mandovi Estuary (\*Jagtap 1985)

Species	Manori				*Mandovi		
	% FO	Ht(m)	DBH(cm)		% FO	Ht(m)	DBH(cm)
<i>Acanthus ilicifolius</i> L.	50	< 0.5	< 2.5		50	0.5-1	< 2.5
<i>Avicennia marina</i> (Forsk.) Vierh	80.55	0.5-2	2.5-8		14.31	1 - 4	10 – 20
<i>Avicennia officinalis</i> L.	2.77	1-1.5	3-5		80	5-10	10-25
<i>Aegiceras corniculatum</i> (L.) Blanco	-	-	-		17.59	< 0.5	< 2.5
<i>Bruguiera cylindrica</i> (L.) Blanco	2.22	0.5	< 2.5		-	-	-
<i>Bruguiera parviflora</i> (Roxb.) Wt.	-	-	-		7.14	2-2.5	8-10
<i>Ceriops tagal</i> (Perr.) Robin	-	-	-		11.11	< 0.5	< 2.5
<i>Excoecaria agallocha</i> L.	3.7	0.5-1	< 2.5		27.5	1-1.5	< 2.5-5
<i>Kandelia candel</i> (L.) Druce	-	-	-		41.77	2-4	< 2.5-5
<i>Rhizophora apiculata</i> Blanco	-	-	-		40.33	2-4	5-15
<i>Rhizophora mucronata</i> Lamk.	-	-	-		45.66	2-4	5-15
<i>Sonneratia alba</i> J.Sm.	-	-	-		45	8-10	25-30
<i>Sonneratia apetala</i> Buch. Ham	4.63	0.5-2	5-8		-	-	-
<i>Sonneratia caseolaris</i> (L.) Engl.	-	-	-		15	8-10	15-25

Legends:

D= Dominant (%FO = > 60), CD- Co Dominant (%FO =40-59), C= Common (%FO = 20-40), LC = Less common (%FO = 10-19), R= Rare (%FO = <9), ab = Absent, Ht = Height, DBH =

Diameter at Breast Height, ES = Ecological Status

Table 2: Comparison of Phytoplankton, Zooplankton and Benthos Population of Manori Creek and Mandovi Estuary (\*Ansari, Sivadas and Ingole 2007; Matondkar 2007)

		<i>Manori</i>			<i>*Mandovi</i>		
parameter	Station	Station			Station		
		MC1	MC2	MC3	M1	M2	M3
Phytoplankton	Count	0.066	0.034	0.026	1.8	5.2	2.1
	No X 10 <sup>5</sup> l <sup>-1</sup>						
	Dominant Genera	<b>Skeletonema</b>	<i>Amphora</i>	<i>Thalassionema</i>	<b>Synedra</b>	<i>Nitzschia</i>	<i>Rhizosolenia</i>
		<i>Biddulphia</i>	<i>Navicula</i>	<i>Navicula</i>	<i>Peridinium</i>	<i>Melosira</i>	<i>Nitzschia</i>
Zooplankton	Count No m <sup>-3</sup>	82.77	17.83	18.77	255	235	207
	Dominant Group	Copepoda	Amphipoda	Copepoda	Decapoda	Decapoda	Decapoda
		Gastropoda	Copepoda	Polychaeta	Chaetognatha	Copepoda	Copepoda
Benthos	Count No m <sup>-2</sup>	904	564	184	1625	408	1941
Macrofauna	Dominant Group	Polychaeta	Tanids	Polychaeta	Amphipoda	Polychaeta	Amphipoda
					Polychaeta	Bivalvia	Tanids

Table 3: Comparison of biodiversity indices and water quality index of Manori creek and Mandovi estuary

Biodiversity Index	Margalef index	Simpson's diversity index	Shannon's index	$E^H$	Evenness	Water quality index
Manori	0.7625	0.5465	0.9225	2.5155	0.5148	53.51
Mandovi	1.5769	0.8629	2.1697	8.7556	0.8731	76.13

