Available online at: www.mbai.org.in doi: 10.6024/jmbai.2017.59.1.1947-01

Meiobenthic diversity off Pudimadaka, Bay of Bengal with special reference to free-living marine nematodes

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Received: 31 Oct 2016, Accepted: 24 June 2017, Published: 30 June 2017

Original Article

Abstract

A study on the community structure of meiobenthic fauna was undertaken during three cruises (June 2008, October 2008 and March 2009). Ten stations at depth between 10 and 40 m off Pudimadaka in Visakhapatnam (Lat.17º29´12˝N and Long. 83º00´09˝), east coast of India, were investigated. Ninety species representing 4 major (meiofaunal) taxa namely foraminifera (2), copepoda (9), nematoda (58) and polychaeta (21) were encountered. Overall, meiofaunal (mean) abundance ranged from 2 individuals to 63 ind. 10cm-^{2} with an average of 24.3 ind. 10 cm^{-2}. The meiobenthic biomass varied between 0.135 to 0.48 mg. 10 cm^{-2} with an average 0.27 ± 0.12. On the whole, nematodes constituted 73.62% of the meiofauna in terms of numerical abundance. Shannon -Wiener index values were 2.053 ± 0.64 (June, 2008), 2.477 ± 0.177 (October 2008) and 2.2815±0.24 (March 2009). Multivariate analyses were used to define the most important taxon in nematode assemblages. Three nematode associations could be recognized off Pudimadaka coast, namely *Laimella longicaudata*, *Euchromodora vulgaris* and *Sabatieria elongata* assemblage (June, 2008); *Catanema* sp. and *Leptosomatum* sp. assemblage (October 2008) *Sabatieria* sp. and *Setosabatieria* sp. assemblage (March 2009). Canonical correspondence analysis showed that temperature, organic matter, silt and mean particle diameter were important in controlling nematode community structure.

Keywords *: Meiofauna, marine nematode, biodiversity, community structure, India*

Introduction

Meiofauna is the major metazoan component of benthic ecosystems and its production is equal or higher than macrofauna in shallow waters to deep sea (Gerlach, 1971; Platt and Warwick, 1980; Heip *et al*., 1985; Coull, 1999). Meiofauna facilitates biomineralization of organic matter (OM) and enhances nutrient regeneration (McIntyre, 1969; Feller and Warwick, 1988; Montagna *et al*., 1995). Estimation of benthic standing stock is essential for the assessment of demersal fishery resources, as benthos form an important source of food for demersal fishes (Damodaran, 1973; Parulekar *et al*., 1982).

To date, there have been many benthic studies undertaken in and around Indian waters. Initial meiofaunal studies reported from the west coast of India were from the Cochin estuary (Kurien, 1972) and the mud bank region of Kerala (Damodaran, 1973). Since then, a few more qualitative and quantitative studies on sub tidal meiofauna have been made off the Indian subcontinent (Parulekar *et al.*, 1976; 1982; Ansari *et al.*, 1977; 1980; Harkantra *et al.*, 1980; Rodrigues *et al.*, 1982; Ansari and Parulekar, 1998; Ingole and Goltekar, 2004; Nanajkar and Ingole, 2007; Sajan and Damodaran, 2007; Sajan *et al.*, 2010a, b; Semprucci *et al.*, 2010, 2011, 2013, 2014; Nanajkar *et al.*, 2011; Mantha *et al.*, 2012; Ansari *et al.*, 2012a, b; Ansari *et al.*, 2014) and a recent review on meiobenthos by Dhivya and Mohan (2013). The literature on the meiobenthos of the Indian seas makes it abundantly clear that no information is available on community structure and diversity of free-living nematodes from the Pudimadaka area, Visakhapatnam District, East coast of India.

The objective of the present study is aimed at describing the spatial and temporal distribution patterns of meiofaunal communities of Pudimadaka coast and to assess the weight of several abiotic parameters as structuring factors. A multivariate and univariate statistical framework is used for testing two general hypotheses: (i) Are there any differences among stations/phases in the community measurements of meiofauna (e.g. number of taxa; multivariate structure) and (ii) Are there any correlative relationships between meiofauna and measured abiotic natural variables (e.g. grain size, organic content, temperature and salinity).

Material and methods

Sediment samples were collected during three phases: Phase I (Summer-June 2008, N=30), Phase II (post monsoon-October 2008, N=30) and Phase III (recovery phase-March 2009, N=30). Ten stations at water depth between 10 and 40 m off Pudimadaka in Visakhapatnam District (Lat.17º29´12˝ N, Long. 83º00´09˝ E), eastern coast of India, were investigated (Table 1).

