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EFFECT OF ESTUARINE EFFLUENTS ON BENTHIC FAUNAL COMMUNITIES IN RELATION TO TIDAL DYNAMICS OF DHAMRA ESTUARY

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ABSTRACT

Estuaries are an integral part of the hydrological cycle and regulate the particle delivery from rivers to the coastal environment and to the ocean. The high human population density and rapid economic growth in coastal Bay of Bengal makes the coastal biodiversity at risk. Now a days pollution monitoring is highly appreciable work for conserving coastal water quality and the aquatic diversity. Benthic invertebrates are useful bio-indicators providing a more accurate understanding of changing aquatic conditions. In this apprehension, the study was deals with benthic monitoring in relation to water and sediment quality along Dhamra estuary of East coast of India. Water, sediment and benthic samples were collected in every tidal rhythm (high tide, mid tide and low tide) over a period of 36 hours from May, 2016 to March, 2017. To know the water quality status, pH, conductance, salinity, total suspended solid, dissolved oxygen, biochemical oxygen demand, alkalinity, total phosphorus and total nitrogen were analysed. Sediment samples were examined for texture (percentage of Sand, silt, clay) and organic carbon. Biological samples like macro benthic and meio benthic were investigated and correlate with physic-chemical and textural characteristics to know the community strength with environmental variables. Most of the study has been carried out in spatial and temporal scale along different estuarine system of Indian coast. This study was focused on seasonal survey of benthic population, community and abundance with diurnal cycle over a period of 36 hours. However in Dhamra estuary no previous records and literature was found on diurnal scale. Hence this is an attempt to know the benthic abundance in Dhamra estuarine sediment with special reference to tidal effect.

KEYWORDS: Benthos abundance, diurnal changes, water quality, sediment quality, Dhamra estuary, East Coast of India.

INTRODUCTION

Pollution from domestic and industrial discharge is a major threat to water quality of marine and coastal Bay of Bengal. The study of hydrographical and environmental characteristics is a privilege for characterizing the ecosystem. Estuaries are highly eco-sensitive aquatic environment, especially those in close proximity to heavily industrialized cities. The Dhamra estuary is a major tropical estuary in the east coast of India. It is a joint convergence of Brahmani and Baitarani River. Dhamra port, the newly constructed port located northern side of the river mouth which is a source of anthropogenic disturbance on the estuarine water quality as well as ecosystem habitat (Sangita et.al, 2014). The estuary enclosed with Bhitarkanika mangrove forest and Gahirmatha marine sanctuary. Both are of international repute being on environmentally sensitive area (Dash and Kar 1990). Bhitarkanika wildlife sanctuary famous for its estuarine crocodiles and Gahirmatha marine sanctuary, which is the world's most important nesting beach for Olive Ridley sea turtles on the Orissa coast of Bay of Bengal (Palleyi et al 2011). Anthropogenic inputs through riverine system may influence the biological and geochemical conditions of the estuarine waters to considerable extent. Study of the macro benthos has received considerable attention due to their significance as biological indicators of environmental change in aquatic ecosystem. They perform varieties of ecological function and comprise the critical link in the marine food web. Macro benthos consumes all kinds of organic matter and in turn acts as a food for many fishes, birds and other marine invertebrates. It is a play an important role in food chains and plays a critical role in the breakdown of organic substance (Sundaravarman et al, 2012). It accelerates the breakdown of decaying organic matter into simpler

inorganic forms such as phosphates and nitrates (Gallep et al., 1978). Hence this energy goes to higher trophic level and can potentially support off-shore and pelagic communities (Lee, S.Y., 1997; Schrijvers et al., 1996). In addition to that tidal action plays a major factor for controlling benthic population and diversity. The benthic organisms have been widely used in assessing the health of marine ecosystem and bio investigation (Ravera, 1998). The benthic zone provides many valuable products and ecological services. The macro benthic organisms are serving as biological indicator species as it is very sensitive towards environmental changes (Sharma et al 2016 a). In order to know the ecosystem health, the present study was deal with monitoring of macro benthos as a key tool.

