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Distribution, density and community ecology of macrobenthic intertidal polychaetes in the coastal tract of Midnapore, West Bengal, India

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Abstract

Species composition, distribution, seasonal variation of population density and community structure of polychaete fauna in the coastal tract of Midnapore District were studied during 2000-2002. The effects of ecological parameters such as temperature, salinity, dissolved oxygen, pH, sediment texture and organic matter on the distribution, density and community of polychaetes were assessed. Eighteen species of polychaetes belonging to 13 genera and 10 families were recorded. Species belonging to the sub group Errantia were found to be more abundant than those belonging to the sub group Sedentaria. Community indices like species diversity index, species richness index, evenness index and dominance index differed among the study sites and seasons.

Keywords: Polychaetes, intertidal belt, Midnapore coastal tract, ecological parameters, distribution

Introduction

The intertidal belt of coastal Midnapore is enriched with macrobenthic fauna of which polychaetes constitute an important component. The taxonomy, biology and ecology of estuarine macrobenthic polychaetes have been well studied in India including the mangrove-estuarine complex of Sundarbans, West Bengal (Fauvel, 1932, 1953; Misra *et al.*, 1984; Harkantra and Parulekar, 1985; Chakraborty and Choudhury, 1994; Sunil Kumar and Antony, 1994; Sunil Kumar *et al.*, 1995; Misra, 1995). However, no study has so far been made from Midnapore coastal belt. The present paper describes the species composition, distribution and seasonal variation of the intertidal polychaete fauna from Midnapore coastal tract in relation to ecological parameters.

Materials and methods

Monthly samplings of benthic fauna were made from three selected intertidal zones of the coastal tract of Midnapore (87^{0}5′ E to 88^{0}5′ E and 21^{0}30′ N to 22^0 2′ N), namely, study site-I (Junput), II (Sankarpur) and III (Talsari) from July 2000 to June 2002 (Fig. 1). Seasons are well represented, each with four months duration. The premonsoon period (March-June) is recognized as the dry season with considerably higher temperature. The southwest

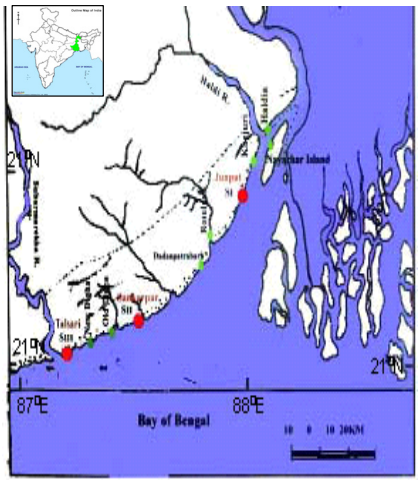

Fig. 1. Coastal tract of Midnapore District with study sites: I (Junput), II (Sankarpur) and III (Talsari)

monsoon season (July-October) is accompanied by heavy rainfall and postmonsoon (November-February) is with comparatively lower temperature and less precipitation.

The selection of the three study sites of the coastal tract of Midnapore District was made considering their contrasting ecological conditions. The study site I is an extensive mudflat with least mangrove vegetation; II is a narrow mudflat having moderate presence of mangrove vegetation in the vicinity of fishing harbour; and III is an intertidal belt having both mudflat and sand flat with good mangrove patch, but in depleting condition. Scattered patches of mangrove vegetation in the study sites include *Avicennia officinalis, A. alba, A. marina, Acanthus ilicifolius, Ipomea pescaprae, Salicornia brachiata, Suaeda maritima* etc.

Quadrates of 6"x 6" area were established for the quantification of polychaetes using a box corer. Random samplings were made at different spots at consistent positions along transects traversing the intertidal zone in the three sites starting from LTL - low tide level, MTL - mid tide level and HTL - high tide level of each site. Three transects were thus established at each study site, each including ten samples. The fauna inhabiting in each quadrate were sorted out carefully by using a sieve with 0.5mm mesh size and counted. The average population density of polychaetes have been expressed as number/m^2 .

