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Polychaete community structure of Vasishta Godavari estuary, east coast of India

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Abstract

The community structure of polychaete fauna from the Vasishta Godavari estuary was analyzed in this study. The data presented in this paper were collected during 1976 - 78 and published in 1983, and now re-analysed using PRIMER 6.1, CANOCO 4.5. The polychaetes were collected from a 16 km stretch of the lower Vasishta Godavari estuary (16°18'N lat., 81°42'E long.) during flood, summer and recovery seasons at 6 permanent stations. Altogether 216 sediment samples were analysed and 73 polychaete taxa were identified. Polychaete diversity was higher (Shannon-Wiener H': 1.94±0.28) in samples from recovery season relative to summer season (H': 1.54±0.44) and flood season (H': 1.44±0.024). Using multivariate statistical techniques two polychaete associations could be recognised from the Vasishta Godavari estuary, namely *Heteromastus similis*, *Nephthys oligobranchia* and *Indonereis gopalai* assemblage Group 1 (samples from recovery and summer season) and Group 2 (samples from flood season). Group 2 did not reveal any particular species from flood season samples. Canonical correspondence analysis (CCA) showed that sand, salinity, clay and temperature have influenced the polychaete distribution. This study therefore provides key information on the biodiversity of polychaete communities of the Vasishta Godavari estuary.

Keywords: Polychaete community, Multivariate analysis, Canonical correspondence, Vasishta Godavari estuary

Introduction

Benthic organisms have an important role (Desai, 1973; Wolff *et al.,* 1976) in the food chain, either at secondary level as feeders of detritus and plant materials or at tertiary level as food for predators like crabs and fishes. Hence, the availability of benthos at a region may be an indicator of demersal fishery potential. The polychaetes are one of the dominant macrobenthic groups in most marine habitats (Mackie and Oliver, 1996; Hutchings, 1998), and their distribution patterns often reflect those of the benthic fauna as a whole (Mackie *et al.*, 1997). Polychaetes are a quantitative key component of benthic fauna in soft substrata (Gambi and Giagrande, 1986). The significant contribution of benthic macrofauna as food sources of demersal predatory fish and others was stressed by Leeuven *et al.* (1985) and Steimle (1985). Twenty-five years ago Srinivasa Rao and Rama Sarma (1983) published a paper on the abundance and distribution of intertidal polychaetes in the Vasishta Godavari estuary. At that time the statistical analysis was done manually and this data is still unique in the sense that no further work was done in that area. We analysed the same data now with the modern statistical software namely, PRIMER 6.1, CANOCO 4.5. In recent years, multivariate methods have been the main forte for distinguishing changes in biological communities in the sea *vis-á-vis* environmental conditions (Clarke and Warwick, 1994). In the case of macrobenthos, a number of studies exist relating to species composition and abundance patterns with ambient sea conditions. In the Indian context multivariate statistical approaches explaining cause-effect relationships among polychaete communities, however, remain fragmentary. The aim of the present paper is to assess species richness in the Vasishta Godavari estuary in order to provide baseline information for future monitoring. This is the first paper that deals with the polychaete community at the species level in this area.

Material and Methods

River Godavari the second largest in India, divides into two branches namely the Vasishta Godavari and Gautami Godavari. The Vasishta Godavari opens into the Bay of Bengal at Antervedi (16°18'N lat.and 81°42'E long.) and the tidal range in the estuary is 1 to 1.5 m. However, only a 16 km stretch of the lower reaches were fixed along the bank of the estuary against permanent land marks for regular sampling (Fig.1). Altogether 270 samples were collected during September 1976 – January 1978, covering six stations. For the present study, 216 samples from January 1977 to December 1977 were re-analysed and based on the salinity fluctuations in the estuary, the year was divided into three well defined periods: (i) the annual freshwater flood period (July-October) when the entire estuary is filled with freshwater at all levels; (ii) the recovery period (November–February) marked by the cessation of high floods and gradual inflow of neretic waters into the estuary; (iii) the high saline period (March–June) when the neretic waters dominate and salinities around 27 psu are encountered even at 16 km up the estuary. Methods of collection of samples and their analyses were published earlier (Srinivasa Rao and Rama Sarma, 1983).