Study Area

Odisha is one of the maritime states of India, bearing an extensive coastline of about 480km endowed with some ecologically and economically important sea beaches, estuaries, creeks, backwater, lake, lagoon and mangroves (Sharma et al 2016 b).The Dhamra estuary is a tropical estuary on the East coast of India, and its hydrological characteristics are governed by monsoon regime. The estuary is a joint stream formed by the convergence of the two rivers i.e. Brahmani and Baitarani. Brahmani and Baitarani rivers combine together to form Dhamra River before meeting the Bay of Bengal. It is situated on the East coast of India within 86^0 57' 00" E − 87^0 01' 00" E and 20^0 45' 00" N − 20^0 48' 00" N (Fig.1). The location of Dhamra Estuary is near proximity to the mineral belt of Orissa, Jharkhand and West Bengal (Barik and Panda, 2014). Dhamra River receives indiscriminate waste discharges mostly agricultural runoff and domestic effluents from two major rivers such as Brahmani and Baitarani. Brahmani River receives effluents from most of the major industries of Rourkela, Angul and Talcher industrial areas of the Odisha state, as a result, the aquatic ecosystem could be exposed to risk (Naik et al. 2014).

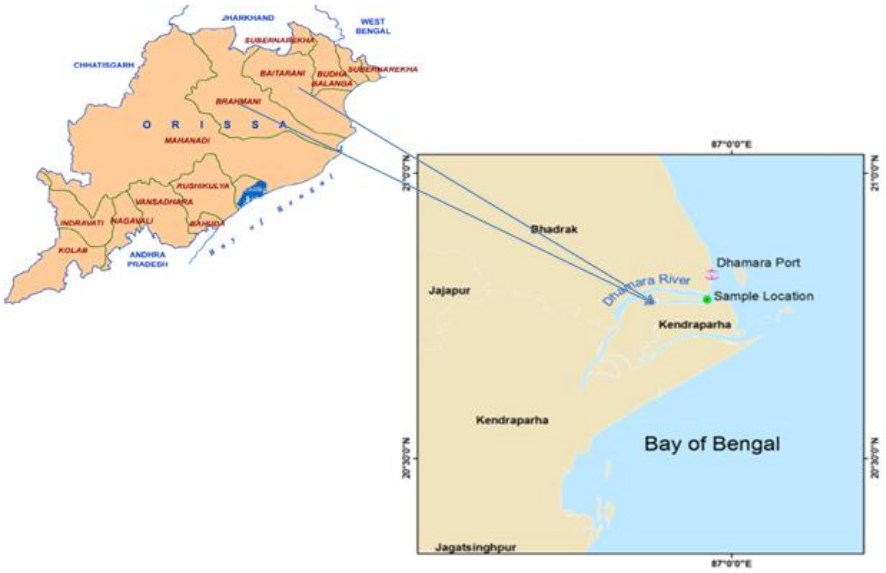

Figure 1: Showing: Map of the study area.

MATERIALS AND METHODS

Most of the study has already been done on Indian estuaries were focused on spatial and temporal pattern but scarce information is available on diurnal monitoring such as low tide (LT), mid tide (MT) and high tide (HT). Therefore, keeping view in mind, samples were collected seasonal basis from a particular estuarine point in an every tidal cycle (LT, MT and HT) over a period of 36 hour. Water and sediment samples collected from estuary point having $20^0$46'37.35"N latitude and $86^0$57'25.41"E longitude of dharma river mouth during 2016-17. Water samples from sampling location were collected in Niskin's water sampler, while sediment samples were collected by using Peterson grab. Physico-chemical parameters such as water temperature (WT), salinity, pH, dissolve oxygen (DO) were analysed on board using WTW kit (multi 340 i) followed by titration method. Nutrient parameters such total nitrogen (TN) and total phosphorus (TP) were analysed by standard photometric method (Grass holf et al. 1999) using Varian 50 U.V-visible spectrophotometer.

Benthic samples were taken with the help of stainless steel Van Veen grab sampler to obtain bottom sediments. The grab collected a sample of sediment with a surface area of 400 cm^2. Benthic samples were taken in an every consecutive tide (LT, MT and HT) for a period of 36 hrs. Samples were sieved through a 0.5 mm mesh sieve and then preserved in 5% buffered formalin with rose bengal solution (Sharma et al 2014). After 3 days the samples were transferred to 70% ethanol for subsequent sorting and identification. Seasonal (pre-monsoon, post-monsoon and summer) sediment samples were collected for macro and meio benthic study during the period of 2016- 2017. In each season, samples were taken

throughout day and night in every tidal peak for 36 hours in order to know the benthic variability in relation to dial cycle.

