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Benthic infauna from mudflats of Atharbanki mangrove waterway in Odisha, India

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Original Article

Abstract

Atharbanki, a mangrove waterway of Mahanadi Estuary (17°49'N-22°34''N; 81°24'-87°29'E) on the east coast of India has been under considerable anthropogenic pressure. Due to lack of sufficient information on benthos from lesser recognized tropical tidal flats, a one-time (21.01.2015) investigation (N=21) from seven GPS fixed locations along a shore transect (1km) parallel to the channel course revealed 30 benthic species represented by five diverse groups and 1065 individuals. Polychaetes were dominant (55%) followed by the amphipod *Eriopisa chilkensis* (40%) and others. While Margalef d exhibited relatively high values (mean 2.35) near the mouth (stations 1, 2) sites (stations 6, 7) subject to runoff from industries depicted lower values (mean 1). Multivariate measures (PRIMER) revealed two distinct benthic assemblages: Group-1 *Namalycastis*-amphipod association (stations 1, 4 & 6 exposed to port/industrial activity) noticed within *Kandelia*, *Aegiceras* and mixed mangrove foliage (low elevation) and Group-2 amphipod- *Dendronereis heteropoda* assemblage (stations 2, 3) associated with *Excoecaria* sp. Station 5 with *Acanthus* sp. on high grounds of gypsum dumps, populated mostly with nephtyids and station 7 surrounded by Fisher hamlets) remained similar to stations 2 and 3. K-dominance plots indicated maximum diversity for sites with mangroves subject to neritic influence (stations 1, 2) whereas mangrove impacted stations 6 &7 subject to human interference recorded least diversity. Mangrove denudation, aquaculture, industrial dump sites appeared to structure the benthic faunal communities of Atharbanki tidal flats.

Keywords: *Estuary, industrialization, macrobenthos, mangroves, polychaetes, tidal flats.*

Introduction

Paradip (20°17'08''N; 86°42'24''E), one of the leading seaports of Odisha State in the vicinity of Mahanadi Estuary and its waterways, on the east coast of India underwent massive changes recently owing to rapid industrialization and urbanization. A number of industrial undertakings have sprung up in the immediate vicinity of this area concomitant with denudation of mangrove vegetation. Shrimp farms and discrete outfalls from industries opening directly either onto mud flats or estuary/mangrove channels have taken their toll as witnessed with other world regions (Dittmann, 2002) upsetting sediment habitats populated by a species-rich benthic fauna. Benthic organisms are recognized to play significant roles in the food web of mangrove ecosystems, as they represent a key food source for juvenile fish and prawns, which use mangroves as nursery grounds (Daniel and Robertson, 1990). Consequently, destruction, degradation, alteration of such wetland habitats for aquaculture, urbanization and industrialization, drives countless species to near extinction. Notwithstanding the ecological implications of such anthropogenic interferences, efforts towards elucidating the benthic infaunal biodiversity inhabiting the estuary and microhabitats of tidal flats as documented in tropical and subtropical regions (Dittmann, 2000; Sheaves *et al.*, 2016; Zabbey and Arimoro, 2017; Barnes, 2017) have not been adequately reported from the Mahanadi Estuary until now, except for stray observations by the Zoological Survey of India, Kolkata (Z.S.I, 1998). The primary objective of this study has been to provide insights of benthic infaunal community structure vis-à-vis environmental conditions associated with mudflats of Atharbanki tidal channel of the Mahanadi Estuary on the east coast of India which is under severe human impingement in recent years.

Material and methods

Study area

Atharbanki (Latitude 17˚49'N-22˚34'' N and Longitude 81˚24'-87˚29'E) is relatively shallow (depth ≤ 2m) and within the mangrove areas *Avicennia, Rhizophora*, *Bruguiera*, *Kandelia*, *Ceriops*, and *Aegiceras* sp. are the most common. The river meanders southeast to northeast for nearly 13.5 km skirting the highly industrial belt of Paradip, courses adjacent a major fishing harbor into Mahanadi Estuary before opening into the Bay of Bengal (Fig. 1).

