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Distribution of Meiofauna and Community Structure of Free-Living Marine Nematodes in Uppanar Estuary South East Coast of India

M. Victorraj[1], P. S. Lyla*, S. Ajmalkhan[1] and T. Suthakar

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai - 608502, Tamil Nadu, India.

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Corresponding Author Email: dr.lailanair3@gmail.com

Abstract
The composition of meiofauna was studied in the Uppanar estuary of southeast coast of India. Overall, seven meiobenthic taxa nematodes, harpacticoid copepods, foraminifera, polychaetes, ostracods, napulii, tardigrada and others (isopodes, cumaceans, kinohycha, amphipoa, gastrotrich) were observed. As many as 72 species of nematodes belonging to 42 genera and 21 families were recorded. The species *Viscosia viscose, Sabatieria pulchra Terschellingia longicaudata* and *Daptonema* sp. were found to be dominant in the study area. This result of the present study showed a basic data of meiobenthic composition in the Uppanar estuary which will be useful for continuous monitoring of the benthic ecological quality.

Keywords
Meiobenthic composition, free living nematodes, Uppanar estuary, feeding types.

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INTRODUCTION
Benthic meiofauna is an important group of organisms in the coastal ecosystem feeding on microalgae and bacteria. They play an important role in primary production and bio- mineralization (Moghadasi *et al*., 2009; Nari Mesa *et al*., 2011). Compared to macrofauna, meiofauna is highly useful in environmental impact assessment and ecosystem health monitoring in view of its higher species richness, short life-cycles (3-5 generation per year) and lack of larval stages (Ansari *et al.,* 2012). This morphologically and taxonomically important group comprises of diverse organism representing wide range of invertebrate taxa. The dominant taxa among meiofauna are usually nematodes and harpacticoid copepods other groups include turbellarians, ostracods, gastrotichs, tardigrades, rotifers, polychaetes, oligochaetes, gastropods and bivalves (Malinga, 2013). Meiofauna especially nematodes have several advantages over the macrofauna in environmental monitoring. Such advantages include its presence in large numbers, high diversity, occurrence in sediment, lack of rapid migration from stressful conditions and extreme

tolerance to disturbance and harmful chemicals. Meiofaunal organisms react quickly to changes in the environment. Moreover, nematodes represent a tropically heterogeneous group (Bongers and Bongers, 1998; Bongers and Ferris, 1999). The whole phylum currently contains about 20,000 species, of which about 4,000 species are free living marine forms. An important feature of nematode populations is the large number of species present in any one habitat, often an order of magnitude higher than any other taxon (Platt and Warwick, 1980). Meiofauna got adapted to an interstitial existence showing high flexibility to anthropogenic and natural disturbances (Altaf *et al*., 2005). These communities are useful for monitoring and evaluating the effects of human activity in the marine environment. The role of meiobenthos in the assessment of environmental stresses due to shorter generation time has been pinpointed in recent years by many investigators (Schratzberger *et al*., 2004; Veit-Kahler *et al*., 2008; Tang *et al*., 2012). Most of the studies on the meiofauna in the Indian subcontinent have been done in the continental shelf (Harkantra *et al*., 1980; Cook *et al*., 2000; Sajan and Damodran, 2007; Sajan *et al*., 2010), shallow coastal waters (Timm, 1961, 1967; Rao and Ganapati, 1968; Ansari, 1978; Ansari *et al*., 1980; Rodrigues *et al*., 1982) and estuarine waters (Ansari *et al*., 1982; Ansari and Parulekar, 1998). This paper deals with the distribution and community structure of meiofauna from Uppanar estuary, with special reference to free living nematode communities.

MATERIALS AND METHODS

Study area

The Uppanar estuary (lat. 11°30′ -11° 43′ N and long.79°30′-79° 47′ E) is formed by the confluence of Gadilam and Paravanar rivers in Cuddalore of Tamil Nadu State, India (Fig. 1). The Perumal Lake is the major recharge area for the river Uppanar. This river also receives water from the canals like Murattaru, Manambattan and Buckingham canals flowing on the southern side of this river. State Industries Promotion Corporation of Tamil Nadu (SIPCOT) complex covering an area of 520 acres with 44 industries manufacturing chemicals, petrochemicals, fertilizers, pharmaceuticals, dyes, soap, detergents, packing materials, resins, beverages, pesticides, drugs, antibiotic etc, is situated on the western bank of this estuary. These industrial units discharge treated/untreated effluents into the estuary. In addition to the industrial wastes, the estuary receives also the municipal wastes from Cuddalore old town.