Table 1. Locations of the sampling stations

Stations	Depth (m)	Coordinates	
		Latitude(N)	Longitude(E)
1	10	17º30'500˝N	83º02'300˝E
2	20	17º30'500˝N	84º04'400˝E
3	30	17º30'500˝N	83º08'000˝E
4	10	17º29'000˝N	83º00'816˝E
5	20	17º29'000˝N	83º02'205˝E
6	30	17º29'000˝N	84º05'086˝E
7	40	17º29'000˝N	83º07'480˝E
8	10	17º29'000˝N	82º57'398˝E
9	20	17º29'000˝N	82º59'259˝E
10	30	17º29'000˝N	83º01'314˝E

Observations on the physicochemical characteristics of sea water (temperature, dissolved oxygen, salinity) were made according to standard methods (Barnes, 1959). Sediments (sub-samples) were oven dried (60°C) onboard and stored until further analysis. The samples were subjected to sieving and sediment texture (Master sizer, 2000, Melvin Instruments, Germany) and proportions of sand, silt, and clay (%) were calculated; and values were plotted on triangular graphs according to the nomenclature suggested by Sheppard (1954). Organic matter was estimated by the wet oxidation method of Walkey-Black but as modified by Gaudette *et al.* (1974).

Biological observations included collection of quantitative meiobenthic samples. At each station, a glass corer (3.6 cm inner diameter) was used for collecting sediment samples of 10 cm length cores from grab (Hydrobios 0.1m^2, Kiel, Germany) hauls. The samples were transferred into plastic containers; living animals were narcotized with saturated $MgCl_2$ and preserved in 4% buffered formalin. The sediment samples were then processed through a set of two sieves with 500 μm and 42 μm mesh size. The residue retained on the 42 μm sieve was stored in glass containers and preserved in 4% buffered formalin. Rose Bengal was used as a stain prior to sorting and enumeration. Meiobenthos was counted on higher taxonomic level using a binocular microscope. The total number of organisms in the sample represented by different phyla was expressed in individuals per 10 cm^{-2}. Taxonomic classification of constituent species was carried out based on standard literature (Wells and Rao, 1987; Higgins and Thiel, 1988; Giere, 2009). Nematode specimens were picked using a fine needle and transferred into pure glycerin (method proposed by Seinhorst, 1959) and mounted on (Cobb, 1917). Nematodes were identified, using mainly the NeMys online identification key (Steyaert *et al.*, 2005) and other relevant literature (Platt and Warwick, 1983; 1988; Warwick *et al.*, 1998).

Data analysis

Analysis of variance (ANOVA) was performed in SPSS to evaluate the difference within the environmental parameters among different seasons. Univariate measures included species richness, Shannon-Wiener (H´) 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). 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). The percentage of each species was quantified to similarity within each group of samples and to dissimilarity between different groups. Other routines (e.g.

BVSTEP-stepwise searches of combinations of species), namely stepwise searches of combinations of species considered to be ultimately responsible for the observed pattern in the biotic assemblages were performed using PRIMER. Canonical correspondence analysis (CCA) (CANOCO 4.53, ter Braak, 1986; ter Braak and Smilauer, 2002) was performed to examine possible correlations between environmental variables, nematode species and variance in site patterns, using a form of step wise regression. A Monte Carlo permutation test (unrestricted) was used to determine the significance of species-environment relationships.

Results

Bottom water temperature at Pudimadaka varied between 27.05 ºC (St. 8, June 2008) and 31ºC (St. 3, June 2008) with a mean value being 28.81 ± 0.71 ºC. The salinity varied between 23.68 PSU (St. 6, October 2008) and 35.35 PSU (St. 7, March 2009) with a mean value being 28.81 ± 0.71 PSU. The dissolved oxygen varied between 4.5 mg.1^{-1} (St. 7, October 2008) and 7.33 mg.1^{-1} (St. 1, March 2009) with a mean value being 6.12 ± 0.60 mg. l^{-1} (Table 2). Salinity has shown significant variations among different phases ($P < 0.01$). Temperature varied significantly in between phase I and phase III ($P < 0.01$), where dissolved oxygen showed no significant variations among the phases ($P < 0.01$).

The sediment characteristics of all the stations during three phases (Phase I: summer - June, 2008; Phase II: post monsoon-October, 2008 and Phase III: recovery phase-March 2009) were found to be silty in nature with varying fractions of clay and sand content. Most of the study sites were characterized by silty sediment. Overall, the sand (%) varied between 6.2 (St. 10, June 2008) and 99.7 (St. 4, June 2008) with a mean value being 25.60 ± 17.77; silt (%) varied between 0.3 (St. 4, June 2008) and 91.36 (St.1, October 2008) with a mean value being 71.90 ± 17.13; clay (%) varied between 0 (Sts. 1, 2, 4 and 8; June 2008; Sts. 1, 4 and 8, October 2008; Sts. 1, 2, 4 and 8, March 2009) and 15.08 (St. 10, October 2008) with mean being 2.48 ± 3.69. The predominant sediment at Pudimadaka coast was sandy - silt (16 samples) followed by silty (13 samples) and sandy (2 samples) (Fig. 1). The Mean Particle Diameter (MPD) during these three seasons varied between 0.06 μm (St. 7, October 2008) and 0.52 μm (St. 4, June 2008) with mean being 0.13 ± 0.07 mm. Organic matter (%) varied between 0.13 (St. 8, October 2008) and 2.67 (St. 6, October 2008) with mean being 1.14 ± 0.71 (Fig. 2). On the basis of the above cited findings, it is concluded that three textural classes sandy - silty, silty and sandy (Sheppard, 1954) could be noticed in the sediments off Pudimadaka.