RESULT AND DISCUSSION

Water Quality

Season wise environmental variables with benthic population during pre-monsoon, post-monsoon and summer are cited (Table 1). The water temperature in Dhamra estuary varied from 29.70 to 30.90^{0}C, 24.70 to 26.40^{0}C and 24.80 to 27.30 for pre-monsoon, post-monsoon and summer respectively. The seasonal pH varied between 7.80 to 8.30 in pre-monsoon, post-monsoon and summer. The lowest pH was recorded in summer and the highest value was recorded in post-monsoon. The pH value was high during post-monsoon may be due to high rate of photosynthesis in winter season. The salinity varied from 23.94 to 32.99 PSU, 13.10 to 22.30 PSU and 23.90 to 28.50 PSU during pre-monsoon, post-monsoon and summer respectively. The lowest salinity was found in post-monsoon due to the river run off in this period and high dilution in the estuary. Dissolved Oxygen is one of the fundamental factors of life. DO range from 4.72 to 6.18 mg/l, 7.35 to 8.70 mg/l and 6.82 to 7.32 mg/l for three different seasons respectively. Lower value was found in pre-monsoon and higher value was found in post-monsoon. The BOD varied from 1.33 to 3.76 mg/l, 1.13 to 3.01 mg/l, and 1.35 to 2.85 mg/l for three different seasons respectively. Maximum value of BOD was observed in pre-monsoon period due to the maximum biological affinity at elevated temperature and low in winter and reduced flow of riverine water (Ghavzan, et. al. 2006).

Table 1: Descriptive Statistics of physic-chemical parameters showing Min, Max, Avg and SD.

		Pre-monsoon				Post-monsoon				Summer			
	N	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
WTEMP	12	29.70	30.90	30.45	0.36	24.70	26.40	25.65	0.49	24.80	27.30	25.89	0.66
PH	12	8.06	8.13	8.09	0.02	7.98	8.30	8.14	0.10	7.80	8.07	7.99	0.08
SALIN	12	23.94	32.99	29.11	3.59	13.10	22.30	18.93	3.07	23.90	28.50	26.54	1.52
ALK	12	109.87	131.76	119.21	6.18	94.25	107.04	99.61	3.61	103.01	112.20	106.24	3.40
DO	12	4.72	6.18	5.62	0.43	7.35	8.70	7.92	0.43	6.45	7.32	6.95	0.29
BOD	12	1.33	3.76	2.87	0.73	1.13	3.01	1.90	0.58	1.35	2.85	2.14	0.43
TN	12	16.27	37.72	28.46	6.45	13.58	25.58	18.11	3.92	12.38	25.21	18.22	3.69
TP	12	0.94	1.97	1.19	0.27	0.19	1.15	0.49	0.25	0.31	1.09	0.60	0.21
SAND	12	3.52	97.69	44.46	38.70	11.00	97.01	42.09	31.07	1.74	81.19	20.87	21.81
SILT	12	0.36	75.98	14.95	21.03	1.95	50.49	28.21	15.05	12.69	88.75	53.16	30.08
CLAY	12	1.47	82.69	40.59	39.21	1.05	75.69	29.69	26.70	1.61	66.70	25.97	28.50
OC	12	1.88	10.25	6.17	3.02	0.91	9.77	6.25	3.23	2.12	10.25	8.07	2.16

Table 2: Seasonal Pearson Correlation matrix (r) between Physico-chemical with benthic abundance.

Season	Benthic Group	WT	Salinity	DO	BOD	TN	TP	SAND	SILT	CLAY	OC	Macro	Meio
Pre-monsoon	Macro	-.076	.002	.189	.107	.317	-.402	-.558	-.001	.551	.668*	1	
Pre-monsoon	Meio	.477	-.348	.010	-.043	.433	-.142	.309	-.523	-.025	-.264	.145	1
Post-monsoon	Macro	-.129	-.022	.087	.093	-.061	-.314	-.692*	.445	.555	.737**	1	
Post-monsoon	Meio	-.128	-.329	-.451	-.048	.201	.305	.361	-.286	-.259	-.499	-.142	1
Summer	Macro	.344	.066	.397	-.629*	-.285	.451	.266	-.451	.272	-.317	1	
Summer	Meio	.401	.556	.028	-.365	-.502	-.118	.696*	-.347	-.166	-.750**	.226	1