Fig. 1. Map showing the study area

Sampling

Totally 36 samples were collected from three stations (Sation1- mouth, Stion2- landing center and Station 3 industrial area) during the present study done for one year. The sediment samples were collected using a Peterson grab (having a bite area of 0.02 m^2). Immediately after the grab was hauled sample was collected, sub sample were taken from undisturbed grab samples using long glass corer (having an internal diameter of 2.5 cm and a length of 15 cm) from the middle of grab samples (Platt and Warwick, 1983). All samples were preserved with 4 % formaldehyde solution. Temperature was recorded with the help of a mercury thermometer. pH was determined with the help of Digital pen. Salinity was measured using the Salinometer (ATAGO- Japan) and dissolved oxygen through the Winkler's methods.

Analysis of meiofauna and marine nematodes

The meiofauna was extracted from the sediment by decantation over 45µm mesh sieve. The material retained on the sieve was stained with Rose Bengal and identified to possible taxon level, under a stero-zoom microscope. All nematodes were extracted subsequently, counted, sorted by hand picking method and mounted on permanent glycerin slides. Meiofaunal taxa belonging to major and minor phyla were identified following Higgins and Thiel (1998). Taxonomic identification of free-living nematodes was undertaken using the pictorial keys (Platt and Warwick, 1983, 1988; Warwick *et al.*, 1998) and Nemys online identification key (Steyeart *et al.*, 2005). Generic and species level Identification was carried out by mounting the key characters and observing them under Olympus CX41microscope at the magnifications of 40X and 100X.

Nematode feeding types

Based on the characteristics of buccal morphology, nematodes were classified based on the feeding types (Wiser, 1953) representing four groups of feeders such as selective deposit feeders (1A), non-selective deposit feeders (1B), epigrowth feeders (2A) and predator or omnivores (2B).

RESULTS

Environmental factors

The temperature recorded was more or less similar at all the stations but fluctuated during the sampling period. The maximum temperature recorded was 34.70^{0}C during May, 2015. The minimum of 24.5^{0}C was recorded in December, 2015. The hydrogen ion concentration (pH) recorded the highest (8.4) during December, 2015 and the lowest (7.1) during March, 2015. The maximum salinity of 38.1 psu was recorded in July, 2015 and the minimum of 22.2 psu in December, 2015. The level of dissolved oxygen was low and varied from 3.9 mg/L in December, 2015 to 2.1mg/L in August, 2015. The nature of the sediment in the study area was observed as silty clay.

Abundance of meiofauna

In the present study, the abundance of meiofauna varied between 4264 and 2058 animals/core sample, among which the most common taxa were Nematodes followed by Copepods, Foraminiferans, Polychaetes, Ostracods, Napulii, Tardigrads and others (Table.1).

Table 1. Mean abundance of meiofauna (ind/10cm^2), Standard deviation and relative abundance (%) in Uppanar estuary.

	St-1 Ind/10cm^2±SD	St-1 %	St-2 Ind/10cm^2±SD	St-2 %	St-3 Ind/10cm^2±SD	St-3 %	Total %
Nematoda	54.7 ±23.7	63.7	**54.5 ± 28.6**	48.0	65.3 ± 36.8	55.7	55.1
Copepoda	5.2±4.5	6.1	6.4 ± 7.7	5.6	**14.6 ±10.9**	12.4	8.4
Polychaeta	11.5±16.7	13.5	**16.62 ± 15.2**	6.2	10.4 ±4.0	8.8	9.1
Foraminifera	4.5±3.9	5.3	10.0 ± 9.7	8.8	**16.9 ±12.1**	14.4	10.1
Ostrocoda	3.9±3.4	4.6	**4.2±4.7**	3.7	3.8 ±2.6	3.2	3.7
Napulii	**0.3±0.8**	0.4	0.1± 0.4	0.1	0.3 ±0.6	0.2	0.2
Tardigrada	0	0	**25.0 ±71.2**	22.0	0	0	7.6
Others	5.2±3.7	6.17	**5.9±7.4**	5.2	5.6 ±4.3	4.8	5.3

Nematodes were found to be the most dominant taxa in all the three stations. Ostrocoda, Tardigrada and Nauplii were recorded less frequently. The abundance was highest at the sediment surface and decreased gradually with depth. Among the three stations lower meiofaunal abundance (54.5 ±28.6) was observed at station 2 and maximum (65.3 ± 36.8) at station 3. The mean abundance of harpacticoid copepods was maximum (14.6 ±10.9) at station-3 and minimum (5.2±4.5) in station-1. The abundance of foraminifera was comparatively high in station-3 (16.9 ±12.1) and low in station-1 (4.5±3.9). In all the stations, nematoda was the most dominant taxon contributing 55.17 % of total abundance, followed by foraminifera, polychaeta and copepod (10.13%, 9.19% and 8.43% respectively). The other groups such as ostracods, napulii, tardigrades, isopods and cumaceans were found less in numbers and together constituted 17.04 %. In general, area near the industries showed relatively higher abundance of meiofauna i.e. in station-3 (Fig. 2).

