



Spatial distribution and diversity inventory of macro-benthic fauna in the Indian Sundarban

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ABSTRACT

In the present study, an attempt was made to document the spatial distribution and rapid diversity inventory of macro-benthic fauna from 21 sampling stations of the Indian Sundarban for a period of six months from November 2014 to April 2015. A total of 1,871 individuals belonging to 35 species were recorded which comprised 12 species of molluscs, 20 species of crustaceans, one species each of xiphosurid, sea anemone and fish. The frequency analysis of species revealed that the most dominant species were *Telescopium telescopium* and *Tubuca rosea* among molluscs and crustaceans, respectively. The density analysis of species showed that *Pirenella cingulata* and *T. rosea* had maximum values among molluscs and crustaceans, respectively. The average values of Shannon-Wiener diversity index, Simpson diversity index, dominance index and Margalef diversity index were found to be 2.712, 0.888, 0.111 and 4.513, respectively.

Keywords: Indian Sundarban, Macro-benthic fauna, Spatial distribution, Species diversity

Introduction

The Indian Sundarban (21°32' to 22°40'N and 88°85' to 89°00'E), the largest delta in the estuarine phase of the tidal Hooghly River, has an area of 9,630 km² and is situated in the east coast of India. Estuaries in general, and mangrove ecosystems in particular are highly productive systems and their sediments are permanently or periodically inhabited by diverse assemblages of benthic invertebrates like polychaetes, molluscs and crustaceans (Day *et al.*, 1987). Macrobenthic organisms in estuaries are generally diverse and typically sedentary in nature (Prabhu *et al.*, 1993). Understanding the biological diversity in terms of the processes by which ecosystems and their components function, is critical for its sustainable use. Macrobenthos play a major ecological role in the mangrove ecosystem by assisting in the breakdown of particulate organic material and exposing them to microbes (Warren and Underwood, 1986). Further, their waste materials contain rich nutrients supporting offshore and pelagic communities (Lee, 1997), thereby exporting energy to higher trophic level.

Small changes in the environment will have substantial response on the macrobenthos, which can be used as a potential indicator to measure the degree of pollution (Coull, 1973) and to assess health of ecosystem. The estimation of benthic production would also serve as a useful index for assessing the fishery potentials, interaction, pollution and intertidal ecology. Studies on

benthic diversity, population dynamics and changes caused by natural or anthropogenic processes are therefore, essential for monitoring changes in mangrove ecosystems and its management (Jahan *et al.*, 1990). Collection of data on spatial and temporal patterns are considered as a primary step in developing models about ecological processes within the ecosystem (Underwood *et al.*, 2000) and to identify changes and assess impact of biotic and abiotic stress. Documentation of diversity will become an inevitable tool to understand *status quo* (Naeem *et al.*, 1994). The present study, therefore was carried out to examine the mangrove associated macrobenthic faunal distribution and rapid diversity in Indian Sundarban.

Materials and methods

The present study was carried out for a period of six months, from November 2014 to April 2015. The total area of the Indian Sundarban (Fig. 1) was divided into three zones *viz.*, Eastern, Central and Western zones and from each zone seven sampling sites (Table 1) were selected randomly. Samples were collected during low tide. For the quantitative study, sampling was made along the transects (100 m for each station) from the low tide mark. Further, 1 m quadrats constructed from nylon ribbon and bamboo sticks, were established along the transects with three replicates for each station. The quadrat was pushed into the sediment and the enclosed deposit was searched first and the deep burrowing organisms were counted