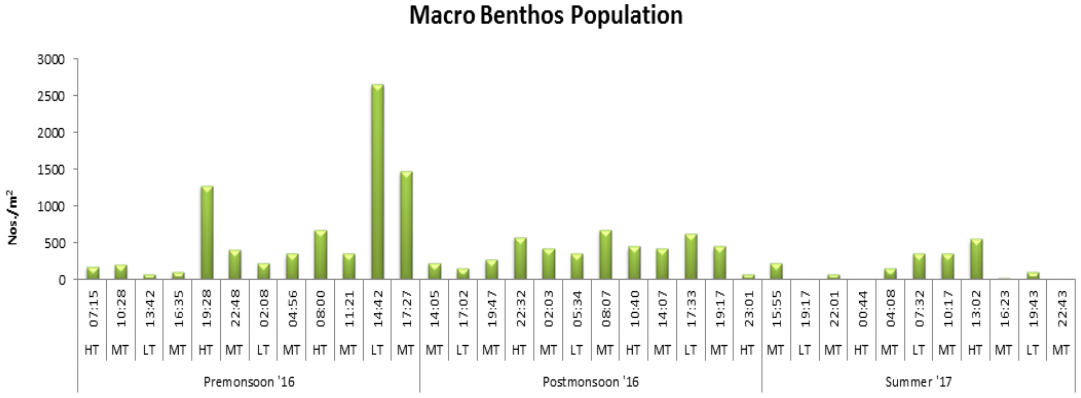

Figure 2.a: Showing: Seasonal and diurnal variation of Macro benthic abundance in Dhamra Estuary.

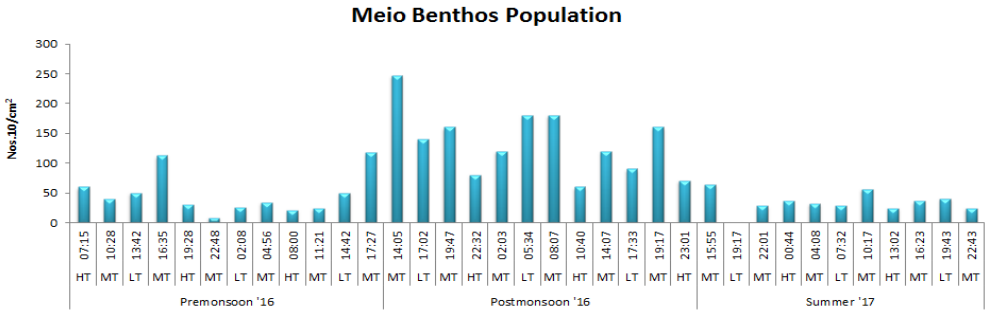

Figure 2.b: Showing: Seasonal and diurnal variation of Macro benthic abundance in Dhamra Estuary.