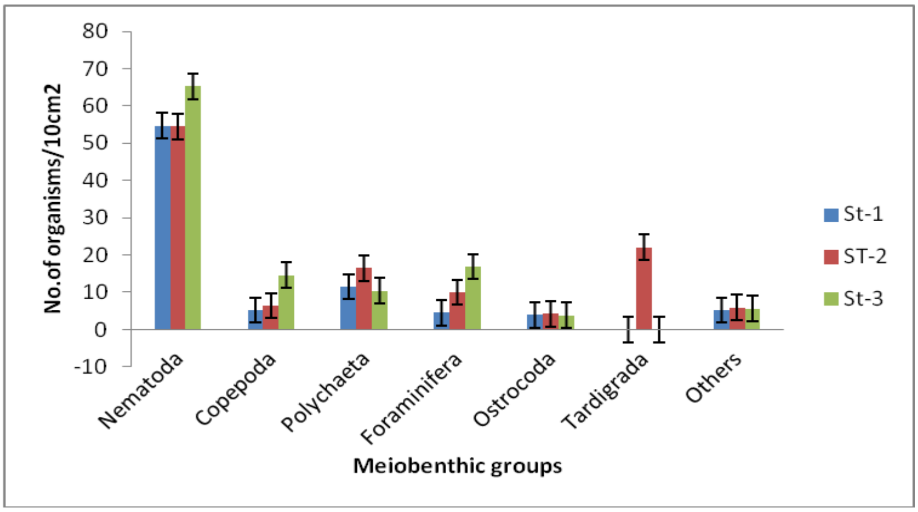

Fig 2. Mean abundance of meiofauna in Uppanar estuary

Table 2. Occurrence, distribution and feeding types of nematodes collected from Uppanar estuary, south east cost of India.

Family	Species	Feeding type	St-1	St-2	St-3
Anoplostomatidae	*Anoplostoma viviparam*	1B	+	+	-
Anticomidae	*Anticoma* sp.	1A	-	+	-
Ironidae	*Trissonchulus obtusus*	2A	-		+
	Trissonchulus oceanus	2A	-		+
	Trissonchulus benepapillosus	2A	-		+
Oncholaimidae	*Metaparoncholaimus campylocercus*	2B	-	-	+
	Oncholaimus oxyuris	2B	-	+	-
	Oncholaimus skawensis	2B	-	-	+
	Viscosia viscosa	2B	+	+	+
	Viscosia abyssorum	2B	-	-	+
	Viscosia cobbi	2B	-	+	+
	Viscosia elegans	2B	+	+	-
	Viscosia glabra	2B	-		+
Tripyloididae	*Tripyloides gracilis*	2B	+	+	+
	Tripyloides sp.	2B	+		+
Chromadoridae	*Chromadora* sp.	2A	+	+	+
	Chromadorita sp.	2A	+	-	-
	Dichromadora cephalata	2A	+	-	-
	Dichromadora geophila	2A	+	+	-
	Hypodontolaimus sp.	2A	+	-	-
	Prochromadora sp.	2A	+	-	-
	Prochromadorella sp.	2A	+	-	-
	Ptycholaimellus sp.	2A	+	-	+
	Spilophorella sp.	2A	+	-	+
Ethmolaimide	*Nannolaimus* sp.	2A	+	-	-
Cyatholaimidae	*Paracanthonchus caecus*	2A	+	+	+
	Paracanthonchus longicaudatus	2A	-	+	+
	Paracanthonchus platti	2A	_	+	_
Selachinematidae	*Gammanema conicauda*	2B	+	+	+

	Gammanema rapax	2B	_	+	_
	Halichoanolaimus robustus	2B	_	+	_
Comesomatidae	*Paracomesoma dubium*	2A	_	_	+
	Paracomesoma longispiculum	2A	_	+	+
	Sabatieria ornate	1B	_	+	+
	Sabatieria pulchra	1B	_	+	+
	Sabatieria punctata	1B	_	+	+
	Sabatireia longispinosa	1B	+	_	_
Desmodoridae	*Desmodora tenuispiculum*	2A	+	_	_
	Desmodora sp.	2A	+	+	+
	Metachromadora sp.	2B	+		+
	Sigmophoranema sp.	2A	+	_	_
	Spirinia sp.	2A	+		+
Draconematidae	*Draconema* sp.	1B	_	+	_
Ethmolaimidae	*Comesa cuanesis*	1B	_	_	+
	Comesa vitia	1B	_	_	+
	Comesa warwicki	1B	_	+	_
Leptolaimidae	*Camacolaimus barbatus*	2A	_	+	+
	Laptolaimus sp.	2A	+	_	_
Haliplectidae	*Haliplectus dorsalis*	1A	_	+	+
	Haliplectus wheeleri	1A	_	_	+
Ceramonematidae	*Ceramonema yunfengi*	1B	+	_	_
Xyalidae	*Steineria pilosa*	1B	_	+	+
	Daptonema hirsutum	1B	+	+	+
	Daptonema normandicum	1B	+	+	+
	Daptonema psammoides	1B	+	_	+
	Daptonema setosum	1B	+	+	+
	Daptonema vicinum	1B	+	+	+
	Daptonema sp.	1B	+	+	+
	Metadesmolaimus pandus	1B	_	_	+
	Metadesmolaimus aduneus	1B	+	+	_
	Metadesmolaimus gelana	1B	_	+	_
	Theristus accer	1B	+	_	+
	Theristus clax	1B	+	_	_
	Xyala riemanni	1B	+	_	_
Sphaerolaimidae	*Sphaerolaimus macrocirculus*	1B	+	+	_
Linhomoeidae	*Eumorpholaimus* sp.	1A	_	_	+
	Terschellingia longicaudata	1A	_	+	+
	Terschellingia communis	1A	_	+	+
	Terschellingia sp.	1A	_	+	+
Axonolaimidae	*Axonolaimus* sp.	1B	+	_	_
	Odontophora sp.	1B	+	_	_
Diplopeltidae	*Araeolaimus longicauda*	1A	+	_	_