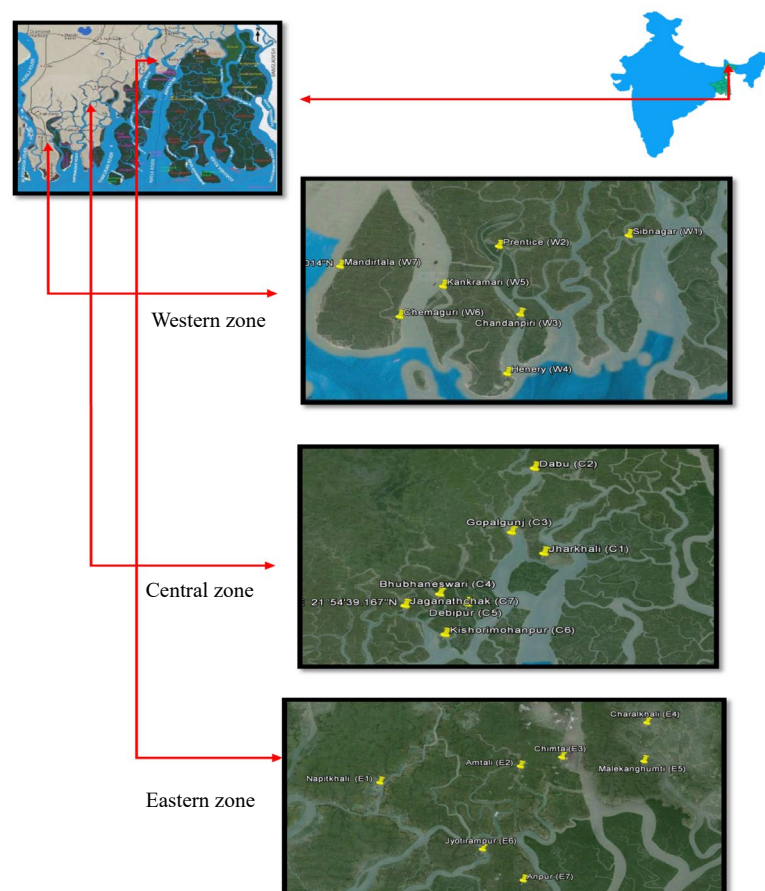


Fig. 1. Map showing sampling sites in the Indian Sundarban

by observing their burrows (Khade and Mane, 2012). Benthic fauna were then collected by digging the soil up to a depth at which no organisms were encountered. Soon after retrieval, the organisms were preserved in 5% formalin and brought to the laboratory of Department of Fisheries Resource Management, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Kolkata for further identification. The sorted organisms were first segregated into different groups and then identified to species or generic levels with the help of standard taxonomic references (Chakraborty *et al.*, 1986; Dey, 2006). The present study, focused mainly on qualitative and quantitative assessments of benthic macrofauna *viz.*, molluscs (bivalves, gastropods) and arthropods (crustaceans and xiphosurids). However, other mud dependent fauna were also recorded. The faunal densities are expressed as the number of animals per square metre.

Diversity analyses

Diversity analyses such as frequency and density of the species (Muller-Dombois and Ellenburg, 1974), Shannon-Wiener diversity index (H) (Shannon and Wiener,

1949), dominance (D) as Simpson index (Simpson, 1949) and Margalef's index as a measure of species richness (Margalef, 1958) were carried out.

Results and discussion

Macrobenthos, the critical link in the mangrove ecosystem food web, inhabits the bottom of the water column and are visible to naked eye. They perform varieties of ecological functions including consumption of all kinds of organic matter and in turn act as food for many fishes, birds and other marine invertebrates. The important benthic faunal and ecological studies of mangrove swamps in Sundarban have been elucidated by earlier workers (Bhunia and Choudhury, 1981; Nandi and Choudhury, 1983; Dey, 2006; Sau *et al.*, 2017). They opined that the distribution of macrobenthos was influenced by physicochemical and biological characteristics of the environment. In the present study, a total of 1,871 individuals belonging to 35 species were recorded from the 21 mangrove sampling stations of Indian Sundarban. Among them, 12 species were molluscs belonging to 8 families and 11 genera; 20 species were crustaceans belonging to 9 families and 15 genera and one