Methodology

Seven stations (spaced nearly 140 meters apart) distinguished on the basis of mangrove vegetation (true/associate), tree density and prevailing salinity, were fixed with a GPS

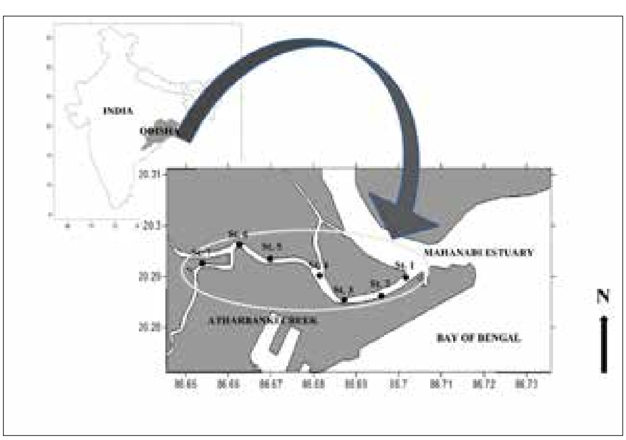

Fig. 1.Study area showing the Atharbanki mangrove channel, Mahanadi Estuary, Odisha

(Garmin eTrex) along a parallel transect on the mud flats of Atharbanki channel. Hydrobiological observations were made at low tide. Water temperature was recorded using a mercury-filled thermometer of 0.5˚C sensitivity, pH with a pre-calibrated pH meter (Hanna HI 98107), salinity by means of a refractometer (Erma) and dissolved oxygen (D.O) estimated through modified Winkler's method (APHA, 2009). During the study (21.01.2015; 1230 to 1600 hours), the infaunal samples were collected with the help of a metal quadrat (0.04m^2) according to standard protocols (Eleftheriou and Moore, 2013). The samples were collected by pushing the metal frame into the sediment up to a depth of 20 cm, material excavated and a small quantity (~100 gm) kept aside for granulometry and organic matter (5 gm). The remaining sediment was then sieved (500 μm sieve) and the residue preserved in 10% formaldehyde containing Rose Bengal (200 mg/l) for later examination. In the laboratory, the material was rewashed and fauna separated into groups using a stereozoom microscope (Luxeo 4Z). All organisms were identified to the extent possible with the help of standard literature (Fauvel, 1953; Day, 1967 and WoRMS, 2017). The sub-sample meant for granulometry was processed for estimating sand, silt and clay content (pipette analysis) according to Krumbein and Pettijohn (1938) and redefined by Eleftheriou and Moore (2013). The weights in each grade (sand, silt and clay) were converted into percentages of dry weight of total sample and its nomenclature assigned (Shepard, 1954). Organic matter (OM) was determined by the wet-oxidation method of Walkey-Black as modified by Gaudette *et al.* (1974).

Data analysis

Univariate indices such as species richness (Margalef's *d*), Shannon-Wiener diversity (*H'* Loge), and Evenness (*J'*), were determined using PRIMER v.7 (Plymouth Routines in Multivariate Ecological Research) (Clarke and Gorley, 2006). The approach consisted of estimating Bray-Curtis similarity after suitable transformation of data. The similarity matrix was then subjected to clustering (hierarchical agglomerative method using group-average linking) and ordination (non-metric multidimensional scaling, MDS) implemented in PRIMER. Environment vs. fauna relationships were examined using Statsoft (StatSoft Inc., 2007).

Results

Environment

Water temperature varied from a low 20ºC (Stn.1 and 4) to a high of 23ºC (Stn.7). pH registered 7.84 (Stn.7) to 8.96 (Stn.1). Salinity varied from a minimum of 8.97 psu (Stn.7) to a maximum 20.75 psu (Stn.1). Dissolved oxygen fluctuated between 0.16 mg/l (Stn.6) and 3.6 mg/l (Stn.1). Nitrite varied from 6.23 μM/l (Stn.2) to 10.66 μM/l (Stn.1) and phosphate registered a low

1.29 (Stn.7) to a high 15.05 μM/l (Stn. 2). Sediments were mostly silty (mean 63.6%) with relatively high organic matter, ranging from 2.38% (Stn.7) to 6.67% (Stn.6) at all sites except station 7 where the intertidal mudflats were devoid of mangrove vegetation (Table 1; Fig. 2).