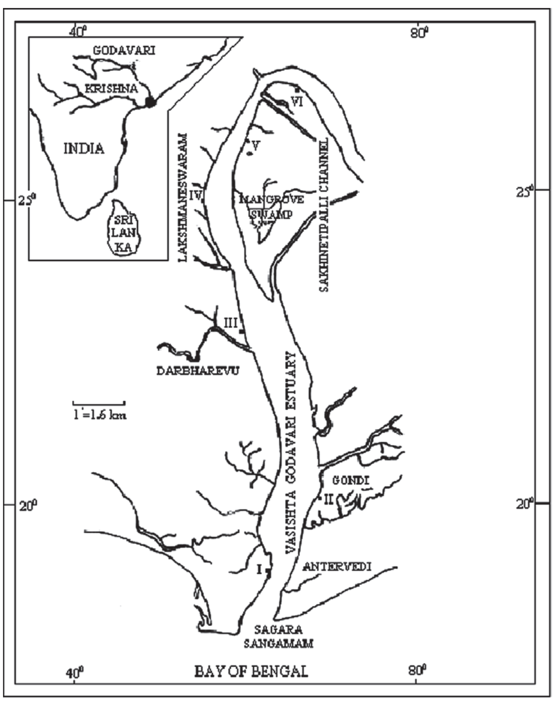

Fig. 1. Vasishta Godavari estuary showing six sampling stations

Data analysis: Univariate measures used included like species richness, Shannon–Wiener (H' $\log_e$) and evenness (J'). Multivariate analysis consisted of estimating Bray–Curtis similarity after suitable transformation of sample abundance data. The similarity matrix was subjected to both clustering (hierarchical agglomerative method using group average linking) and ordination (non metric multidimensional scaling, MDS) using PRIMER 6 (Clarke and Gorley, 2006). Significance tests of sample groupings were made using ANOSIM (1-way) randomization test. The contribution of each species to groupings noticed in the cluster and ordination analysis was examined using SIMPER (similarity percentages) implemented in PRIMER (Clarke and Warwick, 1994) to quantify percentage contribution of each species to similarity within each group (*i.e.* characteristic) of samples and to dissimilarity between different groups. Other routines (*e.g.* BVSTEP), namely step-wise search of combinations of species considered to be ultimately responsible for the observed pattern in the biotic assemblages was carried out by using PRIMER. Canonical correspondence analysis (CCA) (CANOCO 4.53, ter Braak, 1986, ter Braak and Smilauer, 2002) was performed to evaluate possible correlations between environmental variables, polychaete species and variance in site pattern, using a form of step-wise regression. A Monte Carlo permutation test (unrestricted) was used to determine the significance of species–environment relationships.

Results

Monthly changes in hydrographical parameters at six stations were presented in the paper published by Srinivasa Rao and Rama Sarma (1983) whereas in this paper seasonal changes were considered. In the Vasishta Godavari, the bottom water hydrographical conditions varied appreciably (ANOSIM, Global R = 0.719, p = <0.005). Spatially there were differences in the sediment structure (ANOSIM, Global R = 0.005, significance p = <0.005). The predominant texture class in several cases were sand-silt-clay (6), sandy silt (6), silty sand (4), followed by clayey–silt (1) and sand (1) (Fig. 2). Sediment organic matter also varied appreciably (ANOSIM, Global R = 0.343, p = <0.005) in relation to nature of the sediment and seasons (Table 1, Fig. 3).

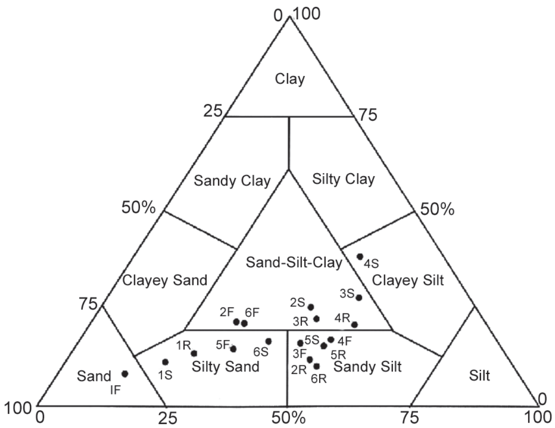

Fig. 2. Triangular graph - sediment texture; 1 - 6 stations; S - Summer, F - Flood, R - Recovery