Assemblage of nematode and harpacticoid copepods

Totally 72 species of nematodes were identified belonging to 42 genera and 21 families. The most common families were Ironidae, Triphyloidae, Chromadoridae, Comesomatidae, Cyatholaimidae, Oncholaimidae, Desmodoridae, Linhomoeidae and Xyalidae whereas Anoplostomatidae, Anticomidae, Ceramonematidae, Enchelidiidae, Leptolaimidae, Sphaerolaimidae, and Diplopeltidae were found to be very rare. The dominant nematode family was Xyalidae which contributed (18%) of total abundance, followed by Chromadordae (13%), Oncholamidae (11%), Comesomatidae (8%), Desomoridae 7%. Other families contributed from 4 to 1 % (Fig.3).

The highest number of species was from the family Xyalidae (13) belonging to 5 genera namely *Daptonema, Steineria, Metadesmolaimus, Theristus* and *Xyala.* The 9 species recorded in the family Chromadoridae belonged to 8 genera namely *Chromadora, Chromadorita, Dichromadora, Hypodontolaimus, Prochromadora, Prochromadorella, Ptycholaimellus*, and *Spilophorella*. The 9 species of family Oncholamidae belonged to genera such as *Metaparoncholaimus, Oncholaimus* and *Viscosia*. The 6 species of Comesomatidae belonged to 2 genera as *Paracomesoma* and *Sabatieria.* More number of species was recorded in the estuarine mouth (38) followed by the industrial area (27) and landing center (24). The number of most common species was 23 and these included *Anoplostoma viviparum, Viscosia viscosa* , *Viscosia cobbi*, *Viscosia elegans, Tripyloides gracilis, Dichromadora geophila, Paracanthonchus caecus, Paracanthonchus longicaudatus, Gammanema conicauda, Paracomesoma longispiculum, Sabatieria ornate, Sabatieria pulchra , Sabatieria punctata, Haliplectus dorsalis, Steineria pilosa, Daptonema hirsutum, Daptonema normandicum, Daptonema setosum, Daptonema vicinum, Theristus clax, Sphaerolaimus macrocirculus, Terschellingia longicaudata,* and *Terschellingia communis*.