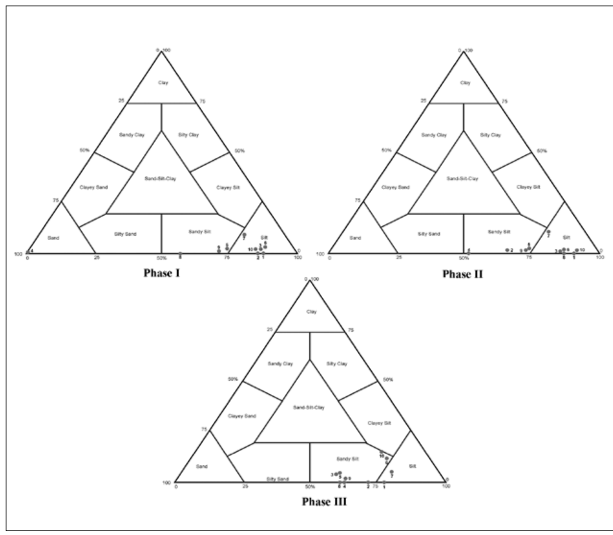

Fig.1. Sediment texture off Pudimadaka coast (% sand, silt and clay fractions) in the three sampling campaigns

Table 2. Hydrographical conditions off Pudimadaka during the study

Station	Temperature (°C)			Salinity (PSU)			Dissolved Oxygen (ml. l^{-1})		
	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
1	28.6	29	28.2	33.67	24.32	34.07	5.89	6.43	7.33
2	30	28.6	28.4	34.31	24.32	33.69	5.89	6.3	6.26
3	31	29	28.1	34.31	24.32	34.84	5.89	5.79	6.77
4	29	28.9	29.1	33.04	24.32	34.07	6.2	5.14	5.5
5	29	28.8	28.7	33.67	24.96	34.58	6.05	5.4	6.76
6	29	29	28.4	34.31	23.68	35.1	6.36	5.27	6.23
7	29.4	29.6	29.1	34.94	25.6	35.35	6.36	4.5	5.88
8	27.9	28.5	27.05	34.31	25.6	34.84	5.74	7.2	6.84
9	28.4	28.3	28.4	34.31	25.6	34.97	6.51	6.43	5.87
10	29.9	28.4	28.6	33.04	25.6	35.1	6.2	6.56	6.22
Mean	29.22	28.81	28.405	33.991	24.832	34.661	6.109	5.902	6.366
STDV	0.90	0.38	0.58	0.62	0.73	0.54	0.26	0.82	0.55

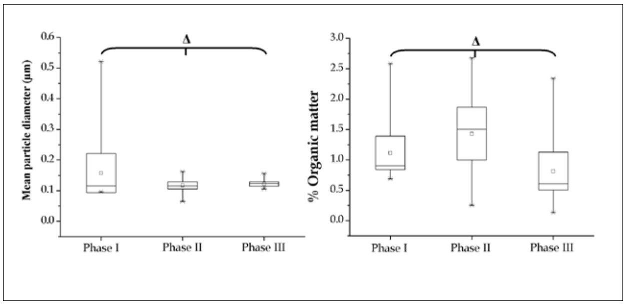

Fig.2. Distribution of sediment characteristics off Pudimadaka coast (mean particle diameter (MPD) and % organic matter) during the three phases of the study

Hydrographical conditions off Pudimadaka coast are largely determined by the events in Bay of Bengal. Off Pudimadaka and nearby areas, the hydrographical conditions are largely influenced by the southerly and northerly currents, which skirt the coast during August - December and January-July periods respectively. The southerly current is known to operate over an effective distance of 8-24 km from the coast and the northerly current over a far more extensive area (Ganapati and Murthy, 1954). During the southerly current period, the fluctuations in salinity off Visakhapatnam are marked due to discharges from the rivers opening into the Bay of Bengal (Ganapati and Murthy, 1954; Ganapati and Ramasarma, 1958). During the northerly current period, stable conditions of salinity prevail owing to influx of Indian Ocean waters into Bay of Bengal.

During this investigation, 4 taxa of meiobenthos represented by nematodes, polychaetes, copepods and foraminiferans were encountered. The fauna was dominated by nematodes followed by polychaetes and copepods, with nematodes being the most consistent abundant group at all stations during all phases (Fig. 3). Nematodes represented 73.62% of the total meiofauna with greater diversity when compared to the remaining groups. A total of 90 species represented by four meiofaunal groups namely, Foraminifera (2 spp.), Nematoda (58 spp.), Polychaeta (21 spp.) and Copepoda (9 spp.) were found.