A total of 30 species of benthos represented by five diverse taxa were encountered during the study. Of these, polychaetes were by far the most dominant (55%) followed by amphipods (40%), molluscs (3%) and others (2%) (Fig.3). Based on the mean abundance of taxa, the nereid *Namalycastis* sp. contributed 480 ind/0.04m^2 of the total numbers followed by amphipod *Eriopisa chilkensis* (409 ind/0.04m^2), *Nepthys* sp. (19 ind/0.04m^2), brachiopod *Lingula* sp. (18 ind/0.04m^2), *Prionospio* sp. (13 ind/0.04m^2) and others (Table 2). Hierarchical clustering (powered by SIMPROF) to discriminate spatial variations between sites revealed, despite overall homogeneity, two major assemblages based on the abundance of benthos: Group-1 (Stns.1, 4 & 6) associated with *Kandelia, Aegiceras* and mixed mangrove foliage (characteristic of low elevation) and Group 2 Stns. 2, 3, 5 & 7 inhabited by *Excoecaria* (Stn.2), *Avicennia* (Stn.3) and *Acanthus* (Stn.5) noticed on high ground affected by gypsum dumps, used by fertilizer and other industries and Stn.7, a mangrove degraded zone (Fig. 4). Benthic infauna accountable for the observed spatial differences were Group-1 characterized by *Namalycastis* sp. and amphipods and Group-2

Table 1. Environmental parameters in the Mahanadi Estuary.

Variable	Stn.1	Stn.2	Stn.3.	Stn.4	Stn.5	Stn.6	Stn.7	Mean	SD
Water Temp °C	20	22	22	20	21	21	23	21.28	1.1
pH	8.96	8.08	7.88	8.12	7.95	8.17	7.84	8.14	0.4
D.O mg/l	3.6	1.68	1.2	1.28	0.8	0.16	0.64	1.34	1.1
Salinity psu	20.75	16.01	15.11	14.99	12.17	9.22	8.97	13.89	4.1
Nitrite μM/l	10.66	6.23	6.59	7.09	7.81	6.37	6.41	7.31	1.6
Phosphate μM/l	12.21	15.05	11.03	8.03	7.92	4.38	1.29	8.56	4.7
Sand%	33.75	25.72	24.17	39.26	31.08	28.4	72.06	36.35	16.5
Silt%	66.2	74.24	75.78	60.7	68.87	71.55	27.9	63.61	16.5
Clay%	0.06	0.04	0.05	0.04	0.05	0.05	0.04	0.05	0.0
Organic Matter%	6.05	5.18	3.54	5.51	5.81	6.67	2.38	5.02	1.5