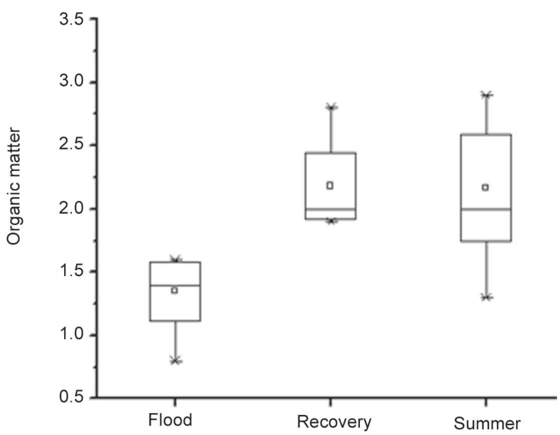

Fig. 3. Box and Whisker plot of sediment organic matter (%) for three seasons. Data presented as mean (□) ±1 S.D (boxes) and Upper '×': maximum; Lower '×': minimum

A total number of 99,865 polychaete specimens belonging to 16 families, 32 genera and 42 species were collected during the period of study with an average density of 308/m^2. The dominant polychaetes were *Heteromastus similis* (30.6%), *Nephthys oligobranchia* (18.2%), *Nereis lamellosa* (15.6%), *Indonereis gopalai* (11.0%), *Dendronereis arborifera* (8.2%) and *Magelona cincta* (3.0%).

Classification of analyses (using Bray–Curtis similarity) followed by an ordination through MDS on polychaete data (no/10cm^2) were undertaken. Figs. 4 and 5 show results of hierarchical clustering using group average linking on species abundance data representing three seasons (flood, recovery and summer). Bray–Curtis similarities were calculated on square root transformed abundance of polychaetes. From the resulting dendrogram (Fig. 4), it was possible to classify the sites into two groups (seasonal categories) determined at 62% similarity. These consisted of group 1 (12) samples representing recovery and summer seasons, group 2 (6) samples representing flood season. The dendrogram provided a sequence of groups confirmed by the MDS plot. A corresponding cluster of these site/samples superimposed with season categories is presented Fig. 5.

Table 1. Environmental characteristics of Vasishta Godavari estuary during January 1976 to December 1977; data presented as mean ± SD; values in parenthesis refer to the range

Parameter	Flood	Recovery	Summer
Temperature (^{0}C)	35.1±0.88 (33.7-36.30)	31.6±1.02 (29.7-32.68)	34.5±1.03 (32.9-35.7)
Salinity (psu)	5.80±2.69 (2.3-9.9)	16.2±1.88 (13.41-18.23)	30.4± 14.03 (20.4-57.7)
Dissolved oxygen (ml/l)	4.2±0.73 (3.2—5.0)	4.6±0.55(3.7-5.27)	4.7±0.78 (4.1-6.2)
Sand (%)	48.3±15.09 (35.0-77.5)	38.4±12.49 (22.92-60.32)	36.0±18.56 (15.1-67.2)
Silt (%)	35.1±10.98 (15.20-47.4)	44.2±10.51 (24.36-56.13)	41.2±11.85 (19.7-55.4)
Clay (%)	16.6±5.03 (7.3-20.80)	17.4±3.70 (13.7-22.92)	22.8±9.03 (13.0-24.2)
Organic matter (%)	1.3±0.29 (0.8-1.6)	2.2±0.34 (1.89-2.80)	2.1±0.57 (1.3-2.5)

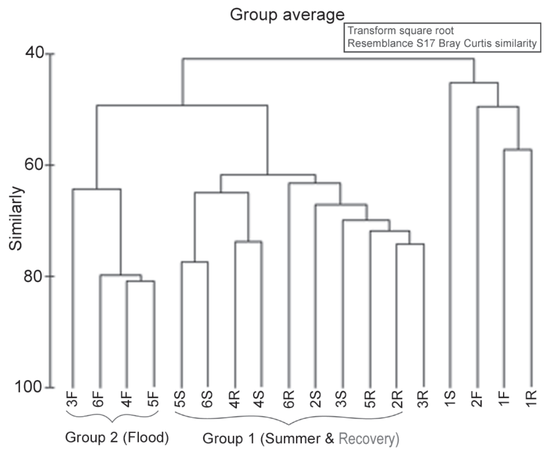

Fig. 4. Polychaetes of Vasishta Godavari estuary. Dendrogram for hierarchial clustering of 18 samples using group average linking of Bray-Curtis similarities (square root transformed abundance data).1 and 2 groups (season categories) determined at 62% similarity (straight line); 1 - 6 stations; S - Summer, F - Flood, R - Recovery