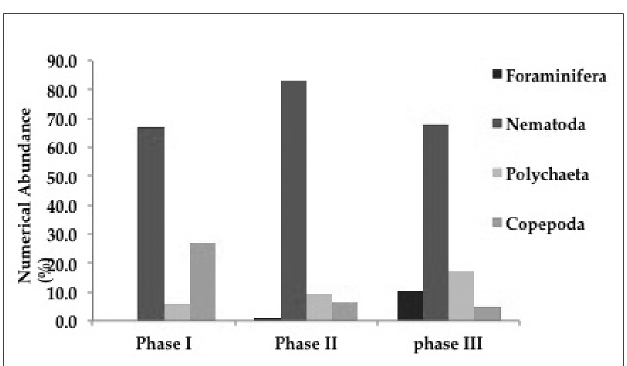

Fig. 3. Numerical abundance (% composition) of the meiobenthic community off Pudimadaka coast

In the present study, altogether 58 nematode species represented by 40 genera and 20 families were encountered and the dominant nematodes include: *Laimella longicaudata* (57 individuals, 7.60%), *Daptonema setosum* (55 ind., 7.40%), *Catanema* sp. (51 individuals, 6.80%), *Euchromadora vulgaris* (47 ind., 6.33%), *Pomponema debile* (35 ind., 4.71%), *Paracomesoma dubium* (34 ind., 4.58%), *Dorylaimopsis punctata* (33 ind., 4.14%), *Setosabatieria* sp. (30 ind., 4.04%), *Sabatieria punctata* (28 ind., 3.77%), *Daptonema oxycera* (28 ind., 3.70%), *Sabatieria elongata* (24 ind., 3.23%), *Leptosomatum* sp. (23 ind., 3.03%), *Axonolaimus spinosus* (21 ind., 2.83%), *Daptonema vicinum* (20 ind., 2.62%), *Daptonema setifer* (19 ind., 2.56%), *Paracanthonchus longicaudatus* (15 ind., 1.95%), (14 ind., 1.88%), *Sphaerolaimus macrocirculus* (14 ind., 1.88%), *Dorylaimopsis* sp. (13 ind., 1.75%), *Axonolaimus paraspinosus* (12 ind., 1.62%), *Symplocostoma* sp. (11 ind., 1.48%), *Onyx* sp. (11 ind., 1.48%), *Viscosia glabra* (10 ind., 1.28%), *Tricoma brevirostris* (10 ind., 1.28%), *Chaetonema* sp. (9 ind., 1.21%), *Halalimus longicaudatus* (9 ind., 1.21%), *Viscosia elegans* (9 ind., 1.21%), *Halalaimus gracilis* (8 ind., 1.08%) and *Astomonema southwardorum* (8 ind., 1.08%).

Polychaetes (juveniles) accounted for 11.23% of the total meiofauna. Altogether 19 species belonging to 11 genera and 13 families were encountered and the dominant species were *Magelona cincta* (27.27%), *Nephthys dibranchis* (18.1%), *Cirratulus* sp. (17.8%), *Aricidea* sp. (14.9%), *Syllis* sp. (10.7%), *Lumbrineris* sp. (9.0%), *Prionospio* sp. (9.0%), *Prionospio malmgreni* (9.0%), *Paraonis* sp. (9.0%), *Lumbrineris abberans* (7.14%), *Prionospio cirrifera* (7.14%), *Magelona* sp. (7.14%), *Prionospio pinnata* (4.57%), *Neries granulata* (3.57%), *Goniada* sp. (3.57%), *Glycera longipinnis* (3.57%), *Prionospio cirrobranchiata* (3.5%), *Cossura coasta* (3.57%) and *Capitella* sp. (3.57%).

Copepods accounted for 10.25% of the total meiofauna and were from a single sub-order (Harpacticoida). Altogether 9 species belonging to 6 genera and 4 families were encountered and the dominant species include *Amphiascopsis cinctus* (23.0%), *Stenhelia* sp. (22.5%), *Stenhelia latipes* (20.0%), *Arenosetella* sp. (13.8%), *Phyllopodosyllus stigmosus* (13.8%), *Diarthrodes dissimilis* (13.8%), *Diarthrodes* sp. (13.8%), *Stenhelia peniculata* (7.69%) and *Amphiascoides* sp. (7.69%).