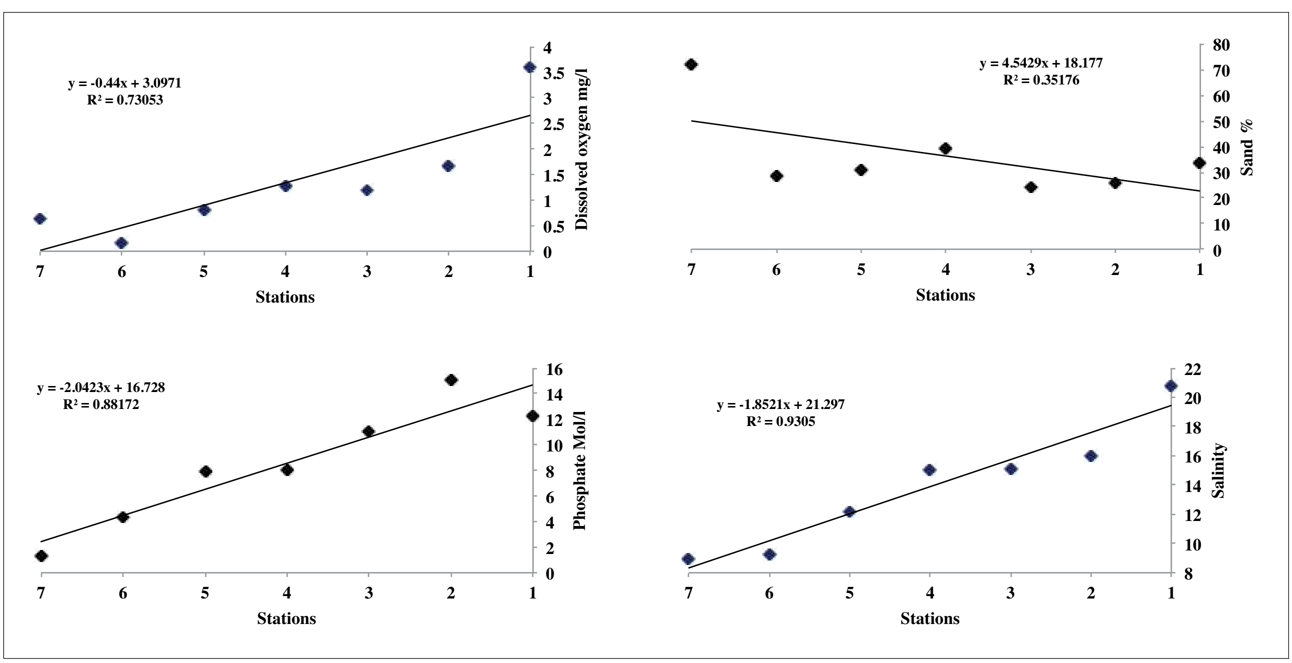

Fig. 2. Trend of hydrgraphical and sediment variables across stations on the mudflats of Atharbanki

Table 2. Numerical abundance (nos/0.04 m^2) of benthic infauna of Atharbanki mud flats.

Taxa	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Ind/ 0.04m^2
Polychaetes								
Paraonids	7	-	-	-	-	-	-	7
Prionospio sp.	6	-	-	2	5	-	-	13
Polydora sp.	-	-	-	-	2	-	-	2
Capitella sp.	5	-	-	-	5	-	-	10
Ancistrosyllis sp.	-	-	-	-	-	-	3	3
Namalycastis sp.	287	5	5	138	-	60	-	480
Perinereis sp.	-	5	-	4	-	-	-	9
Dendronereis arborifera	-	2	3	-	-	-	-	5
D. aestuarina	-	2	2	-	-	-	-	4
D. heteropoda	-	3	2	1	1	-	-	7
Glycera sp.	8	-	-	2	-	-	-	10
Nephtys sp.	1	-	-	3	11	2	2	19
Diopatra sp.	-	-	2	-	-	-	-	2
Eunice sp.	-	-	-	-	-	-	1	1
Sternaspis sp.	1	-	-	-	-	-	-	1
Cirratulid sp.	-	-	-	-	1	-	-	1
Sabella sp.	-	-	-	1	-	1	-	2
Molluscs								
Pirenella cingulata	3	-	-	-	-	-	-	3
Nassarius stolatus	1	-	-	-	-	-	-	1
Tellina sp.	1	-	-	-	10	-	-	11
Solen sp.	8	-	-	-	-	-	-	8
Meretrix sp.	3	1	-	-	3	2	-	9
Telescopium sp.	3	-	-	-	1	-	-	4
Crustaceans								
Cumacids	-	-	-	-	1	-	-	1
Caprellid sp.	3	3	1	-	-	-	-	7
Eriopisa chilkensis	8	11	60	10	304	2	14	409
Sphaeroma sp.	-	-	-	4	-	-	-	4
Scylla serrata juvenile	-	-	-	1	-	-	-	1
Brachiopod								
Lingula sp.	18	-	-	-	-	-	-	18
Pisces								
Boleopthalmus sp.	-	-	-	-	1	-	-	1
Total individuals/ 0.04m^2	363	32	72	166	345	67	20	1065