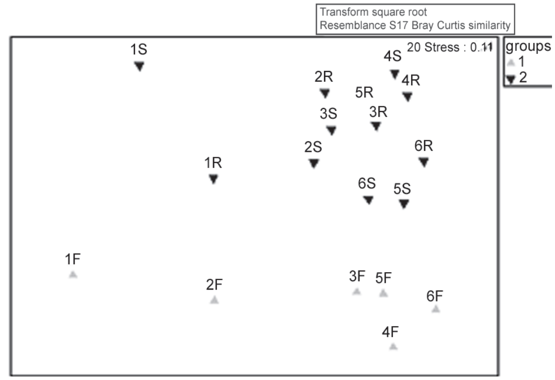

Fig. 5. Polychaetes of Vasishta Godavari estuary: Multidimensional scaling (MDS) plot superimposed with seasons. 1 - 6 stations; S - Summer, F - Flood, R - Recovery

Polychaete densities varied (nos/m^2) significantly among seasons (ANOSIM Global R=0.634, p=>0.005). The samples from summer supported up to 51% of the total population numerically, the

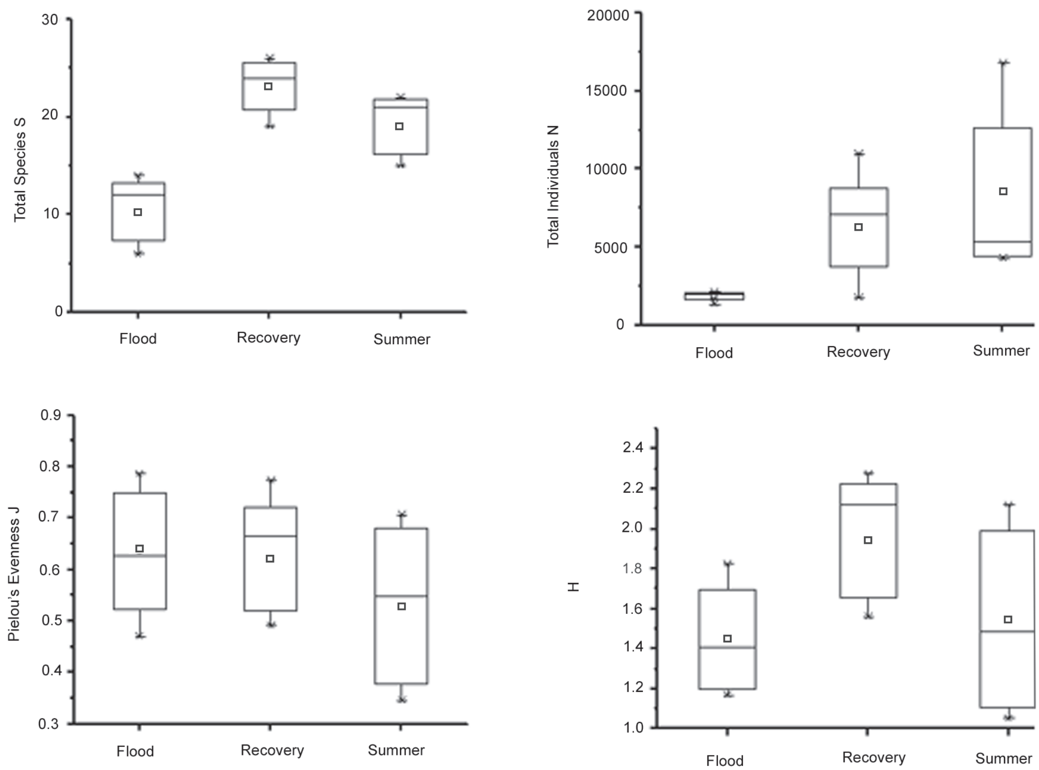

Fig. 6. Univariate measures for polychetes of Vasishta Godavari estuary. (a) No. of species; (b) abundance; (c) eveness J' ; (d) Shannon-Wiener index H' data presented as mean (□) ± SD (boxes), Upper x: maximum; Lower x: minimum

predominant species was *Heteromastus similis* (35.73%). Between the seasons, the mean polychaete abundance was 8539±5458 nos/m^2 (summer), 6279±3348 nos/m^2 (recovery) and 1825±298 nos/m^2 (flood). The polychaete abundance swiftly dwindled with seasons.