During this investigation, meiofaunal densities ranged between 2 ind. 10 cm^{-2} (St. 5, June 2008) and 63 ind. 10 cm^{-2} (St. 1, October 2008) with mean being 24.3 ind. 10 cm^{-2}. The nematode densities varied from 2 ind. 10 cm^{-2} (St. 5, June 2008) to 55 ind. 10cm^{-2} (St. 8, October 2008) with mean 17.9 $\pm$ 12.5; polychaetes from 1 ind.10 cm^{-2} (Sts. 3 and 10, June 2008) to 7 ind. 10 cm^{-2} (Sts. 1 and 2, March 2009) with a mean value 2.8 $\pm$ 2.1; copepods from 1 ind. 10 cm^{-2} (Sts. 7, 8 and 10, June 2008, St. 5, October 2008 and Sts. 1 and 4, March 2009) to 21 ind. 10 cm^{-2} (St. 4) and others 1 ind. 10 cm^{-2} (Sts. 1 and 2, June 2008, St. 1, October 2008) to 12 ind.10 cm^{-2} (St. 2, March 2009) with mean 2.5 ± 4. Nematodes, polychaetes and copepods mainly contributed (95%) to the total meiobenthic biomass during the study. Over all biomass (mg. 10 cm^{-2}) varied between 0.184 mg. 10 cm2 and 0.48 mg. 10cm^{-2} with mean being 0.27 ± 0.12 (Fig. 4). Altogether 58 nematode species represented by 40 genera and 20 families were encountered in this study. Of the 20 nematode families, the most dominant with respect to abundance were Comesomatidae (29.56%), Xyalidae (19.5%, Desmodoridae (9%) and Cyatholaimidae whilst the most commonly occurring species of each family were Xyalidae (9 species) Comesomatidae (8 sp) Desmodoridae (4 species) and Cyatholaimidae (4 sp). Since nematodes constituted one of the most important meiofaunal groups in view of their numerical abundance and species richness in this study, they were examined and studied in detail and correlated with various environmental parameters.

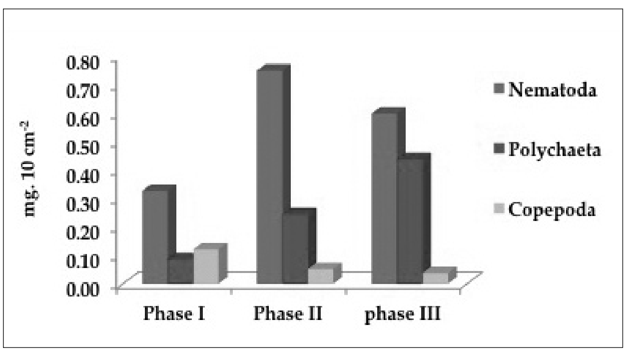

Fig. 4. Biomass of the meiobenthic taxa (mg. 10cm^{-2}) during the study

Bray-Curtis similarities were calculated on the square-root transformed nematode data and from the resulting dendrogram, it was possible to define the locations into three groups determined at 38% similarity (Fig. 5). The dendrogram provided a sequence of fairly convincing groups of stations confirmed

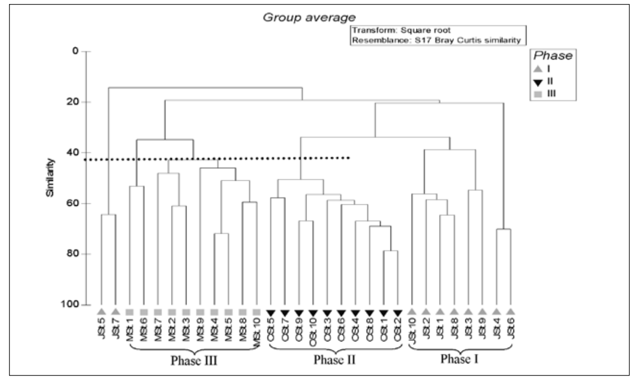

Fig. 5. Nematodes of Pudimadaka coast. Dendrogram clustering of 58 species using group average linking of Bray-Curtis Similarity (Square root transformed data) at 38% similarity. Phase1: June, 2008; Phase II: October, 2008; Phase III: March 2009; J: June 2008; O: October 2008; M: March 2009

by MDS plot for the same locations of which Group I consisted of stations representing June 2008, Group II (October 2008), Group III (March 2009). The communities were named after the most important (determining species) species identified by the SIMPER analysis: *Laimella longicaudata*, *Euchromodora vulgaris* and *Sabatieria elongata* assemblage (Group I); *Catanema* sp. and *Leptosomatum* sp. assemblage (Group II) assemblage; *Sabatieria* sp. and *Setosabatieria* sp. assemblage (Group III) (Table 3). The investigations showed a great degree of difference (ANOSIM Global R: 0.751 at 0.1%) in the composition, seasonal succession and numerical abundance of nematodes in Pudimadaka region.

Nematode species diversity estimation showed that the mean of Shannon-Wiener index recorded 2.053 ± 0.64 (phase I), 2.477 ± 0.177 (phase II) and 2.2815 ± 0.24 (phase III) (Fig. 6). The evenness component (J) varied in conformity with H´. On the basis of these findings, it is concluded that the June 2008 samples are least diverse both in terms of species richness (Margalef d) and Shannon-Wiener index (H´). In this study, a subset of 13 species (Influential species) were

Table 3. SIMPER analysis for 58 species of nematodes

Species	Average abundance		Average dissimilarity	SD	Dissimilarity/ SD	% Contribution
	Group 1	Group 2	74.11			
Catanema sp.	0	1.98*	6.07	3.372222	1.8	8.19
Leptosomatum sp.	0	1.37*	4.32	2.009302	2.15	5.83
	Group 1	Group 3	80.11			
Laimella longicaudata	1.29*	0	4.25	2.514793	1.69	5.3
Euchromadora vulgaris	1.01*	0	3.53	2.654135	1.33	4.4
Sabatieria elongata	1.06*	0	3.19	2.416667	1.32	3.98
	Group 2	Group 3	82.76			
Setosabatieria sp.	0.2	1.57*	5.42	2.822917	1.92	6.77
Sabatieria punctata	0	1.23*	4.4	2.972973	1.48	5.49