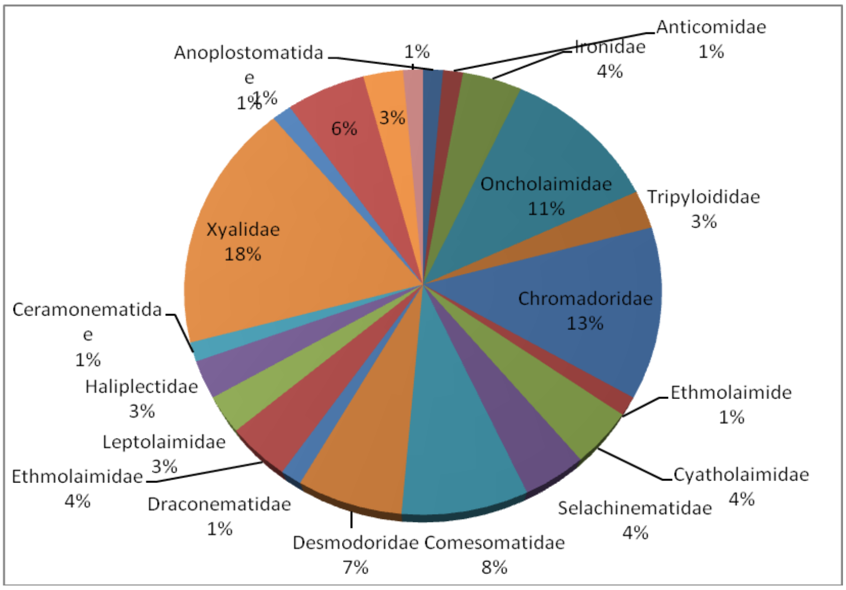

Fig 3. Percentage contribution of various free-living marine nematode families

The most common species in the study were *Viscosia* spp., *Sabatieria* spp., *Daptonema* spp. and *Terschellingia* spp. In station1, the dominant species were *Viscosia viscose*, *Daptonema hirsutum, Daptonema normandicum Dichromadora geophila* and *Siplophorella* sp. In station 2 the dominant species were *Gammanema conicauda*., *Viscosia elegans* and *Sabatieria pulchra and Sabatieria punctata*. In station 3 the dominant species were *Viscosia viscose*, *Viscosia cobbi, Viscosia glabra, Daptonema hirsutum, Daptonema normandicum, Sabatieria ornate, Sabatieria pulchra, Sabatieria punctata,* and *Terschellingia longicaudata.* Among the feeding groups, the nematode community was dominated in terms of abundance by non-selective deposit feeders. The epigrowth feeders ranked second, followed by predators and deposit feeders (Fig.4).

Harpacticoid copepods constituted the second dominant group among the meiobenthos. They were found in all the stations. The most dominant harpacticoid copepod species recorded were *Canuella perpiexa, Ectinosoma melaniceps, Laophonte* spp., *Darcythompsonia fairliensis* and *Leptastacus macronyx*. The common species found in all the three stations were Foraminiferans ranked third in term of abundance in *Ammonia becarii, Rosalina bertheloti, R.bradyi, R.globularis, Triloculina austriaca, Quinqueloculina* spp. and *Globigerinita glutinata* species.

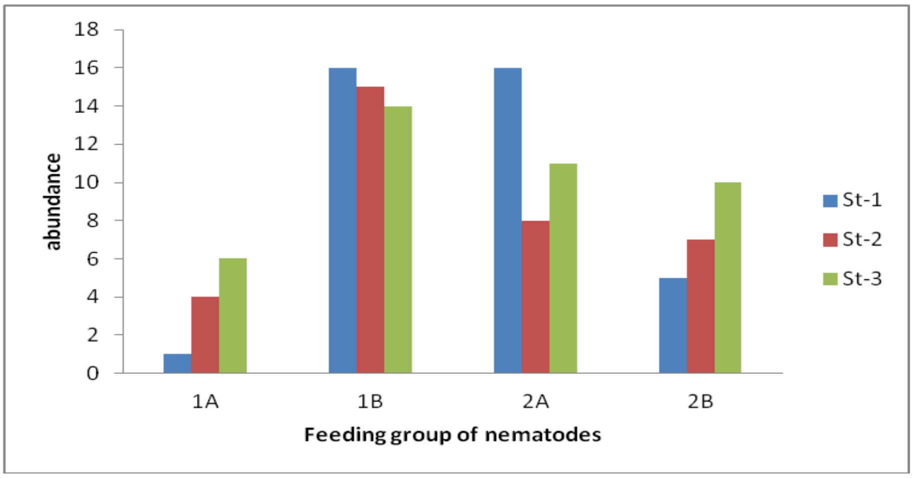

Fig 4. Feeding type of nematodes in three stations of Uppanar estuary

DISCUSSION

The meiobenthic fauna of Uppanar estuary included nine taxa such as nematodes, harpacticoid copepods, foraminifeans, polychaetes, ostracods, isopods, cumaceans, tanaidaceans and tardigrads. The vertical distribution of meiofauna, nematodes in particular was controlled by the vertical profile of environmental factors. Differences in food availability both quantitative and qualitative appear to be an important factor controlling total abundance and the faunal composition of the metazoan meiobenthos (Vincx *et al*., 1994; Soltwedel, 1997; Sajon *et al*., 2010; Ingole *et al*., 2010). An important feature of nematode population is the presence of large number of species in a single habitat (Ingole *et al*., 2010). Physico-chemical factors and competition, both among the individuals within a species as well as among the species also play a major role in limiting the faunal abundance and distribution (Soltwedel 2000; Sajan and Damodaran, 2010). Sheltered regions with muddy sediments rich in detritus generally are characterized by high meiofaunal densities (Heip *et al.,* 1985; Coull, 1988; Giere *et al*., 1988).