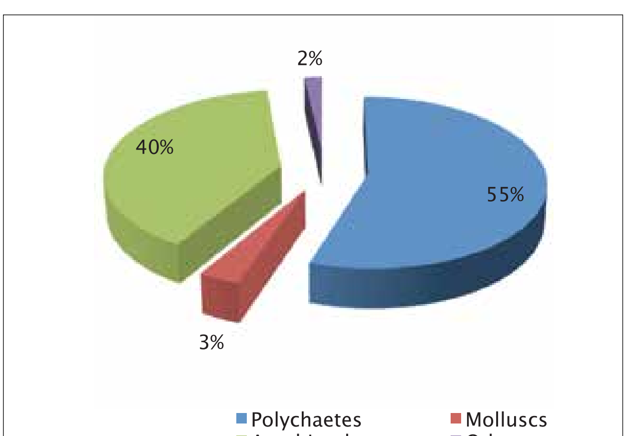

Fig. 3. Benthic infaunal groups on the mudflats of Atharbanki

assemblage predominantly amphipods and *Dendronereis heteropoda* (Fig. 5a-b).

Within the two groups of benthos, Margalef *d* was highest at Stn.1 (*Kandelia* zone) near the mouth while Stn.6 affected by industrial wastewater and Stn.7 with degraded mangrove vegetation showed fairly lower values (Table 3). In order to further validate results of diversity across stations, K-dominance plots were constructed where species contribution (>1%) was taken into consideration to rank them as Biologically Important Species (Clarke and Warwick, 2001). The cumulative relative abundance of the population was plotted on the Y-axis against increasing species rank on the X-axis stations-wise and an attempt made to link them to the presence of mangroves (Fig. 4) While sites subject to neritic influence from the Mahanadi estuary (Stn.1) within the *Kandelia* mangrove zone showed the highest species rank (17) indicative of maximum diversity (healthy conditions), it was a mere 4 (least species rank) at the denuded site (Stn.7) (Fig. 6). Observations also revealed comparatively large populations of the nereid worm *Namalycastis* sp. (average 161 individuals per 0.04 m^2) from organically enriched (Group-1) stations 1, 4 & 6 (organic matter ≥5.5 %) with mostly *Kandelia* species and mixed mangrove vegetation. Within Group-2 sites, station 5 with *Avicennia/Acanthus* sp. and gypsum dumps in the upper mudflats was colonized by high numbers of amphipod *Eriopisa chilkensis.*

Table 3. Diversity indices of benthic infauna of Atharbanki mud flats.

Stations	S	N	d	J'	H'(loge)
Stn.1	17	363	2.7	0.4	1.1
Stn. 2	8	32	2	0.9	1.8
Stn. 3	7	72	1.4	0.4	0.7
Stn. 4	10	166	1.8	0.3	0.8
Stn. 5	12	345	1.9	0.2	0.6
Stn. 6	5	67	1	0.3	0.5
Stn. 7	4	20	1	0.7	0.9