In order to determine the abundance of different polychaete species, relative abundance was calculated at the three tidal levels *viz.*, LTL, MTL and HTL. The most numerically abundant species was ranked one (Shaw *et al*., 1983), and other community indices like relative abundance (Tamura, 1967), species diversity index (Shannon and Weaver, 1949), species richness index (Menhinick, 1964), index of dominance (Simpson, 1949) and species evenness index (Pielou, 1966) were computed.

The temperature of interstitial water was measured with a mercury thermometer having 0.1ºC graduation. pH of water was measured using a portable pH meter. Dissolved oxygen (DO) content and Biochemical Oxygen Demand (BOD) of interstitial water were estimated by employing method of Strickland and Parsons (1968). The salinity of interstitial water was determined by employing Knudson method (Strickland and Parsons, 1968). The total phosphate phosphorus and total nitrogen of interstitial water were determined by a standard method (APHA, 2005). Textural compositions of soils were estimated by means of mechanical analysis following international pipette method as illustrated by Banerjee and Chattopadhyay (1980).

Results

***Ecological parameters*:** Ecological parameters studied from the selected study sites through different months, seasons and years are shown in Fig. 2. Water temperature ranged from 20.8ºC to 32.8ºC and in the sediment, from 20.1ºC to 34.8ºC. Salinity of water showed annual variations from 8.6 ‰ to 26.0 ‰ and in the sediment from 10 ‰ to 33.4 ‰. Salinity was high at site-I followed by site-II and site-III. The lowest salinity was observed during the southwest monsoon (July-October) in all the three study sites and the highest was recorded during premonsoon (March-June) followed by postmonsoon (November-February). The dissolved O_2 ranged from 3.24 mg/l to 5.47 mg/l. The highest value of dissolved O_2 was during monsoon and the lowest was during premonsoon. The pH of water and sediment ranged from 7.15 to 8.17 and from 7.68 to 8.72 respectively.

***Sediment texture*:** The textural components of the sediment in the coastal tract of Midnapore District varied not only between the three sites but also between the three tidal levels of each intertidal belt. The substratum of site I and II was mainly composed of clay and silt with an admixture of sand. At HTL of site I and II, the substratum was composed of mainly sand with an admixture of silt and clay. Textural analysis of sediment from site III revealed higher percentage of sand followed by silt and clay at LTL, MTL and HTL (Table 1).

***Population density*:** Eighteen species of polychaetes belonging to 13 genera and 10 families were recorded in the three sites (Table 2). The population density of different polychaete species