Among the meiofauna, nematodes alone constituted 57.17% of the total meiofauna. Many investigations carried out also showed the predominance of nematodes among the meiofauna in the estuaries and coastal waters (Sultan Ali *et al*., 1983; Abdul Azis and Nair, 1983; Krishnamurthy *et al*., 1984; Rao, 1986; Kondalarao and Ramananamurty, 1988; Ansari *et al.,* 1993 & 2012; Ansari and Perulekar, 1994 & 1998; Sarma and Wilsanand, 1994; Sinu *et al*., 2015). Presently a total of 72 species were identified belonging to 42 genera and 21 families. The dominant families in the present study were Xyalidae, Comesomatidae, Oncholamidae, Chromadoridae, and Desmodoridae. Similar results have been reported from Western continental shelf of India and southeast continental self of in India by Sajan and Damodaran (2007) and Ansari *et al.,* (2012) respectively. The presence of sensitive or tolerant meiofaunal taxa and nematode genera appears to be particularly informative in highlighting the state of sediment pollution which allows a better assessment of the spatial heterogeneity of environmental disturbance within each station. Generally, the meiofaunal abundance was recorded lower in heavily polluted sediment with Kinorhynchchs and tanaids being totally absent (Table 1). The nematodes are typically found in organically rich and muddy sediment (Heip *et al*., 1990; Schratzberger *et al*., 2006 and Moreno *et al*., 2008). In the present study the namtode assemblage was dominated by *Terschellingia* spp.*, Sabatieria* spp.*, Daptonema* spp. and *Viscosia* spp. Similar observations were also made elsewhere which indicated of pollution in the habitat (Mereno *et al*., 2008). In particular, the *Sabatieria* genus has been widely recognized as tolerant to pollution as it sustains in low oxygen and high sulphide concentrations which happen to be unsuitable for most other nematode species. They are also able to survive and reproduce even at high levels in places having anthropogenic impact (Tietjen, 1980; Hendelberg and Jensen, 1993; Austen and Somerfield, 1997; Steyaert *et al*., 1999; Somerfiled *et al*., 2003; Schratzberger *et al*., 2006; Moreno *et al*., 2008; Vezzulli *et al*., 2008; Semprucci *et al*., 2010; Beyrem *et al*., 2010). Species of *Chromadora* and *Viscosia* may be abundant in sediments characterized by high organic content (Danovora *et al*., 1995; Schratzberger *et al*., 2004;

Beyrem *et al.,* 2011; Boufahja *et al*., 2011). Next to the above the dominance of species such as *Terschellingia longicudata* and *T. communis* was recorded in station 3. Physiological and behavioral adaptations besides a low respiratory rate, slow movements and deposition of insoluble metal sulfides in intracellular inclusions (as a mechanism of detoxification) of sulfide enable their survival in poor oxygenated environment and in places with metal and hydrocarbon contamination (Warwick and Price, 1979; Warwick and Gee, 1984; Nicholas *et al*., 1987 Somerfeld *et al*., 1994; Austen and Somerfield, 1997; Armenteros *et al*., 2009; Beyrem *et al*., 2010). Knowledge of the harpacticoid copepods distribution and diversity in the Indian water is limited as copepods are very sensitive to oxygen depletion and the presence of sulfide (Coull and Palmer, 1984). Similar observation was made by Sajan and Damodaran (2007) in the shelf region and Eldose (2008) in the slope region.

Higher mean abundance of foraminiferans noticed presently in station 2, is also supported by the finding of Sajan and Damodaran (2007) in the Western continental shelf of India. Similar observations were made from Godavari and Krishna estuaries (Narappa *et al*., 1982). In the present study, sediment nature was found to be an important factor determining the distribution of meiofauna, particularly nematodes (Sajan and Domadaran, 2007; Sajan *et al*., 2010). In the coastal areas, the density of meiobenthos also decreases which might be due to anthropogenic disturbances. Benthic communities are widely used in monitoring the effect of marine pollution as these organisms are mostly sessile and readily integrate the effects of pollutants. It has also been suggested that benthic fauna might be used as an integrating indicator of water quality. The analysis of nematodes assemblage done in the present study was found to be an informative tool for environmental monitoring.