*Determining species of corresponding sector class

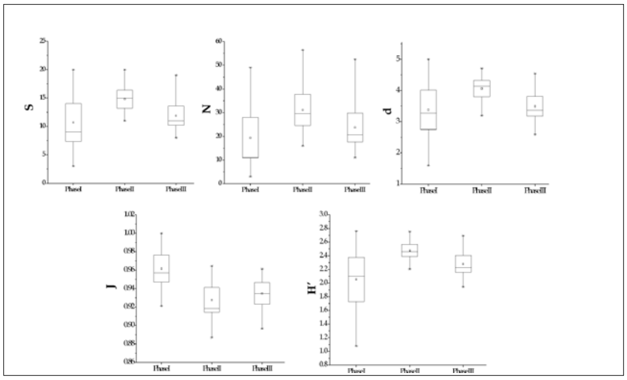

Fig. 6. Univariate measures for nematode species off Pudimadaka coast. S-Species (no.), N- abundance (no.10cm^{-2}), H'- Shannon index, d-Margalef diversity and J'-Evenness

identified by the BVSTEP procedure, which showed a good correlation (ñ = 0.95) with the relationship generated from the full set of 58 species (Table 4). They are *Halalaimus gracilis, Euchromadora vulgaris, Dorylaimopsis punctata, Paracomesoma dubium, Laimella longicaudata, Sabatieria punctata, Setosabatieria* sp., *Pomponema debile*, *Catanema* sp., *Daptonema oxycerca, Daptonema setosum, Daptonema vicinum* and *Axonolaimus spinosus*.

CCA was performed on selected nematode species (identified through BVSTEP), i.e. on the basis of their abundance and in the light of known environmental data. It was found that axes 1 and 2 on the canonical ordination plot (Fig. 7) were the most important (Table 5) since they were able to explain 67 and 78 % of variation in species abundance data. Monte Carlo permutation tests (with forward selection) were used to identify which environmental variables explained the significant variance (p< 0.05 level), nematode distribution and species abundance pattern. The direction of the vectors indicates that clay, pH and salinity increase with the first axis (x) whereas silt and organic matter decrease with this axis. Turbidity and water temperature increase along the second axis (y). Axis 1 is strongly associated with pH (r = 0.64), and salinity (r = -0.94) whilst water temperature (r = 0.61), and turbidity (r = 0.84) are closely linked with axis 2. Only the variable mean particle diameter (MPD) characterized (r = 0.71) the third axis, while clay (r = 0.58), organic matter (r = 0.77) are linked with the fourth axis. The noteworthy feature, however, is the high correlation (weighted correlation coefficient > 0.6) between faunal abundance and environmental variables on all CCA axes (Table 5). The nematode CCA ordination, the distribution of nematode species such as *Laimella longicaudata, Axonolaimus spinosus, Daptonema oxycerca, Daptonema setosum* and *Euchromadora vulgaris* were influenced by water temperature and silt content. Organic matter appeared to relate well with

Table 4. Distribution of important nematode species (ind. 10 cm^{-2}) during different phases in Pudimadaka area (identified through SIMPER/BVSTEP analyses). Abbrev: abbreviation used in Figure 7. Data presented as mean ± SD (range). -: not found in this phase

Species	Abbrev	Phase-I	Phase-II	Phase-III
Halalaimus gracilis	Hala gra	0.20±0.42 (1)	0.20±0.42 (1)	0.40±0.52 (1)
Euchromadora vulgaris	Euchr vul	1.60±1.58 (1-4)	3.10±1.54 (1-6)	-
Dorylaimopsis punctata	Dory pun	1.35±1.56 (1-5)	-	1.95±1.79 (1-5)
Paracomesoma dubium	Paraco dub	0.90±0.88 (1-2)	-	2.50±1.31 (1-5)
Laimella longicaudata	Lai long	2.40±2.46 (1-7)	3.25±1.69 (2-7)	-
Sabatieria punctata	Saba punc	-	0.60±0.52 (1)	2.20±2.63 (1-9)
Setosabatieria sp.	Setosa sp	0.20±0.42 (1)	0.20±0.42 (1)	2.60±1.39 (1-6)
Pomponema debile	Pom deb	0.50±0.97(1-3)	1.65±1.16 (1-4)	1.35±2.19 (1-7)
Catanema sp.	Cata sp	-	4.95±3.85 (1-11)	0.10±0.32 (1)
Daptonema oxycera	Dapt oxy	0.90±1.29 (1-4)	1.85±1.43 (1-5)	-
Daptonema setosum	Dapt seto	1.55±1.92 (1-6)	2.10±1.15 (1-5)	1.85±2.44 (1-9)
Daptonema vicinum	Dapt vici	0.80±0.63 (1-2)	-	1.15±1.49 (1-4)
Axonolaimus spinosus	Axo spin	0.50±1.08 (2-3)	0.90±0.70 (1-2)	0.70±0.95 (1-3)

Table 5. Result of CCA; eigenvalues, species-environment correlation and percentage variance for Pudimadaka Coast nematode abundance data; weighted correlation between environment variables and CCA axes. Environmental variables identified by Monte Carlo permutation tests based on forward selection with 499 unrestricted permutation; variance of environmental variables accepted at P<0.05, * Significance at P<0.05(in bold).