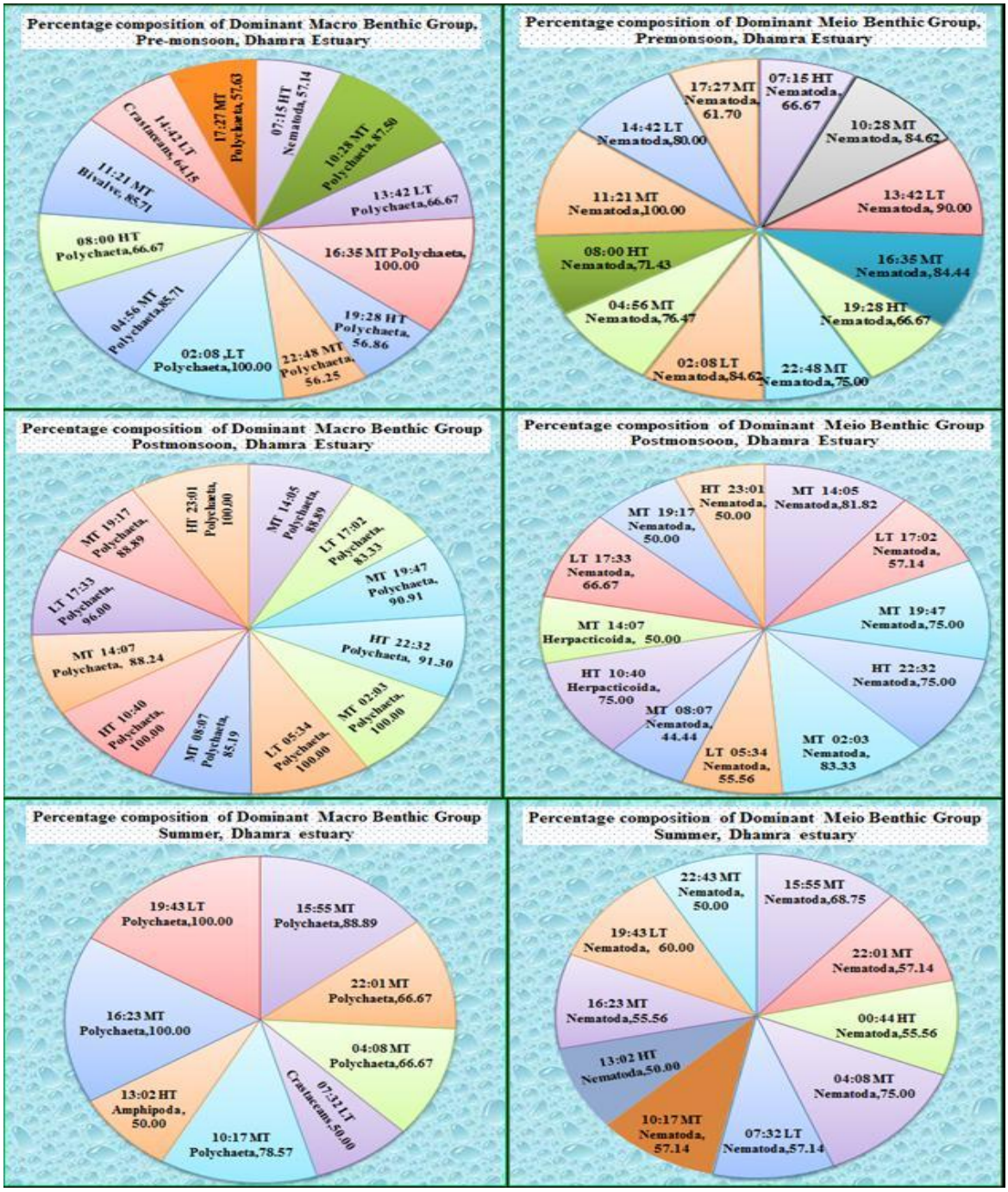

Figure 3: Showing: Season wise percentage composition of macro and meio benthic group in Dhamra estuary.