Table 4: Kolmogorov – Smirnov test

Species	Manori			Species	Mandovi		
	Total number of plants	% Pi (n/NX100)	Cumulative Pi		Total number of plants	% Pi (n/NX100)	Cumulative Pi
<b>A. marina</b>	402	57.10	57.10	<i>A. officinalis</i>	240	22.42	22.42
<i>A. ilicifolius</i>	250	35.51	92.61	<i>R. mucronata</i>	222	20.74	43.16
<i>S. apetala</i>	24	3.4	96.01	<i>S. alba</i>	120	11.21	54.37
<i>E. agallocha</i>	19	2.69	98.7	<i>A. ilicifolius</i>	115	10.74	65.11
<i>B. cylindrica</i>	9	1.27	99	<i>K. candel</i>	83	7.75	72.86
<i>A. officinalis</i>	7	0.9	100	<i>R. apiculata</i>	80	7.47	80.33
<i>B. parviflora</i>	0	0	100	<b>A. marina</b>	70	6.54	86.87
<i>A. corniculatum</i>	0	0	100	<i>E. agallocha</i>	56	5.23	92.1
<i>C. tagal</i>	0	0	100	<i>A. corniculatum</i>	36	3.36	95.4
<i>K. candel</i>	0	0	100	<i>C. tagal</i>	24	2.24	97.7
<i>R. apiculata</i>	0	0	100	<i>B. parviflora</i>	14	1.3	99
<i>R. mucronata</i>	0	0	100	<i>S. caseolaris</i>	10	0.93	100
<i>S. alba</i>	0	0	100	<i>B. cylindrica</i>	0	0	100
<i>S. caseolaris</i>	0	0	100	<i>S. apetala</i>	0	0	100
	N = 704				N =		
					1070		



Table 5: Summary of 2 Way ANOVA Performed on Dominant Phytoplankton Species and Zooplankton Groups.  
 Levels of significance are as follows: +  $p < 0.05$ , ++  $p < 0.01$ , +++  $p < 0.001$

Phytoplankton Species	Station	Season	Station X Season
<i>Skeletonema costatum</i> (Greille) Cleve	-	-	-
<i>Biddulphia biddulphiana</i> (J. E. Smith) Boyer	-	+	-
<i>Amphora turgid</i> Gregory	-	+	-
<i>Navicula halophila</i> (Grun.) Cleve	+	++	+
<i>Thalassionema nitzschioides</i> Grunov	+	++	-
<i>Thalassiosira eccentric</i> (Ehrenberg) Cleve	-	+	-

Zooplankton Groups	Station	Season	Station X Season
Copepoda	++	+++	+
Amphipoda	+	++	-
Gastropoda	-	-	-
Fish Larvae	-	+	-
Hydromedusa	-	-	-

Table 6: Time Series Data of Water Quality from Manori Creek (\*Anon 1989; #Anon 2000; ##Anon 2007)

Parameter	1982 <sup>#</sup>	1989 <sup>*</sup>	2000 <sup>#</sup>	2007 <sup>##</sup>
Temperature (°C)	25.6	26.2	29.4	27.2
pH	8.1	7.9	7.8	7.4
Salinity (PSU)	34.9	31.5	33.4	31.2
DO (ml/l)	5.1	6.26	3.6	1.66
BOD (mg/l)	-	-	1.8	2.43
NO <sub>3</sub> <sup>-</sup> (μmol/l)	29.8	4.4	7.6	6.53
NO <sub>2</sub> <sup>-</sup> (μmol/l)	0.8	-	1.6	6.86
PO <sub>4</sub> <sup>-3</sup> (μmol/l)	0.7	3.4	11.6	23.06
SS (mg/l)	35	121.66	47	23.06

(-) Data not available

Table 7: Metal Concentrations from Sediments of Manori Creek (\*Anon 2000; \*\*Anon 2007)

Metal	Al	Cr	Mn	Fe	Co	Ni	Cu	Zn	Hg
2000*	7	102	1205	8.7	65	125	132	130	0.20
2007**	8.5	242	1244.5	7.8	64.5	137	103	195.5	0.64

List of figures:

Figure 1 - Geographical coordinates for sampling stations.