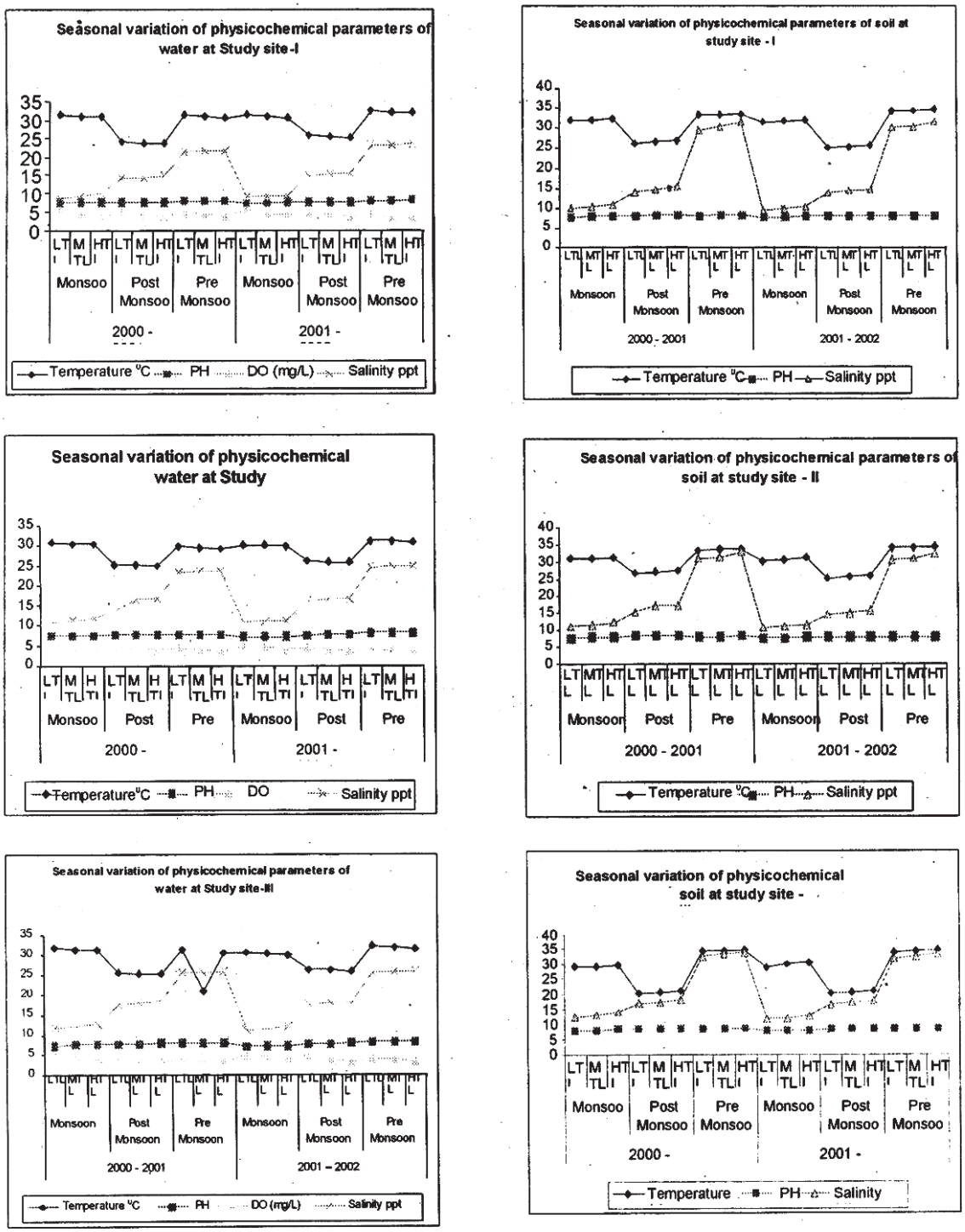

Fig. 2. Seasonal variation of physicochemical parameters of interstitial water and soil at study sites I, II and III

Table 1. Seasonal variation in soil composition (%) at study sites I, II and III

Composition	2000 - 2001									2001 - 2002								
	Monsoon			Postmonsoon			Premonsoon			Monsoon			Postmonsoon			Premonsoon		
	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL
Study site – I (Junput)																		
Sand	3.3	5.6	54.2	5.2	7.8	55.3	8.4	9.2	57.4	3.8	5.2	52.6	6.3	6.9	54.8	7.9	8.7	58.6
Silt	44.3	48.8	38.4	50.4	51.2	39.6	50.8	51.8	38.2	45.2	47.5	39.5	51.8	52.3	39.5	52.3	53.2	36.5
Clay	52.4	45.6	07.4	44.4	41	5.1	40.8	39	4.4	51.0	47.3	7.9	41.9	40.8	5.7	39.8	38.1	4.9
Study site –II (Sankarpur)																		
Sand	8.2	10.3	40.9	9.8	11.2	42.3	10.3	11.6	44.3	8.6	11.2	42.7	10.4	10.6	44.2	12.4	11.2	48.7
Silt	46.4	45.2	39.4	46.8	46.1	48.4	46.7	46.5	49.2	45.8	46.3	38.5	45.9	45.7	47.8	47.2	45.9	50.1
Clay	45.4	44.5	19.7	43.4	42.7	9.3	43.0	41.9	6.5	45.6	42.5	18.8	43.7	43.7	8.0	40.4	42.9	1.2
Study site –III (Talsari)																		
Sand	85.5	88.2	94.5	93.4	94.6	95.8	92.4	94.3	96.2	86.4	90.4	94.4	94.2	95.2	95.6	93.3	96.2	97.4
Silt	2.5	3.4	3.5	2.5	2.6	2.5	3.4	2.5	2.4	4.3	4.8	4.6	3.8	3.0	3.4	5.2	2.6	1.66
Clay	12.0	8.4	2.0	4.1	2.8	1.7	2.2	3.2	1.4	9.3	4.8	1.0	2.0	1.8	1.0	1.5	1.2	0.94

varied considerably from season to season (Fig. 3). Maximum densities of *Talehsapia annandalei* (4-101/m^2), *Lumbrinereis polydesma* (4-115/m^2) and *Diopatra cuprea* (86-490/m^2) were recorded during premonsoon while *Perinereis nuntia* (32-338/m^2), *Eteone ornata* (22-364/m^2) and *Mastobranchus indicus* (14-331/m^2) occurred in maximum numbers during monsoon. Higher abundance of *Glycera alba* (18-187/m^2) and *Maldane sarsi* (36-652/m^2) were recorded during postmonsoon season.