Srinivasa Rao and Rama Sarma (1983) calculated the percentage affinity among stations during salinity periods following Sanders (1960) and species diversity by rarefaction method as suggested by Sanders (1968).

In the present paper, species diversity was estimated following Shannon–Wiener H' ($\log_e$) and evenness (J') indices. In polychaetes, the Shannon–Wiener index H' (Fig. 6) was H': 1.94±0.28 (recovery), H': 1.54±0.44 (summer) and 1.44±0.024 (flood). The evenness component (J') varied in conformity with H'. The low evenness (0.38) is indicative of the presence of large numbers of certain taxa (*e.g. Heteromastus similis*) in the population.

The analysis presented in the present paper has clearly indicated the evenness and diversity of polychaetes in the study area in three seasons. In the earlier publication (Srinivasa Rao and Rama Sarma 1983), higher species diversity was reported whereas the present analysis showed lower species diversity. Because of the wide fluctuations in salinity, sediment composition and possibly other physical and chemical parameters, the Vasishta Godavari estuary may be expected to belong to a physically controlled area in the sense of Sanders (1968) and hence to exhibit a low diversity. The salinity ranges from near zero to 35 psu and substratum at times becoming highly variable making the area under study highly uninhabitable.

CCA was performed on select polychaete species (identified through SIMPER, Table 2 and BVSTEP), *i.e.* on the basis of their abundance and in the light of known environmental characteristics (Table 1). It was found that axes 1 and 2 on the canonical ordination plots (Fig.7) were the most important (Table 3) since they were able to explain 80.2% of variations in species abundance data. Monte Carlo permutation tests (with forward selection) were used to identify the environmental factors that influenced the variance of polychaete distribution and species abundance pattern significantly ($p< 0.05$ level). The

(a) (b)

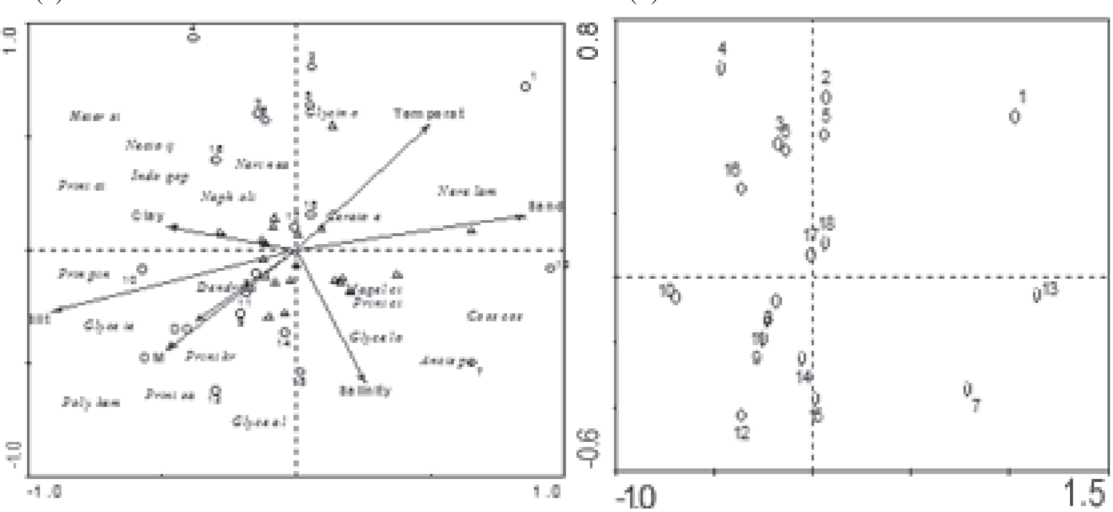

Fig. 7 (a). Canonical correspondence analysis (CCA), showing 20 most important polychaete species, environmental variables and sampling sites. Vector lines represent the relationship of significant environmental variables to the ordination axes; their length is proportional to their relative significance. (b) showing scatter plot for 18 polychaete samples of Vasishta Godavari estuary;

Temperat-Temperature; DO-Oxygen; S-Salinity; OM-Organic matter.
For full species names see Table 2.