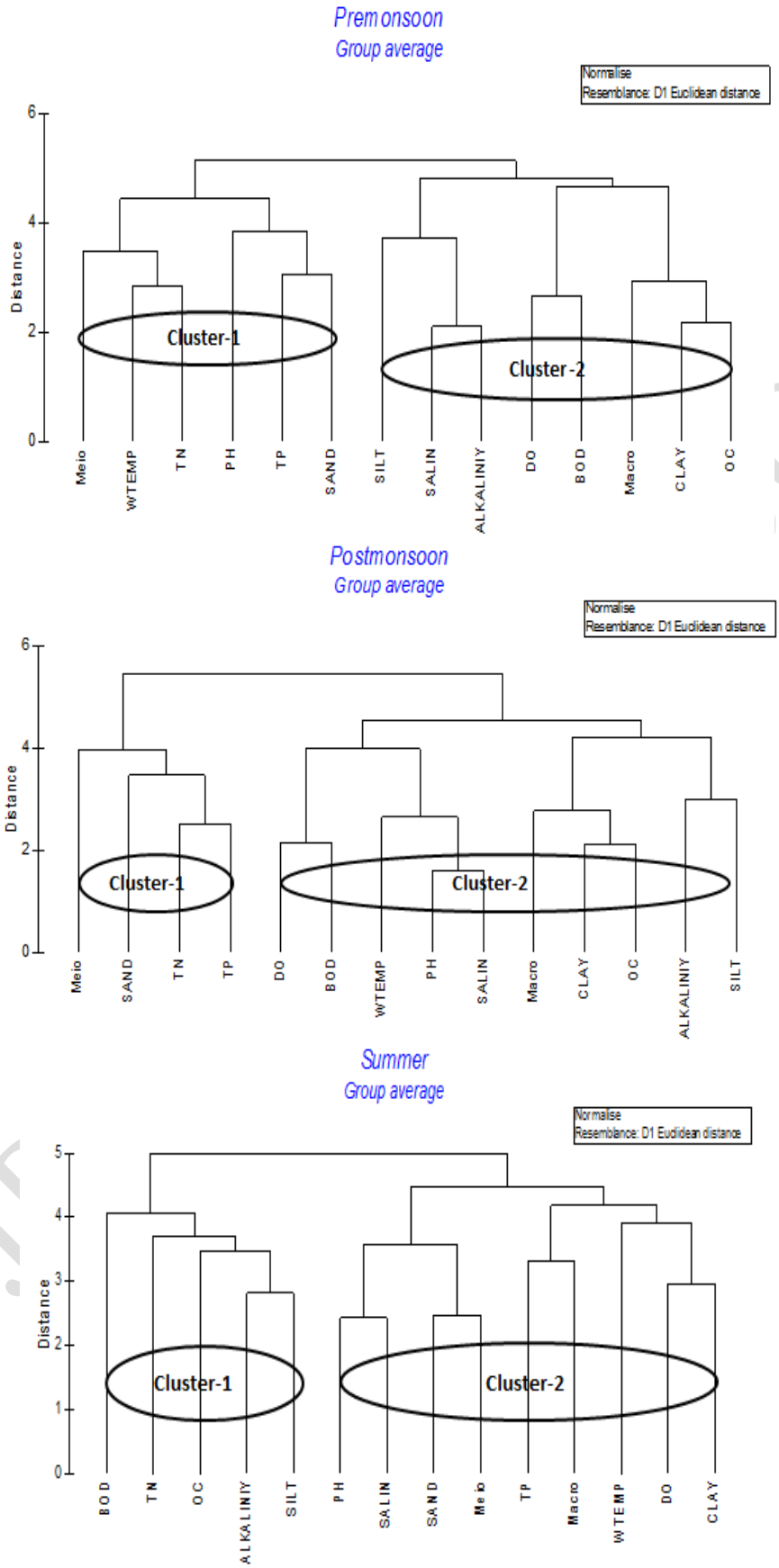

Figure 4: Showing: Clustering dendograms relationship between benthos with environmental variables.