Axis	1	2	3	4	Total inertia
Eigen values	0.378	0.062	0.055	0.029	1.082
Species-environment correlations	0.951	0.706	0.605	0.611	
Cumulative percentage variance					
of species data	34.9	40.7	45.7	48.5	
of species-environment relation	67.1	78.2	87.9	93.1	
Correlation coefficient					
Water Temperature	-0.3041	0.1032	-0.2236	-0.2559	
Turbidity	0.2389	0.2272	-0.3819	-0.5357*	
pH	0.6779*	0.297	-0.211	-0.0434	
Salinity	0.9417*	-0.02	-0.2228	0.0451	
Dissolved Oxygen	0.2346	-0.1908	0.3065	-0.2156	
Sand	0.3821	-0.2465	-0.3848	0.0325	
Silt	-0.4688	0.2399	0.214	-0.2247	
Clay	0.2746	0.0482	0.6526*	0.6885*	
MPD	0.0948	-0.6947*	-0.1004	-0.0987	
Organic Matter	-0.3655	0.2172	0.3554	0.4711	

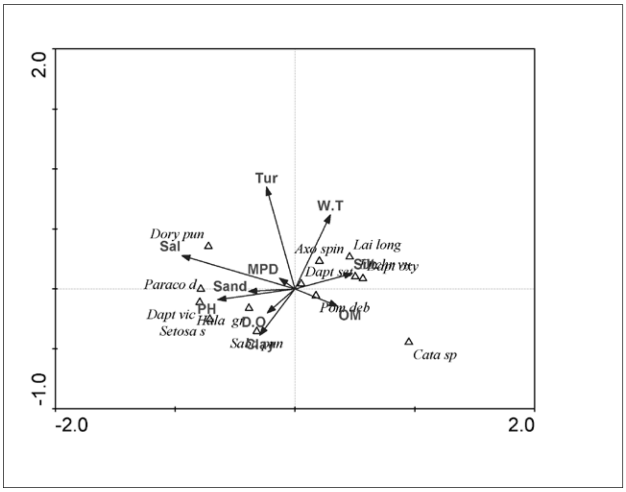

Fig. 7. Canonical correspondence analysis (CCA) showing scatter plot for 13 important nematode species and environmental variables. Vector lines represent the relationship of significant environmental variables to the ordination axes; their length is proportional to their relative significance. D.O: Dissolved oxygen, Tur: Turbidity, Temp: Temperature; MPD: Mean particle diameter; Carbon: Organic Carbon. For full species names see Table: 4

the distribution of *Pomponema debile* while turbidity, mean particle diameter and salinity played a significant role in the distribution of *Dorylaimposis punctata*; and *Paracomesoma dubium*. *Sabatieria punctata, Halalaimus gracilis, Sabatieria pulchra, Setosabatieria* sp. and *Daptonema vicinum* are closely associated with pH, dissolved oxygen and clay content.

Discussion

The meiobenthos off Pudimadaka appeared patchy and very poor in terms of their numerical abundance and distribution. Copious data supports the view that this patchy distribution is determined mainly by the aggregation of microorganisms, selective feeding preferences, and direct or indirect trophic interrelations (Findlay, 1981; Snelgrove and Butman, 1994; Li *et al*., 1997; Somerfield *et al*., 2007).

Nematodes constituted the most dominant group contributing more than 70% of the bulk of meiobenthic population density. Nematode dominance has been reported as common feature with respect to the distribution of meiofauna in intertidal as well as subtidal regions as evident from many earlier studies (Montagna *et al*., 1983; Blanchard, 1990; Blackburn and Fenchel, 1999). The crustaceans represented by copepods emerged as second dominant group in the summer and third dominant group in post-monsoon and recovery phase of the total population. The polychaete worms, which also included juveniles constituted the second most dominant group in post-monsoon and recovery phase of the total population. This leads to believe that post monsoon and recovery phase is favourable for the reproduction of polychaete worms in the sediments of the region.