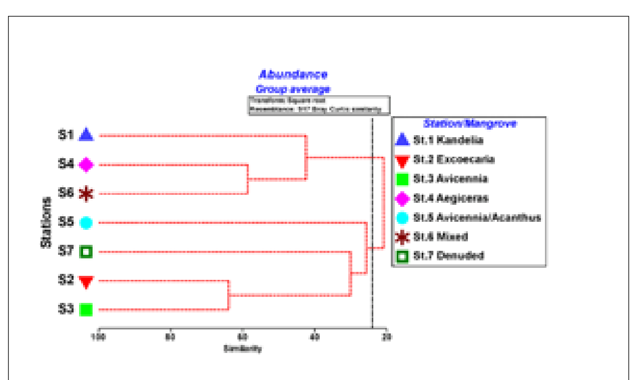

Fig. 4. Bray-Curtis similarity for benthic infauna

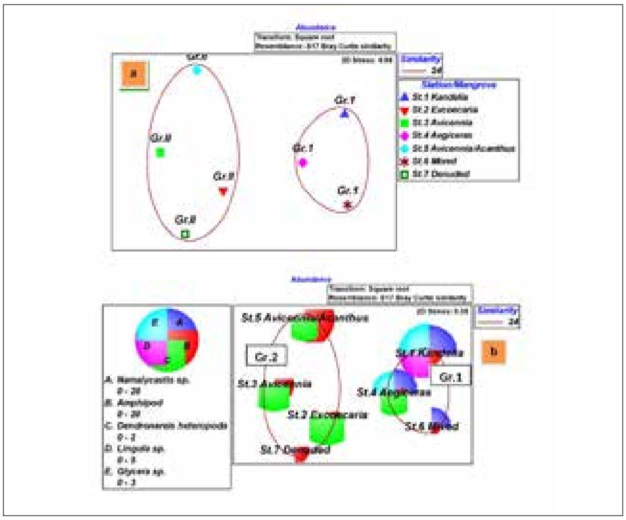

Fig. 5. MDS ordination validating a. station groups and b. depicting distribution of dominant species in the study area

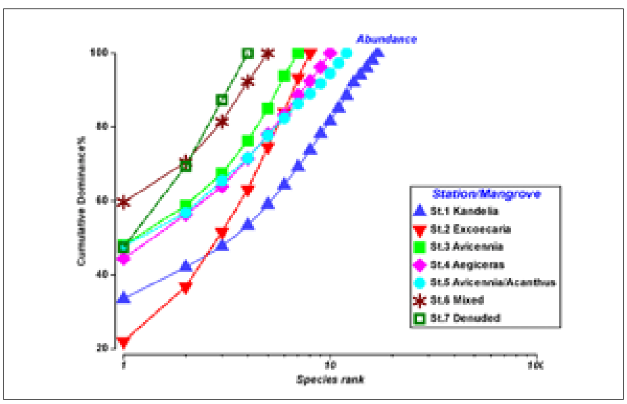

Fig. 6. K-Dominance plots across stations in the study area as related to mangrove vegetation

Discussion

Characteristically nearshore, estuarine habitats and mangroves have been observed to be strongly influenced by abiotic factors such as freshwater runoff, sedimentation and rapid temperature fluctuations from the influence of sun and wind on tidally driven shallow waters (Nagelkerken *et al*., 2010). Channel mudflats in Atharbanki predisposed to tidal flows from the Mahanadi estuary, creeks and outwelling from mangroves depict perceptible spatial variation in salinity causing near mesohaline (8.97 psu) conditions towards the riverine end owing to freshwater inputs from smaller creeks to a relatively polyhaline (20.75 psu) environment in the vicinity of the estuary mouth inclined to neritic influence from the Bay of Bengal. Dissolved oxygen dynamics of coastal tidal wetlands understood to be complex, depend on a range of biotic and abiotic conditions varying at multiple spatial and temporal scales (Smith and Able, 2003). For example, a positive relationship (Pearson correlation) between dissolved oxygen and salinity (r 0.93; $p<0.05$) could apparently be due to microphytobenthos (MPB) photosynthetic productivity during immersion (high salinity) by certain species inhabiting the surface of sediment mudflats (Juneau *et al*., 2015). Photosynthetic activity of MPB coupled with effects caused by dissolved organic matter such as polyphenolic compounds (humic acids, fluvic acids, tannins from mangrove leaf exudates) explains the correlation between pH and dissolved oxygen (r 0.84 p <0.05) as reported from mangrove waterways (Boto and Bunt, 1981). Leaching of liquid wastes from outfalls of fertilizer industries in the proximity and incursion of sewage waters from the adjoining fisher hamlets could be causative factors of microphytobenthos enrichment of the mudflats. Their decay along with anaerobic degradation of outwelled mangrove detritus could sufficiently deplete oxygen levels in mudflats supporting mangrove cover as described elsewhere for tropical mangrove forests (Mattone and Sheaves, 2017). Fine-silty mudflats linked with mangrove stands in Atharbanki have been associated with low oxygen and relatively high levels of nutrients such as phosphate, nitrite and organic matter in particular, observed to be the second highest after Pichavaram mangrove mudflats (Ramanathan *et al*., 1999). Their lesser permeability leads to trapping of detritus which together with a large surface area for microbial colonization, leads to higher oxygen uptake (Eagle, 1983). Sulphate leaching from gypsum dumps in the vicinity (Stns. 6, 5) could get oxidized, utilizing the available oxygen resulting in near hypoxic conditions (dissolved oxygen 0.16 mg/l at station 6) as similarly reported from Matang mangrove estuarine regions (Nagelkerken *et al*., 2010). Build-up of significant pools of sulphur in the sediments of wetlands and creeks are an emerging risk for the management of inland waterways (Hall *et al*., 2006).