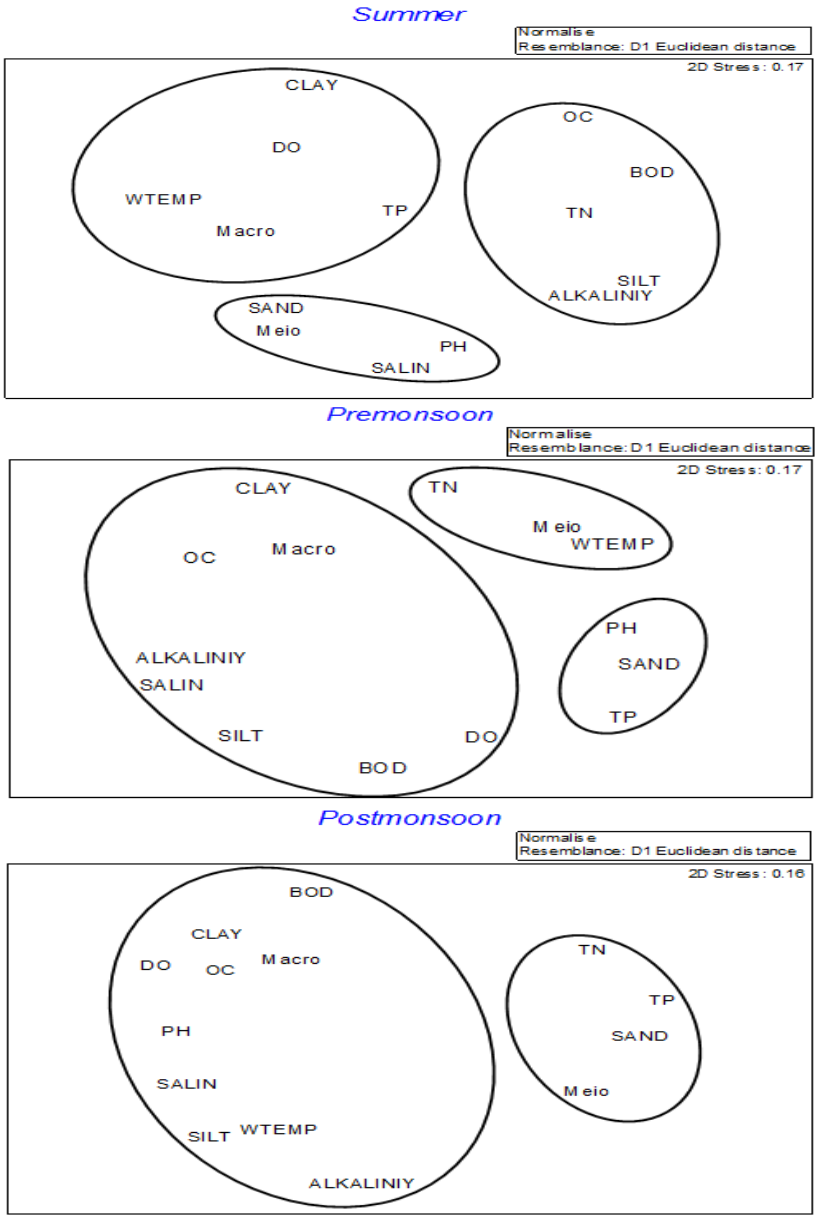

Figure 5: Showing: Multi-dimensional scaling (MDS) between benthos with environmental variables.

Nutrients in water play an important role in the lives of aquatic organisms including fish. Nutrients, especially nitrogen and phosphorus, are key indicators of water quality in estuaries. Nitrogen and phosphorus naturally enter estuarine waters when freshwater runoff passes over geologic formations rich in phosphate or nitrate, or when decomposing organic matter and wildlife waste get flushed into rivers and streams. The seasonal variations of nutrients concentrations were well marked in dharma estuary. The TN value was observed to be 16.27-37.72, 13.58-25.58 and 12.38-25.21 µmol/l respectively during the three consecutive seasons. The TP value was observed to be 0.94-1.97, 0.19-1.15 and 0.31-1.09 µmol/l during pre-monsoon, post-monsoon and summer. Maximum concentration of nitrogenous and phosphorous compounds in form of TN and TP was observed in pre-monsoon than other seasons. Generally during monsoon it is present in higher concentration due to the anthropogenic sources like domestic sewage, agricultural wash offs and other waste effluents containing nitrogenous compounds. The present study showed the phosphate and nitrogen load is high in pre-monsoon which may be due to soil disturbance and discharge of sewage and other wastes.

Sediment texture and Organic Carbon

The percentage of Sand, Silt and Clay in Dhamra estuary was ranged from 3.52-97.69, 0.36-75.98, 1.47-82.69 during pre-monsoon; 11.00-97.01, 1.95-50.47, 1.05-75.69 during post-monsoon; 1.74-81.19, 12.69-88.75 and 1.61-66.70 during the period of summer respectively. From the above data, the annual variation of Sand, Silt and Clay was 1.74 to 97.69, 0.36 to 88.75 and 1.05 to 82.69 separately. The organic carbon varied from 1.88-10.25 during pre-monsoon, 0.91- 9.77 during post-monsoon and 2.12 – 10.25 during the period of summer

continuously. The annual range of organic carbon was in a range of 0.91 to 10.25 mg/g.

Abundance and percentage composition of Macro Benthos

Season wise benthic abundances with tidal and time series are cited in the text (Fig.2a and 2b). Macro faunal abundance during pre-monsoon-2016 in Dhamra estuarine sediment ranged from 75 to 2650 nos. /m^2 and group diversity fluctuated from 1 to 5 in nos. Polychaetes found to be dominant over macro groups followed by bivalves, nematodes and crustaceans. The population and diversity of each tidal sample was varied to its successive sample. Macro faunal abundance during post monsoon in Dhamra estuary was in a range of 75 to 675 nos./m^2. (Macro benthic groups diversity found very low and counted as only 1- 2 in nos. Polychaetes found to be dominant groups over 36 hrs of sampling period. Macro faunal population during summer found to be 25 to 550 nos./m^2. The group diversity was counted 1 to 4 in nos. Polychaetes were dominant group followed by amphipods. The above study reveals macro faunal population during summer was less in number as compared to post-monsoon and summer (pre-monsoon> post-monsoon >summer).