***Community indices*:** Following Bookmann-Jerosch scale (Tamura, 1967), the polychaetes were ranked in each tidal level depending upon the relative abundance for two consecutive years as shown in Table 3. Out of six species at site I, four species were classed as dominant at LTL and MTL and one species as subdominant and two species as dominant at HTL. At site-II, out of five species of polychaetes, four at LTL were as dominant, all five species were dominant at MTL and two were dominant at HTL. At site-III, five species of polychaetes were recognised as dominant and three species as subdominant at LTL, at MTL six species came out as dominant, three species as subdominant and one species was rare. At HTL, three species were dominant and one species as subdominant.

The maximum value of species richness index was found during premonsoon and that of minimum during monsoon. The dominance index was the highest during postmonsoon and the lowest was observed during premonsoon. Species diversity index exhibited maximum value during premonsoon and minimum during postmonsoon. The highest and lowest values of evenness index were observed during premonsoon and postmonsoon respectively (Table 4).

***Statistical analysis*:** The result of correlation coefficient between population density of different polychaete species and physicochemical parameters of water and soil at site I showed significant negative correlation of *Perenereis cultrifera, P. nuntia, Neanthes chingrighattensis, Lycastonereis indica and M. indicus* with pH . Salinity of water displayed same relationship with *P. nuntia, N. chingrighattensis, L. indica and M. indicus*. Significant positive correlation was found between *N. chingrighattensis* and *M. indicus* with DO and *T. annandalei* with water temperature. Significant positive correlation was observed between *P. nuntia, N. chingrighattensis* and *L. indica* with moisture of soil while the correlation was significantly negative for *L. indica and M. indicus*