REFERENCE

1. Harkantra, S.N., Nair, A., Ansari, Z.A. & Parulekar, A.H., Benthos of the shelf region along the west coast of India, *Indian j.mar. Sci.,*9 (1980)106-110.
2. Sajan, S., JoydasT.V & Damodaran, R., Meiofauna of the western continental shelf of India, Arabian Sea, *Estuar.Coast. Shelf Sci,* 86 (4) (2010) 665-674.
3. Sajan, S. & Damodaran, R., Faunal composition of meiobenthos from the shelf region off west coast of India,*J.Mar.Biol.Ass. India*, 49 (1) (2007) 19-26.
4. Cook, A.A., Lambshead, P.J.D., Hawkins, L.E., Mitchell, N. & Levin, I.A., Nematode abundance at the oxygen minimum zone in the Arabian sea*, Deep-Sea Res*., II (47) (2000) 75-85.
5. Timm R.W., The marine nematodes of the Bay of Bengal. *Proc.Pakistan Acad. Sci*., 1 (1961) 1-84.
6. Timm R.W., Some estuarine nematodes from the Sunderbans. *Proc. Pakistan Acad.Sci.,*4 (1967) 1-14.
7. Rao, G.C & Ganapati, P.N., Interstitial fauna inhabiting the beach of sands of Waltair coast, *Proc.Nat.Ins.Sci*., India.34 (1968) 82-125.
8. Ansari, Z.A., Parulekar A.H & Jagtap, T.G., Distribution of sub-littoral meiobenthos off Goa coast, India, *Hydrobiologia*, 74 (3) (1980) 209-214.
9. Ansari, Z.A., Meiobenthos from the Karwar region (Central west cost of India), *Mahasagar-Bulletin Natinal Institute of Oceanography* 11 (1978) 163-167.
10. Rodrigues, C.I., Harkantra, S.N. & Parulekar, A.H., Sub littoral meiobenthos of the northeastern Bay of Bengal, *Indian J.Mar. Sci*.,11 (1982) 239-242.
11. Ansari, Z.A., Rodrigues, C.I., Chatterji, A. & Parulekar, A.H., Distribution of Meiobenthos and Macrobenthos at the mouth of some rivers of the East coast of India, *Indian J. Mar.Sci.,*11 (4) (1982) 341-343.
12. Ansari, Z.A. & Parulekar A.H., Community structure of meiobenthos from a tropical estuary, Indian *J.Mar*. *Sci.*, 27 (1998) 362-366.
13. Abdul Azis, P.K. and Nair, N.B., The meiofauna of Edava-Nadayara-paravur Backwater system, southwest coast India. *Mahasagar, Bull.Natn. Inst.Oceanogr*., (1983) 16:55-65.
14. Ansari, Z.A. & Parulekar A.H., Meiobenthos in the sediments of seagrass meadows of Lakshadweep atoll, Arabian sea, *Vie Milieu*, (1994) 44: 185-190.
15. Sinu, J., Varghese, and Miranda, M.T.P., Meiobenthic diversity and abundance along Arthunkal coast in Kerala, southwest coast of India J. Mar.Biol. Ass.India(2015) 57(1): 78-83.
16. Nicholas W.L., Goodchild D.J., Steward A. The mineral composition of intracellular inclusions in nematodes from thiobiotic mangrove mud-flats. Nematologica, (1987) 33,167-179.
17. Warwick R.M., Gee J.M. Community structure of estuarine meiobenthos. *Marine Ecology Progress Series*, (1984) 18,97-111.
18. Warwick R.M., Price R. Ecological and metabolic studies on free-living marine nematodes from an estuarine mud-flat. *Estuarine and Costal Marine Science*, (1979) 9, 257-271.
19. Coull Bc, and Palmer M.A,) Field experimentation in meiofaunal ecology. *Hydrobiol* (1984) 118: 1-19.
20. Eldose, P.M., *Studies on benthic meiofaunal diversity and demersal standing stock prediction of the southeast continental slop (200-1000 m depths) of India (Bay of Bengal),* Ph.D. thesis, Annamalsi University, India, (2008).
21. Pascual, A., Lazaro, J.R., Rubio, M.M., Jouanneau, J. M. & Weber, O., A survey of the benthic microfauna (foraminifera, ostracoda) on the Basque shelf, southern Bay of Biscay, *J.Mar.Syst*.,72 (2008) 35-63.
22. Ingole, B. & Singh, R., Biodiversity and community structure of free living marine nematodes from the Larsemann ice Shelf, East Antarctica*, Curr. Sci.,* 99 (10) (2010) 1413-1419.