Figure 2 – Dominance plot of mangrove ecosystem of Manori creek and Mandovi estuary.

Figure 3 – Correlation plots of phytoplankton, zooplankton and benthos from Manori creek.

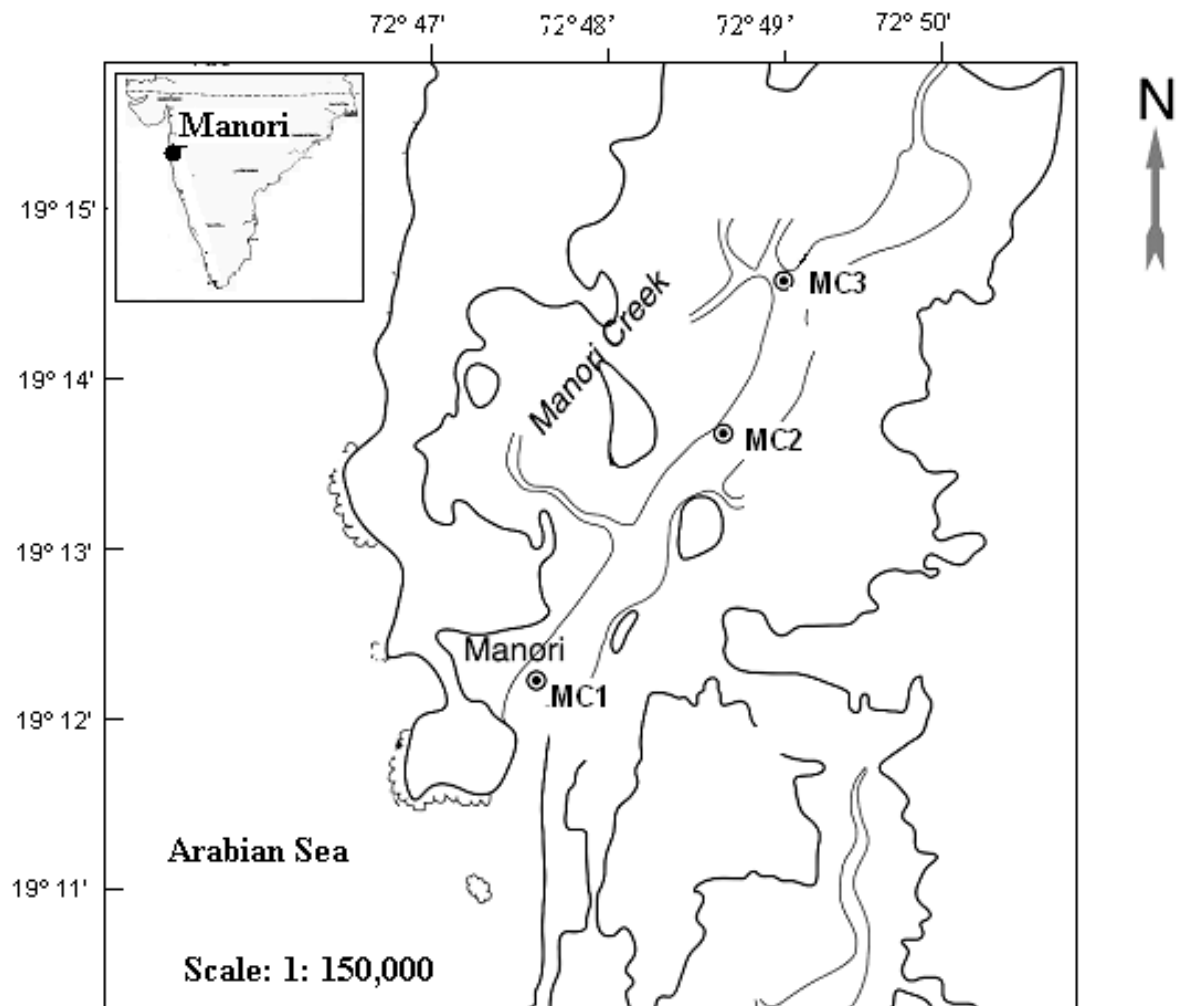