A notable overlap in generic composition can be observed between the nematode assemblage found in this study and those reported for other tropical and even temperate areas (Heip *et al*., 1985; Alongi, 1986; Gourbault and Renaud-Mornant, 1990; Gourbault *et al*., 1995; Boucher, 1997; Ndaro and O'lafsson, 1999; Raes *et al*., 2007 and Semprucci *et al*., 2010, 2011, 2014). The dominant families in the present study were Comesomatidae, Xyalidae, and Desmodoridae. Similar results have been reported by Sajan and Damodaran (2007) in the west coast of India and Ansari *et al*., 2014 in south east coast of India and Semprucci *et al*., 2010, 2011 from Maldives (Indian Ocean). Non-selective deposit feeders were found to be dominant in the present study. Twenty two species were found to be non-selective deposit feeders (1B), followed by epistrate feeders (2A, 13 species), predators or omnivores (2B, 12 species) and selective deposit feeders (1A, 11 species).The dominant non-selective deposit feeders encountered were *Daptonema biggi, Sabatieria punctata, Cyatholaimus gracilis* and *Metalinhomoeus longiset*a, while *Halalaimus gracilis, Syringiolaimus* sp., *Oxystomina asetosa* and *Desmoscolex* sp. were selective deposit feeders. *Dorylaimposis punctata, Paracanthonchus longicaudatus, Laimella longicaudata* and *Paracomesoma dubium* were epistrate feeders and *Enoplus* sp., *Gammanema* sp., *Viscosia glabra* and *Sphaerolaimus balticus* were the predators found in this study. Thus, most of the nematodes off Pudimadaka were found to be mainly non-selective deposit feeders and epistrate feeders. Epistrate feeders are commonly found in medium coarse sands with a very poor fine fraction (Alongi, 1986), and in tropical habitats they can find a large number of benthic primary producters, a great abundance of diatoms, and wide surfaces suitable for scraping off the algal and bacterial biofilms (Boucher, 1997; Raes *et al*., 2007). In general, there is a tendency for the proportion of epistrate feeders to be higher in larger grain sediments and for the deposit feeders to dominate in fine sediments (Wieser, 1959; Tietjen, 1969; Hodda and Nicholas, 1986; Alongi, 1986; Boucher, 1997; Giere, 2009). As in the present study, epigrowth feeders have been reported by other authors to be among the dominant trophic group in sub tidal carbonate sediments (Alongi, 1986; Gourbault and Renaud-Mornant, 1989, 1990; Tietjen, 1991; Ólafsson, 1995; Boucher, 1997; Ndaro and Ólafsson, 1999 and Semprucci *et al*., 2013).

As observed in the present study, decline in abundance, number of species and families with increase in depth was reported (Ansari *et al*., 1980; Parulekar *et al*., 1982; Muthumbi *et al*., 2004; Sajan and Damodaran, 2007; Sajan *et al*., 2010 a, b and Mantha *et al*., 2012) in the Indian shelf sediments and (De Bovee *et al*., 1990; Tietjen 1992; Soltwedel, 2000; Liu *et al*., 2007; De Leonardis *et al*., 2008; Armenteros *et al*., 2009) from other parts of the world. There is a general tendency for the biomass and density of benthic organisms to decrease with increasing bathymetric depth (Ganesh and Raman, 2007; Joydas and Damodaran, 2014).

Canonical correspondence analysis (CCA) showed that temperature, organic matter, silt and mean particle diameter (MPD) were important in controlling nematode community structure). In the present study, nematodes showed an affinity towards finer sediments. Sediment nature is an important factor in the determination of the distribution of meiofauna, in particular the nematodes (Sajan and Damodaran, 2007 and Cook *et al.*, 2000). Sediment grain size is one of the important factors affecting the distribution of meiofauna (Wieser, 1960; Heip *et al.*, 1985; Ansari and Parulekar, 1998).

Low species diversity indices (2.0) characterised most of the study sites in Pudimadaka. The Shannon-Wiener diversity index (Shannon and Weaver, 1949) is the most widely used measure of benthic community diversity (Clarke and Warwick, 1994) that may also be indicative of sediment conditions. Lewis (2005) mentioned that sediment quality is considered poor if the index value was 2.0 or less based on a frequency distribution of Ponar diversity values reported by Friedman and Hand (1989). It is generally accepted that sediment quality affects the community structure of marine nematodes. However, nematode diversity is also affected by other factors such as competition between species, predation pressure, structural heterogeneity of the habitat, and alterations in environmental predictability (Gray and Elliot, 2009; Chen *et al.*, 2012).

In the Indian sub-continent the knowledge of sub tidal meiofauna is rather scarce compared to other areas, particularly with regard to the nematode community structure. The present work provides a preliminary base line study of free living nematode communities in this area for the first time. Basic information of meiofauna and community structure of free living marine nematodes is thus essential to understand base line benthic conditions (Liu *et al.*, 2007). Therefore, the data presented herein adds further information on the sub tidal meiofauna, and provides valuable knowledge on the biodiversity of the nematode communities of tropical situation like Pudimadaka coast. Further long term studies will throw more light on the meiofaunal community structure in this part of the Indian coast.

Acknowledgements

The authors are thankful to the BARC (Babha Atomic Research Centre) Dept of Atomic energy, Govt. of India, Bombay (BARC/ACTS/Works/327 Dt. 4.4.2008) for financial assistance to carry out this work.

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