Abundance and percentage composition of meio benthos

The percentage composition of dominant macro and meio faunal group are also demonstrated in order to know their dominancy along the estuarine system (Fig.3). During pre-monsoon, meio faunal population in Dhamra estuary ranged from 16 to 117.5 nos./10cm^2. Nematoda was only dominant group over 36 hrs. diurnal period as no other groups were found. Meiofaunal population in post-monsoon period ranged from 60-247.5 nos./10cm^2) with a group diversity 2 to 3 in nos. Nematodes were dominant group followed by herpacticoid. Meio benthic counts during summer in Dhamra were observed to be 24 to 64nos/10cm^2. Nematodes were the only dominant group as no other groups were found during summer. The above result explains, meio faunal population of post-monsoon dominated over summer and pre-monsoon (post-monsoon>pre-monsoon >summer).

Multivariate statistical analysis

The statistical analysis was carried out for 14 environmental parameters. Multivariate statistical analysis was performed through person's correlation matrix, cluster analysis (CA) and Multidimensional scaling (MDS) using advance software (IBM SPSS 20 and Primer 6). Season wise Pearson correlation matrix was formulated between benthic group and physic-chemical analysis (Table.2). It was seen that the macro benthos was appeared a strong positive correlation with organic carbon and clay whereas, negative correlation with Sand during pre-monsoon and post-monsoon. The reverse case was found in the field of Meio fauna. The meio fauna were made a negative correlation with organic carbon and clay whereas, positive with sand during pre-monsoon, post-monsoon and summer season.

For better understanding, season wise MDS and cluster analysis (CA) were performed between benthos and environmental variables (Fig.4 and 5). CA and MDS through Euclidean distance have applied to Dhamra water and sediment quality with benthic abundance data set intending to explain similarity between variables. Multivariate statistical technique is the best tool to understand of an ecosystem by summarizing a large number of data set and to draw a meaningful conclusion (Sundarray 2006). Today, it is used to evaluate coastal water quality and gives a concluding remark on its seasonal variation, possible sources and impact (Helena et.al. 2000). Cluster and MDS analysis in the form of Euclidean distance helps in grouping objects (cases) into classes (cluster) on the basis of similarity with on class and dissimilarity between different classes (Singh et.al. 2004). From CA and MDS it was clearly explained that macro benthos was in close relationship with OC and clay (cluster-2) during pre-monsoon and post-monsoon. The meio-faunal abundance was in a close group with TN, TP and sand during pre-monsoon and post-monsoon (cluster-1) while close with only sand during summer. The above study concludes all the statistical analysis showed a similar type of results.

CONCLUSION

Estuaries are the nursery ground for many juvenile and adult organisms. The fluctuating physico-chemical conditions of estuaries limit the diversity of organisms. Only a few organisms can able to adapt to life in estuaries under stress condition. The above study showed that the physic-chemical parameters and the benthic abundance are extensively fluctuated seasonal and also diurnal. So we may conclude the tidal action may take a greater part for the variability of abiotic and biotic parameters in Dhamra estuarine system. The community structures of macro benthos are basically decided by several physic-chemical and biological factors [Veloso et al 2003; Defeo and McLachlan 2005]. Light, temperature, depth, salinity, dissolved oxygen, nutrients, circulation, tidal exposure, sediment grain size, the turbulence of water, organic content and the substratum can take the vital role for the growth and survival of macro benthic community. Beside these, biological factors like food availability, feeding activities, prey-predator relationship and species removal, reproductive effects on breeding, spawning, dispersal and settlement behavioural effects which induce movement and aggregation, the presence of symbiotic organisms, growth and mortality also take an active part for their existence (Sharma et al 2016 a). The macro benthic diversity and population at Dhamra Estuary was found to be low than other coast of Bay of Bengal. Seasonal and diurnal study showed the study area was mainly dominated by polychaetes species. The dominance of polychaeta group clearly explained that the estuarine area

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is under pollution stress. This may due to movement of localised trawlers boats and port activity. The discharge of oils and toxic organic load may destroy or totally rooted out many juvenile macro faunal animals which make the loss of diversity and ecological balance. The anthropogenic influx leads to retard their growth and metabolism.

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