Table 2. Distribution of important polychaete species (nos/m^2) during three seasons in the Vasishta Godavari estuary (identified through SIMPER/BVSTEP analyses)

Species	Abbreviation	Flood	Recovery	Summer
Ancistrosyllis parva	*Ancis par*	1.3 ± 3.2 (0-8)	88 ± 63 (41-208)	142±213 (24-575)
Ceratonereis erythraeensis	*Cerato erythr*	24.83 ± 29.74 (0-83)	38 ± 24 (16-67)	58±45 (8-125)
Cossura coasta	*Coss costa*	4.16 ± 10.20 (0-25)	16 ± 10 (0-25)	75±163 (0-408)
Dendronereis arborifera	*Dendro arbo*	41.16 ± 70.68 (0-183)	1034 ± 997 (58-2413)	282± 230 (50-674)
Glycera alba	*Glyce al*	-	34 ± 27 (0-74)	26±41 (0- 73)
Glycera longipinnis	*Glyce long*	8.3 ± 20.41 (0-50)	(18 ± 11) 8-34	7±10 (0-25)
Glycera tesselata	*Glyce tess*	0.7 ± 1.6 (0-4)	48 ± 35 (8-92)	46± 60 (0-158)
Glycinde oligodon	*Glycin oligo*	95.83 ± 234.74 (0-575)	-	4±7 (0-16)
Heteromastus similis	*Heter sim*	500 ± 268 (166-767)	1596 ± 1740 (141-4933)	2991±3395 (525-9756)
Indonereis gopalai	*Indo gopa*	233 ± 132 (66-391)	1108 ± 1034 (33-3008)	489 ± 337 (191-1058)
Magelona cincta	*Magel cinc*	36 ± 73 (0-183)	127 ± 122 (33-317)	336 ± 410 (8-917)
Nectoneanthes ijimai	*Necto ijim*	0.66 ± 1.63 (0-4)	96 ± 133 (0-349)	82 ± 171 (0-442)
Nephthys oligobranchia	*Neph oligo*	463 ± 376 (24-940)	769±1393 (76-2460)	1170 ± 696 (108-1850)
Nereis lamellosa	*Nere lame*	263 ± 604 (0-1495)	83±124 (0-275)	2217 ± 5351 (0-13141)
Nereis neanthes capensis	*Neri nean cape*	23 ± 23 (0-58)	93±220 (0-542)	55 ± 66 (0-183)
Polydora kempi	*Poly kemp*	4 ± 7 (0-16)	51±45 (8-108)	4 ± 4 (0-8)
Prionospio pinnata	*Prin pinn*	29 ± 60 (0-150)	78±88 (0-242)	64 ± 85 (0-183)
Prionospio saldanha	*Prini sald*	-	53±36 (0-100)	42 ± 90 (0-225)
Prionospio cirrifera	*Prini cirr*	44 ± 32 (0-83)	73±41 (17-125)	48 ± 34 (0-91)
Prionospio cirrobranchiata	*Prini cirro*	4 ± 10 (0-25)	33±52 (0-125)	125 ± 168 (0-442)
Prionospio krusadensis	*Prini krus*	-	58±73 (0-176)	-

Abbreviation used in Fig. 7a. Data presented as mean ± SD (range); - not found in the season

first CCA initially separated the samples of flood season from the samples of recovery and summer seasons. Axis 1 is strongly associated with sand (r = 0.891) and silt (r = -0.888), while salinity (r = 0.5916) and clay (r = 0.5567) are closely linked with axis 2. Single variable temperature characterized (r = 0.7273) the third axis and salinity (0.5577) the fourth axis (Table 3).

Discussion

Estuarine benthic animals are commonly thought to be distributed along gradients of physiological stress according to their environmental tolerance (Remane and Schlieper, 1971). Spatial differences in the composition of the benthic communities along estuarine gradients have been related mainly to

Table 3. Results of the CCA: Eigen values, species - environment correlations and percentage variance polychaete abundance data; weighted correlation coefficient between environmental variables and CCA axes

Axes	AX1	AX2	AX3	AX4	Total inertia
Polychaetes					
Eigen values	0.454	0.259	0.126	0.05	1
Species and environment correlations	0.919	0.737	0.754	0.731	
Cumulative percentage variance					
of species data	45.4	71.3	83.9	88.9	
and species environment relationship	58.7	80.2	91.1	95.2	
Correlation coefficient					
Temperature	0.4343	-0.0652	0.7273*	0.1789	
Salinity	0.0623	0.5916*	-0.3435	0.5577*	
Oxygen	-0.4056	0.2619	-0.1857	0.0998	
Sand	0.891*	-0.3683	0.0615	-0.1299	
Silt	-0.888*	0.1843	-0.2957	-0.0445	
Clay	-0.6137*	0.5567*	0.3599	0.389	
Organic matter	-0.5007*	0.4103	-0.3067	0.2427	

*significance at $p < 0.05$

changes in salinity, depth, sediment grain size and organic content (Day *et al.,* 1989). Polychaetes play an important role in the functioning of benthic communities (Hutchings, 1998). They have been shown to be good indicators of species richness and community patterns in benthic invertebrate assemblages (Olsgard and Somerfield, 2000; Sparks-McConkey and Watling, 2001; Van Hoey *et al.,* 2004), and have recently been proposed as surrogates for marine biodiversity (Olsgard *et al.,* 2003).