During the last few decades, tropical wetlands have been destroyed, degraded and considerably altered, driving many associated species to near extinction (Thivakaran, 2017). The mangrove wetlands of Mahanadi estuary and waterways at Paradip are no exception. Indiscriminate denudation of mangroves at many places by the local population for firewood, timber, aquaculture practices such as the construction of shrimp farms, industrial units have altered the once dense vegetation of the intertidal belt. In Paradip, urbanization, industrialization and shrimp farming are identified as the key reasons which could imperil mangroves and associated mudflat inhabiting fauna.

Our study indicates small sized (≤500 μm) polychaetes as the preponderant taxa (55%) amongst benthic infauna, a finding in agreement with other works (Dittmann, 2001; Sarkar 2018). Of significance here is the occurrence of the nereid *Namalycastis* sp. (45.1%) a deposit feeder and amphipod

Eriopisa chilkensis (38.4%) a filter feeder, in large numbers, possibly behaving as opportunists characterizing benthic infaunal assemblages. Observations indicate high individual densities for the two-aforementioned species whereas the rest recorded low densities. 19% species (comprising *Namalycastis* sp. amphipod, *Nepthys* sp. *Lingula* sp. *Prionospio* sp. and *Tellina* sp.) (Fig. 7) accounted for 90% of the total population of infauna, in accordance with studies on tropical mudflats (Dittmann, 1995). Organically enriched muddy areas (organic matter ≥ 5.5 %) subject to neritic influence as with station-1 adjacent to the fishing harbour with considerable boat traffic and station 4 located a little interior surrounded by *Kandelia* and mixed mangrove vegetation nearer industries were characterized by the nereid *Namalycastis* sp. in large numbers (mean 212 nos./0.04 m^2) indicative of the species preference/ tolerance to organically enriched sediments. This is in contrast to station 5 where *Avicennia/Acanthus* sp. were found and gypsum dumped in the upper mudflats colonized by high numbers of the amphipod *Eriopisa chilkensis.* Most amphipods are free-living benthic gammaridians that can occur in such high densities with absolute dominance at times (Cunha *et al.*, 2000). Though considered responsive to pollution (Carretero *et al.*, 2011), sensitivity to disturbances for the same taxonomic group could differ from one species to another (Afli *et al.*, 2008). Similar to our observations, *Eriopisa chilkensis* has been reported from organically enriched sites of Cochin Estuary, southwest coast of India with tolerance to organic pollution (Aravind *et al.*, 2007). Dominance by very few species and low taxonomic richness explains the low Shannon diversity indices reported here (Table 3). Low diversity seems to be a major feature of bare intertidal mudflats (Jourde *et al.*, 2017) an observation in conformity with the comparatively lower species richness, diversity and paucity of fauna at station 7, a mangrove denuded site.

The present investigation as a one- time study provides a preliminary evaluation of the fast vanishing mangrove foliage with information on benthos from the mudflats of Atharbanki–an indiscriminately used mangrove waterway. Near impoverishment of infauna from mangrove denuded mud flat sites clearly specify the significance of this unique vegetation, necessitating sensitization/mangrove restoration programs in the region and further monitoring studies.

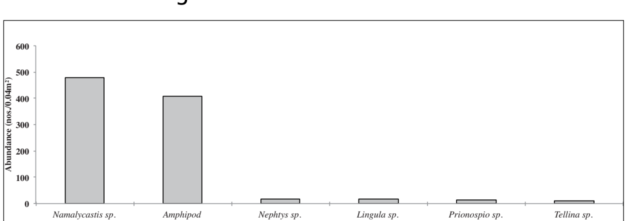

Fig. 7. Abundance (ind/0.04m^2) and percentage contribution of ranked taxa

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