Table 1. Details of sampling stations and geolocation

Zone	Station code	Name	Geographical coordinates
Eastern	E1	Napitkhali	88°44'48.58"E; 22°13'40.275"N
	E2	Amtali, Taranagar	88°53'19.004"E; 22°14'48.447"N
	E3	Chimta	88°55'48.165"E; 22°15'28.449"N
	E4	Charalkhali, Kanaikhali	89°0'59.039"E; 22°17'52.156"N
	E5	Malekanghumti	89°0'48.335"E; 22°15'10.398"N
	E6	Jyotirampur	88°50'14.158"E; 22°8'8.129"N
	E7	Anpur	88°53'29.367"E; 22°6'48.651"N
Central	C1	Jharkhali	88°41'6.864"E; 22°1'24.492"N
	C2	Dabu	88°40'11.386"E; 22°12'26.368"N
	C3	Gopalgunj	88°37'51.765"E; 22°4'8.841"N
	C4	Bhubhaneswari	88°30'38.833"E; 21°56'8.652"N
	C5	Debipur	88°33'27.09"E; 21°54'52.911"N
	C6	Kishorimohanpur	88°31'11.306"E; 21°50'53.941"N
	C7	Jaganathchak	88°27'10.736"E; 21°54'39.167"N
Western	W1	Sibnagar	88°27'4.154"E; 21°47'40.814"N
	W2	Prentice	88°16'45.548"E; 21°46'43.128"N
	W3	Chandanpiri	88°18'27.299"E; 21°40'26.936"N
	W4	Henery	88°17'26.502"E; 21°35'4.133"N
	W5	Kankramari	88°12'20.86"E; 21°43'0.707"N
	W6	Chemaguri	88°8'57.024"E; 21°40'14.936"N
	W7	Mandirtala, Harinbari	88°4'10.748"E; 21°44'52.014"N

species each of xiphosurid, sea anemone and fish (Table 2). The orders Littorinimorpha and Caenogastropoda were found to be dominant among molluscs with three species each, whereas the order Decapoda was dominant among crustaceans with 18 species (Fig. 2). Potamididae and Sesamidae were the most dominant families among the molluscs and crustaceans with three and six species, respectively (Fig. 3).

Mangrove associated molluscs of India were studied by many workers (Ganapati and Rao, 1959; Radhakrishna and Janakiram, 1975; Mandal and Nandi,

1989; Ramamoorthy and Rao, 1993; Rao, 2003; Dey, 2006; Saravanakumar *et al.*, 2007; Venkatesan *et al.*, 2010; Suresh *et al.*, 2012; Satheeshkumar and Khan, 2012; Susan *et al.*, 2012) and the total number of species reported varied between 9 and 70; gastropods being the dominant group. A comparison of the diversity of mangrove associated molluscs of India reported by other researchers is given in Table 3. Though the species composition recorded by earlier authors could be comparable with the present study, the total number of species recorded during the present study is very low compared to earlier researchers.