One of the objectives of this study was to locate the presence of specific polychaete species assemblages for the Vasishta Godavari estuary, east coast of India. Multivariate analyses were used to define assemblages named after the most determining taxon. Two polychaete associations could be recognised from the Vasishta Godavari estuary, namely *Heteromastus similis*, *Nephthys oligobranchia* and *Indonereis gopalai* assemblage (Group 1, samples from recovery and summer seasons) and group 2 (samples from flood season). Group 2 did not reveal any particular species from flood season samples (Table 4). No such attempt was made to establish the polychaete assemblages by Srinivasarao and Rama Sarma (1983).

During the annual flood period, station I remained distinct due to differences in the substratum composition. During the recovery phase, station I showed more than 25% similarity with all the stations. Obviously, a large number of polychaete larvae entered from the neretic end and settled at stations I to VI. This extended their distribution higher up due to the establishment of uniformly high saline conditions in the estuarine regions. In summer, because of the greater neretic influence at station I, it became distinct again not only in water quality and nature of substratum, but also faunistically.

Diversity is related to the season and nature of the substratum. While samples collected during recovery season supported species richness, the samples collected during summer season supported fauna in terms of abundance. Species richness and diversity indices are commonly used for conservation purposes and to assess ecosystem fitness (Colombini *et al*., 2003).

Using CCA routine in CANOCO linked the polychaete communities with environmental variables (sediment texture, organic matter, dissolved oxygen, salinity and water temperature). In the case of polychaete communities, the first axis of the CCA had an eigenvalue of 0.45, implying a large percentage of explained variance (ter Braak 1986; Narayanaswamy *et al.,* 2003). The noteworthy feature, however, is the high correlation (weighed correlation coefficient > 0.92) between faunal abundance and environmental variables on all CCA axes (Table 4). In the polychaete CCA ordination (Fig. 7), the distribution of species such as *Magelona cincta*, *Prionospio cirrifera, Cossura coasta, Ancistrosyllis parva* and *Glycera longipinnis* were influenced by salinity. Sand and temperature appeared to relate well with the distribution of *Ceratonereis erythraeensis, Nereis lamellosa* and *Glycinde oligodon* while organic matter, silt and dissolved oxygen content played significant role in the distribution of *Prionospio krusadensis, Dendronereis arborifera, Polydora kempi, Prionospio pinnata, Prionispio saldanha, Glycera tesselata* and *Glycera alba*. Clay played an important role in the distribution of *Prionospio cirrifera, Heteromastus similis, Indonereis gopalai, Nephthys oligobranchia, Nereis neanthes capensis* and *Nectoneanthes ijimai.* In the present analyses the relationship between environmental parameters and polychaete distribution is evident which was not so in the earlier publication.

Table 4. Results of SIMPER analysis for polychaetes of Vasishta Godavari estuary; species are ranked according to their average contribution to dissimilarity between seasons

Species	Group 1 Av.Abund	Group 2 Av.Abund	Av.Diss	Diss/SD	SD	Contrib%
Heteromastus similis *	42.32*	21.47	6.27	1.21	5.18	11.33
Nephthys oligobranchia *	33.68*	19.41	5.06	2.97	9.15	9.15
Indonereis gopalai *	25.47*	8.58	3.54	1.34	2.64	6.39

Group 1: Summer and Recovery; Group 2: Flood; *Determining species of corresponding season

In conclusion, our findings reveal a close concordance between polychaete species patterns and environmental variables namely oxygen, sand, organic matter, salinity, clay and silt content. Monte Carlo permutation tests confirmed significant association ($p < 0.05$) between environmental variables and polychaete distribution in the Vasishta Godavari estuary. The data analysed here add further information on the biodiversity of the polychaete communities of Vasishta Godavari estuary.

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