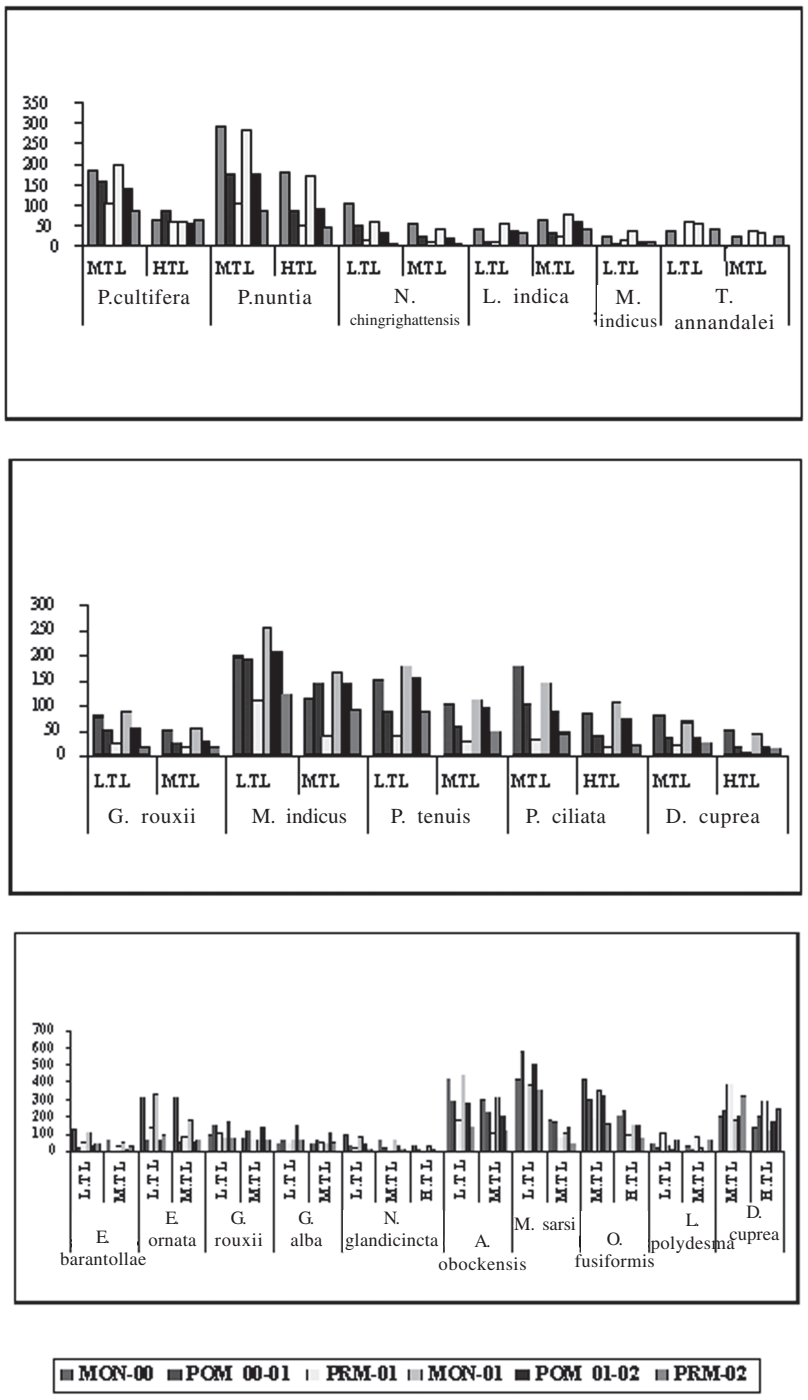

Fig. 3. Seasonal fluctuations in densities (number /m^2) of polychaete species at study sites I, II and III; Mon = monsoon; Pom = postmonsoon; Prm = premonsoon

Table 2. Distribution of polychaetes in the three study sites in the coastal belt of Midnapore District

Species	S-I Junput	S-II Sankarpur	S-III Talsari
Sub Class : Errantia			
Family: Phyllodocidae			
Eteone ornata Grube	-	-	+++
Eteone barantollae Fauvel	-	-	++
Family: Glyceridae			
Glycera rouxii	-	++	+++
Glycera alba Rathke	-	-	++
Family: Nereidae			
Perinereis cultrifera	+++	-	-
Perinereis nuntia Saviguy	+++	-	-
Neanthes chingrighattensis	++	-	-
Lycastonereis indica	++	-	-
Nereis glandicincta	++	-	++
Family: Hesionidae			
Talehsapia annandalei Fauvel	++	-	-
Family: Lumbrinereidae			
Lumbrinereis polydesma	-	-	+
Family: Eunicidae			
Diopatra cuprea Bosc	-	++	+++
Sub Class: Sedentaria			
Family: Capitellidae			
Mastobranchus indicus	+	+++	-
Paraheteromastus tenuis Monro	-	++	-
Family: Spionidae			
Polydora ciliata	-	++	-
Family: Maldanidae			
Axiothella obockensis Gravier,	-	-	+++
Maldane sarsi	-	-	+++
Family: Oweniidae			
Owenia fusiformis Delle Chiaje	-	-	++

+++ Highly abundant, ++ Moderately abundant, + Occasional visitor, - Not found.

with pH and for *N. chingrighattensis* with salinity of soil (Table 5).

At site-II, significant positive correlation was recorded between *Glycera rouxii, Polydora ciliata* and *D. cuprea* with DO while *G. rouxii, M. indicus*, *Paraheteromastus tenuis, P. ciliata* and *D. cuprea* showed significant negative correlation with pH and salinity of water. In soil, moisture exhibited significant positive correlation with *G. rouxii, M. indicus*, *P. tenuis* and *D. cuprea* and correlation was found significantly negative for *G. rouxii, M. indicus*, *P. tenuis, P. ciliata* and *D. cuprea* with salinity and for *G. rouxii* and *P. ciliata* with pH (Table 5).