23. Vincx, M., Bett, B.J., Dinet, A., Ferrero, T., Gooday, A.J., Soltwedel T.& Vanreusel, A., Meiobenthos of the Deep Northeast Atlantic, *Adv.mar. Biol.,* 30 (1994) 2-88.
24. Krishnamurthy, K., Sultan Ali, M.A., Jeyaseelan, M.J.P., 1984. Structure and dynamics of the aquatic food web community with special reference to nematodes in mangrove ecosystem. In: Soepadmp, E., Rao, A.N., MacIntosh, D.J.(Eds), Proceeding of the Asian Symposium on Mangrove Environment: Research and Management, 1984. University of Malaya Kuala Lumpur, pp.429-452.
25. Rao, G.C. Meiofauna of the mangrove sediments in South Andaman. Journal of Andaman Science Association (1986) 2, 23-32.
26. Sultan Ali, M.A., Krishhamurthy, K., Jeyaseelan, M.J.P., Energy flow through the benthic ecosystem of the mangrove with special reference to nematodes. Mahasagar Bulletin of the Natinal Institute of Oceanography (1983) 16, 317-325.
27. Sarma A.L.N., Wilsanand, V., Littoral meiofauna of Bhitarkanika mangroves of river Mahanadi system, East coast of India. Indian Journal of marine Science (1994) 23,221-224.
28. Kondalarao, B., Ramanamurthy, K.V., Ecology of intertidal meiofauna of the Kakinada Bay (Gautami-Godavari estuarine system). East coast of India. Indian Journal of Marine science (1988) 17, 40-47.
29. Platt, H.M. and R.M. Warwick, The significance of nematodes to the littoral ecosystem. In: Peince, J.H., D.E.C. Irvine and W.H. Franham (Eds.), *The shore environment ecosystems* Vol.2, Academic Press, London. (1980) P. 729-759.
30. Platt, H.M, and R.M. Warwick. Free living marine nematodes. Part I: British Enoplids. *Synopses of the British Fauna (New Series). No.28*, Cambridge University Press, Cambridge. (1983) 307 pp.
31. Steyaert, M., T. Deprez, M.Raes, T.Bezerra, I. Demesel, S. Derycke, G. Desmet, G. Fonseca, M. de Assunc ao Franco, T. Gheskiere, E. Hoste, J. Ingels, T. Moens, J. Vanaverbake, S. VanGaever, S. Vanhove, A. Vanreusel, D. Verschelde and M. Vincx. 2005. Electronic Key to the free-living marine Nematodes, *http://nemys.ugent.be*
32. Warwick, R.M, Platt, H.M & Somerfild, P.J. (1998) free-living Marine Nematodes. Part III. British Monhysterids. The Linnaean Society of London and The Estuarine and Coastal Sciences Association
33. NariMesa, Q., Nabavi, M and Pour, S. Ecological capability of District Raphe using GIS and Fuzzy Logic (GIS) Geographic. Environmental Studies, (2011) 2,29-40.
34. Narappa, K.V., Subba Rao. M and Rao.M.P. Comparison of foraminiferal assemblages from Godavari & Krishna river eastuaries *Indian, jou.marine, science* ., (1982) vol.11 Pp.220-224.
35. Moghadasi, B, Nabavi, M., Fatemi, Mand Vosoghi,Gh. Comparison of Species Diversity and Distribution Patterns of Benthic Foraminifera in the Northern and Southern Continental Shelf of Oman. Journal Marine Biology from. (2009) 0.13 to 27.
36. Moghadasi, B, Nabavi, M., Fatemi, Mand Vosoghi, Gh. (2008) Ostracoda Species Diversity and Distribution Patterns of Benthic Foraminifera in the Northern and Southern Continental Shelf of Oman. Thesis, Islamic Azad University, Science and Research Branch of Tehran.
37. Urban-Malinga, B., Meiobenthos in marine coastal sediments. In: Martini, I.P., Wanless, H.R., (Eds.), Sedimentary Coastal Zones from High to Low Latitudes: Similarities and Differences. Geological Society, London, Special Publications (2013).
38. Tang, L., Li, X.H., & Yan. Y., Temporal and spatial distribution of the meiobenthic community in Daya Bay, South China Sea, *Ocean Sci.Discuss*., 9 (2012) 1853-1885.
39. Altaf, K., Sugumaran, J., & Naveed, S.M., Impact of tsunami on meiofauna of marine beach, Chennai, *India, Curr.Sci. India.*, 89 (2005) 34-38.
40. Schratzberger, M., Whomersley, P., Warr, K., Bolam, S.G., & Ress, H.L., Colonisation of various types of sediment by estuarine nematodes via lateral in faunal migration: a laboratory study, *Mar.Biol.,* (2004) 145:69-78.
41. Veit-Kahler, G., Laudine, J., Knott, J., Velez, J., & Sahade, R., Meiobenthic colonization of soft sediments in arctic glacial Kongsfjorden (Svalbard), *J.Exp.Mar.Biol.Ecol*., 363 (2008) 58-65.
42. Bongers, T & M. Bongers, Functional diversity of nematodes. *Appl.Soil Ecol*. (1998)10:239-251.
43. Bongers, T & H. Ferris, 1999.Nematode community structure as a bio-indicator in environmental monitoring TREE14:224-228.
44. Beyrem, H., Louati, H., Essid, N., Aissa, P., Mahmoudi, E., Effects of two lubricant oils on marine nematode assemblages in a laboratory microcosm experiment. *Marine Environmental Research* (2010) 69,248e253.
45. Austen, M.C., Somerfield, P.J., A community level sediment bioassay applied to an estuarine heavy metal gradient. *Marine Environmental Research* (1997) 43,315e328.
46. Armenteros, M., Prez-Angul., Regadera, R., Beltran, J., Vincx, M., Decraemer, W., Effects of chronic and heavy pollution on macro-and meiobenthos of Havana Bay, Cuba. Revista de Investigations Marinas (2009) 30 (3), 203e214.
47. Somerfield, P.J., Gee, J.M., Warwick, R.M., Soft sediment meiofaunal community structure in relation to a long-term heavy metal gradient in the Fal estuary system. *Marine Ecology Progress Series* (1994) 105,79e88.
48. Wieser W. Benthic studies in Buzzards Bay: II. The meiofauna. Limnology and Oceanography, (1960).5 (2): 121-137.
49. Ansai, K.G.M.T. S, P.S. Lyla and S. Ajmal Khan. 2012b. Faunal composition of metazoan meiofauna from the southeast continental shelf of India. Indian.J. Geo-Mar. Sci., 41(5): 457-467.

50. Higgins, R.P and H. Thiel, Introduction to the Study of Meiofauna. Smithsonian Inst. Press, (1998) 1-488.