Figure: 1

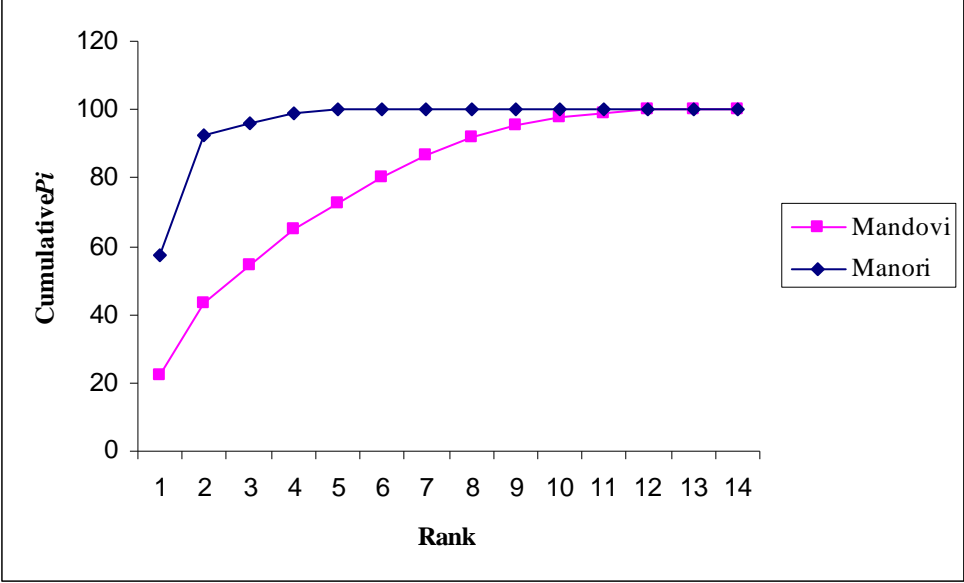


Figure: 2

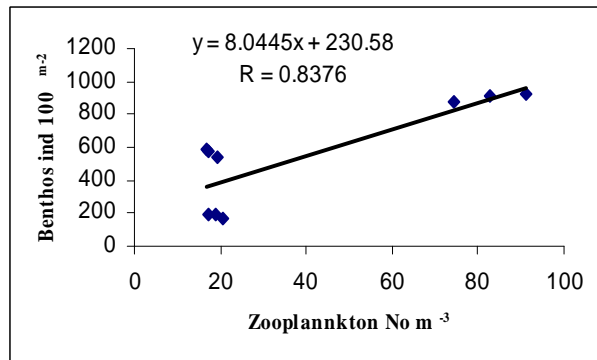
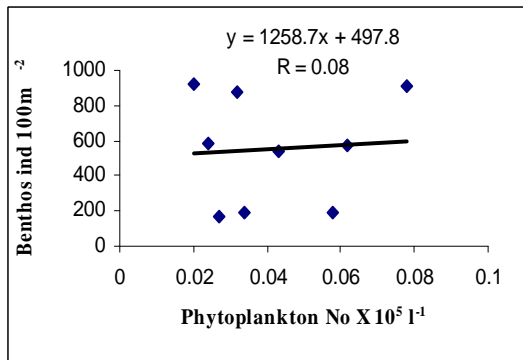
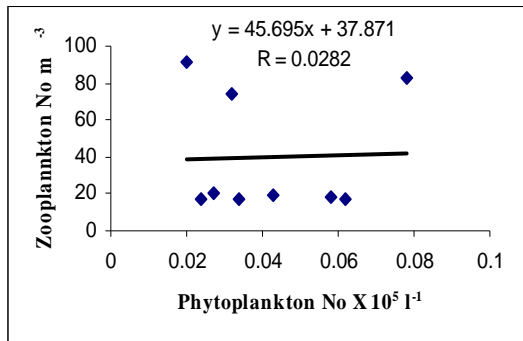


Figure: 3