At site-III, significant positive correlation was displayed by *E. barantollae, E. ornata,* and *L. polydesma* with temperature, by *D. cuprea* with pH and by *L. polydesma* with salinity and by *E. barantollae, E. ornate, N. glandicincta, A. obockensis* with DO. Significant negative correlation was noted between *E. barantollae, E. ornata, N. glandicincta, A. obockensis, M. sarsi* and *O. fusiformis* with pH and salinity of water. Physicochemical parameters of soil like temperature showed significant positive correlation with *L. polydesma,* pH with *D. cuprea,* moisture with *N. glandicincta, A. obockensis* and *O. fusiformis* and salinity with *L. polydesma* and *D. cuprea*. Significant negative correlation was noted for soil temperature with *G. rouxii* and *M. sarsi*, for pH with *E. barantollae* and *E. ornate*, moisture with *D. cuprea* and salinity with *N. glandicincta, A. obockensis* and *O. fusiformis* (Table 5).

Discussion

The most important physical factor that controls the distribution and abundance of benthic fauna, particularly the polychaete fauna, is the nature of the substratum (Sanders, 1958; Woodin, 1981; Azovsky *et al*., 2000; Paul, 2002). The faunal distribution in relation to the type of the sediment shows high species diversity and richness in the sandy substratum. High population density and diversified species with sandy substratum was reported earlier by many workers (Stickney and Stringer, 1957; Sanders, 1968; Horikoshi, 1970; Holland and Polgar, 1976; Chandran *et al.*, 1982). The present study shows no direct correlation between the density of polychaete fauna and the organic content of the sediment. The maximum number of species (10) was recorded in site-III (Table 2) and this was supposed to be due to mixed nature of the soil in this area (Table 1). In this investigation, high population density of the polychaete fauna was observed at MTL and LTL. In general, the polychaete population was poor in

Table 3. Species composition, relative abundance (%) and rank of polychaetes in three tidal levels

Sl. No.	Species	Relative abundance (%) at LTL	Rank at LTL	Relative abundance (%) at MTL	Rank at MTL	Relative adundance (%) at HTL	Rank at HTL
	Study site – I (Junput)						
1	*Perinereis cultrifera*	-	-	33.8***	2	38.6***	2
2	*Perinereis nuntia* Saviguy	-	-	43.5***	1	61.4***	1
3	*Neanthes chingrighattensis*	35.9***	1	6.1***	4	-	-
4	*Lycastoneries indica*	24.6***	3	11.7***	3	-	-
5	*Mastobranchus indicus*	13.4***	4	-	-	-	-
6	*Talehsapia annandalei* Fauvel	25.8***	2	4.8**	5	-	-
	Study site – II (Sankarpur)						
1	*Glycera rouxii*	14.7***	3	8.7***	5	-	-
2	*Mastobranchus indicus*	51.9***	1	32.1***	1	-	-
3	*Paraheteromastus tenuis* Monro	33.3***	2	20.1***	3	-	-
4	*Polydora ciliata*	-	-	26.9***	2	69.9***	1
5	*Diopatra cuprea* Bosc	-	-	12.05***	4	30.1***	2
	Study site – III (Talsari)						
1	*Eteone barantollae* Fauvel	4.9**	5	2.2*	10	-	-
2	*Eteone oranata* Grube	13.5***	2	9.7***	5	-	-
3	*Glycera rouxii*	8.9***	3	6.67***	6	-	-
4	*Glycera alba* Rathke	5.8***	4	4.9**	7	-	-
5	*Nereis glandicincta*	3.7**	6	2.5**	9	3.6**	4
6	*Axiothella obockensis* Gravier,	23.07***	1	17.2***	4	-	-
7	*Maldane sarsi*	-	-	35.7***	1	9.3***	3
8	*Owenia fusiformis* Delle Chiaje	-	-	23.6***	2	42.4***	2
9	*Lumbrinereis polydesma*	-	-	2.7**	8	-	-
10	*Diopatra cuprea* Bosc	3.5**	7	20.9***	3	53.9***	1

*** = Dominant (>5%), ** = Subdominant (>2.5%), * = Rare (<2.5%)

Table 4. Community indices for polychaetes through different seasons in three study sites (Junput-SI, Sankarpur-SII and Talsari– SIII); Mon= Monsoon, Pom = Postmonsoon, Prm = Premonsoon

Seasons	**Community Indices**											
	Richness index			**Dominance index**			**Diversity index**			**Evenness index**		
	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III	S-I	S-II	S-III
Mon-2000	0.25	0.22	0.28	0.50	0.52	0.44	0.48	0.46	0.81	0.87	0.90	0.93
Pom – 2000-01	0.28	0.26	0.29	0.59	0.57	0.51	0.44	0.43	0.79	0.84	0.89	0.92
Prm - 2001	0.39	0.31	0.43	0.45	0.48	0.39	0.57	0.55	0.86	0.89	0.94	0.99
Mon-2001	0.26	0.23	0.27	0.47	0.51	0.44	0.49	0.45	0.82	0.88	0.92	0.94
Pom – 2001-02	0.29	0.25	0.34	0.53	0.67	0.50	0.46	0.42	0.78	0.85	0.90	0.92
Prm - 2002	0.38	0.33	0.41	0.48	0.51	0.43	0.56	0.54	0.85	0.87	0.93	0.98

Table 5. Correlation coefficient analysis between population densities of different polychaete species with physicochemical parameters of water and soil at study sites - I, II and III (W - water, S - soil, LTL - low tide level, MTL – mid tide level, HTL – high tide level); *significant, **highly significant

Polychaetes		Temperature			pH			DO			Moisture			Salinity		
		LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL	LTL	MTL	HTL
Site I																
P. cultrifera	*w*	0	-.043	-.043	0	-.525**	-.102	0	.395	-.093				0	.387	-.272
	s	-	-	-.187	-	-	.3712				-	-	.006-	-	-	-.102
P. nuntia	*w*	0	.002	.054	0	-.598	-.645**	0	.455	.309				0	.178	-.917**
	s	-	-.277	-.028	-	-.576	-.687				-	.968**	.959**	-	-.946	-.865*
N. chingrighattensis	*w*	-.006	.117	-	-.521**	-.457*	-	.410*	.372	-				-.852**	.433*	-
	s	-.121	-.040	-	-.148	-.609	-				.854*	.908**	-	-.825*	-.840*	-
L. indica	*w*	.360	.170	-	-.296	-.436*	-	.079	.192	-				-.510	.317	-
	s	.189	-.054	-	-.871*	-.951**	-				.671	.865*	-	-.480	-.748	-
M. indicus	*w*	.288	-	-	-.542**	-	-	.427*	-	-				-.639**	-	-
	s	.372	-	-	-.832*	-	-				.699	-	-	-.494	-	-
T. annandalei	*w*	.618**	.580**	-	-.125	-.073	-	-.054	0.48	-				.022	-.153	-
	s	.917*	.865	-	-.129	-.302	-				-.101	-.049	-	.363	.298	-
Site II																
G. rouxii	*w*	*.085*	.264	-	-.683**	-.592**	-	.471*	.359	-				-.906**	-.834**	-
	s	-.412	-.169	-	-.774	-.845*	-				.993**	.955*	-	-.935**	-.852*	-
M. indicus	*w*	-.026	-.311	-	-.599**	-.455*	-	.221	.238	-				-.800	-.706**	-
	s	-.620	-.709	-	-.592	-.258	-				.927**	.756	-	-.942**	-.839*	-
P. tenuis	*w*	.105	.125	-	-.609**	-.536**	-	.294	.295	-				-.782**	-.800*	-
	s	-.458	-.481	-	-.741	-.734	-				.870*	.924**	-	-.845*	-.917**	-
P. ciliata	*w*	-	.113	.127	-	-.609**	-.719**	-	.412*	.347				-	-.869**	-.875**
	s	-	-.315	-.094	-	-.666	-.859*				-	.976	.914	-	-.910*	-.799
D. cuprea	*w*	-	.319	.334	-	-.612**	-.575**	-	.474*	.385				-	-.849**	-.797**
	s	-	-.121	.020	-	-.801	-.693				-	921**	.621	-	-.818*	-.522
Site III																
E. barantollae	*w*	.671**	.708**	-	-.437*	-.231	-	.306	.422*	-				-.607**	-.496*	-
	s	*.437*	.536	-	-.842*	-.916	-				.596	.516	-	-.426	-.335	-
E. ornata	*w*	.616**	.644**	-	-.561**	-.440*	-	.328	.535**	-				-.707**	-.723**	-
	s	.344	.230	-	-.844*	-.725	-				.668	.687	-	-.512	-.538	-
G. rouxii	*w*	-.755**	-.731**	-	.162	.090	-	-.129	-.180	-				.100	-.011	-
	s	-.866*	-.970**	-	.542	.689	-				.053	.260	-	-.245	-.430	-
G. alba	*w*	-.527**	-.545**	-	.207	.256	-	-.094	-.300	-				-.169	.196	-
	s	-.650	-.745	-	.165	.589	-				-.006	-.013	-	.150	-.155	-
N. glandicincta	*w*	.282	.341	.355	-.610**	-.539**	-.526**	.380	.509*	.501*				-.892**	-.853**	-.837**
	s	-.232	-.138	-.057	-.807	-.694	-.706				.961**	.944**	.916*	-.897*	-.871	-.803
A. obockensis	*w*	.158	.128	-	-.693**	-.673**	-	.441*	.542**	-				-.942**	-.947**	-
	s	-.313	-.373	-	-.747	-.479	-				.978**	.994**	-	-.931**	-.968**	-
M. sarsi	*w*	-.624**	-.008	-	-.016	-.453*	-	-.100	-.233	-				-.168	-.684**	-
	s	-.910*	-.731	-	.451	.136	-				.226	.753	-	-.397	-.799	-
O. fusiformis	*w*	-	.129	-.085	-	-.432*	-.473*	-	.305	.276				-	-.777**	-.711**
	s	-	-.493	-.706	-	-.322	-.338				-	.967**	.808	-	-.953**	-.791
L polydesma	*w*	.380	.420*	-	.212	.342	-	-.105	.147	-				.568**	.566**	-
	s	.904*	.865*	-	.208	-.197	-				-.704	-.740	-	.821*	.852*	-
D. cuprea	*w*	-	.038	-.194	-	.587**	.642**	-	-.393	-.389				-	.845**	.902**
	s	-	.594	.420	-	.323	.856*				-	-.937**	-.925**	-	.970**	.951**

the HTL. The firm substratum with dense roots seems to consolidate the substratum, which was supposed to be the main reason for the lower population density of polychaete fauna at HTL. Which remained exposed completely during low tide (Sunil and Antony, 1994). Polychaetes mostly prefer an unconsolidated substratum where burrowing is easy (Misra *et al*., 1984).

Among different ecological parameters studied, salinity was the most fluctuating factor which appeared to have direct influence on the distribution and abundance of polychaete fauna. Increase in temperature and salinity during premonsoon and postmonsoon period probably shows a favorable ecological condition for the settlement of polychaetes. The other ecological parameters such as dissolved oxygen and pH of the water do not seem to act as limiting factors for the polychaete fauna in the given conditions.

A dominant species may exert a powerful control over the occurrence of other species. It is contended that the controlling influence in the communities is divided among fewer species in extreme environmental conditions. The dominance index is always higher, where the communities are dominated by less number of species and lower when the dominance is shared by a large number of species (Whittaker, 1965). The present study shows that the maximum dominance is during the postmonsoon season and minimum during the premonsoon season (Table 4).

In the present study, species diversity index was registered higher during the premonsoon season (Table 4) implying the existence of long food chains and more cases of symbiosis and greater possibilities for positive or negative feedback control, which may reduce oscillations and hence increase stability (Margalef, 1968).

Species evenness index is the expression of abundance *i.e*., how equally the species are abundant. High evenness occurs when species are equal or virtually equal in abundance. In the present study, highest evenness value was observed during premonsoon season and lowest during postmonsoon season (Table 4).

Species richness index is expressed by ratio between total number of species and total number of individuals. It is known to increase with increased complexity in a community and decrease where simplification occurs within a community (Bhattacharya and Bhattacharya, 1983). Magurran (1988) opines that species richness is a measure of number of species in a defined locality. In the present study species richness value was measured highest during premonsoon season and lowest during monsoon season (Table 4).

Seasonal fluctuations have been found both in species diversity and dominance indices in the three study sites. However, there existed an inverse relationship between these two indices and such relationship also revealed seasonal variation among different study sites (Table 4).

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