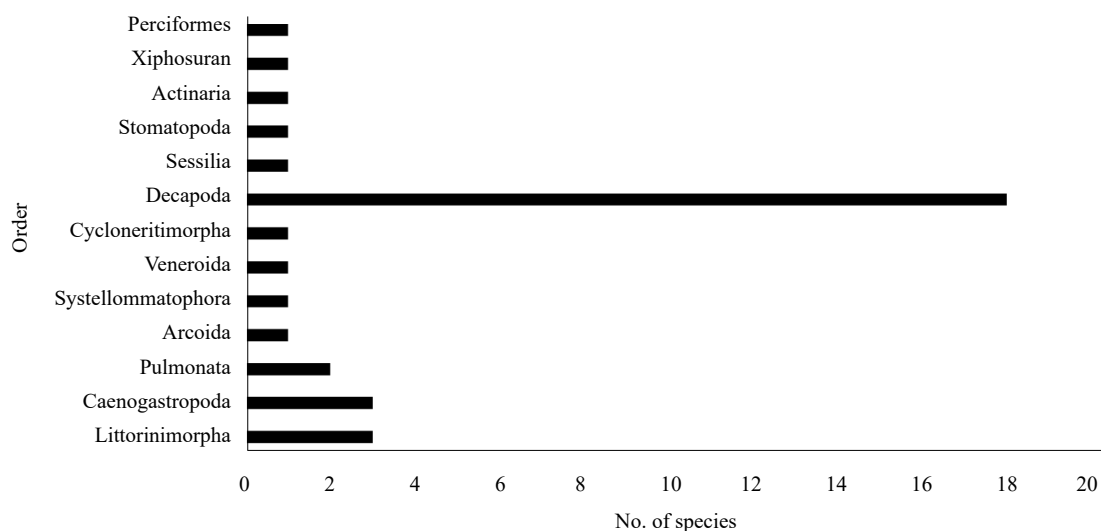


Fig. 2. Contribution of taxa by different orders in the Indian Sundarban

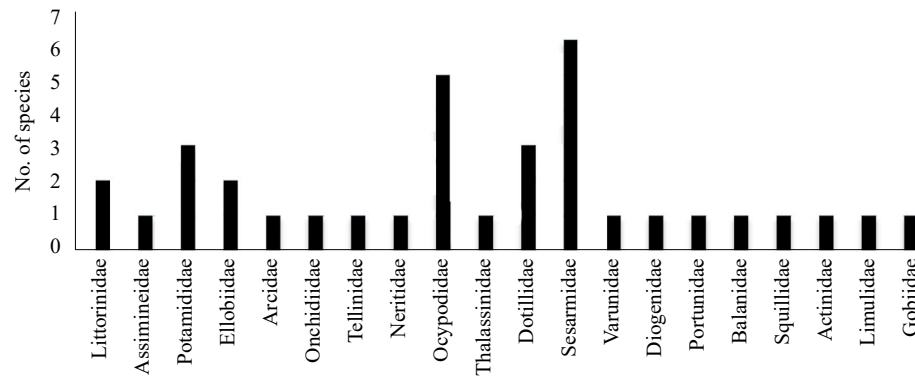


Fig. 3. Contribution of taxa by different families in the Indian Sundarban

Table 2. Checklist of macrobenthic fauna and their occurrence in Western, Central and Eastern zones of Indian Sundarban

Phylum	Class	Order	Family	Scientific name	Occurrence in zone		
					W	C	E
Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littoraria melanostoma</i> (Gray, 1839)	-	+++	++
				<i>Littoraria scabra</i> (Linnaeus, 1758)	++	+	+
		Caenogastropoda	Assimineidae	<i>Austropilula beddomeana</i> (G. Nevill, 1880)	+	+	+
			Potamididae	<i>Cerithidea obtusa</i> (Lamarck, 1822)	+++	+++	++
				<i>Pirenella cingulata</i> (Gmelin, 1791)	+++	+++	++
				<i>Telescopium telescopium</i> (Linnaeus, 1758)	+++	+++	+++
				<i>Pythia plicata</i> (Ferussac, 1821)	+	+	+
	Bivalvia	Pulmonata	Ellobiidae	<i>Cassidula nucleus</i> (Gmelin, 1791)	+	+	+
		Cycloneritimorpha	Neritidae	<i>Nerita balteata</i> Reeve, 1855	+++	+++	+
			Onchidiidae	<i>Plateindex tigrinus</i> (Stoliczka, 1869)	-	+	+
		Systellommatophora	Arcidae	<i>Tegillarca granosa</i> (Linnaeus, 1758)	+	+	+
		Veneroida	Tellinidae	<i>Psammacoma</i> sp.	+	+	+
Arthropoda (Sub phylum: Crustacea)	Malacostraca	Decapoda	Ocypodidae	<i>Tubuca acuta</i> (Stimpson, 1858)	-	-	+
				<i>Tubuca rosea</i> (Tweedie, 1937)	+++	-	++
				<i>Austruca lactea</i> (De Haan, 1835)	++	+	+
				<i>Austruca triangularis</i> (A. Milne-Edwards, 1873)	++	++	+
				<i>Tubuca dussumieri</i> (H. Milne Edwards, 1852)	++	+	+
			Thalassinidae	<i>Thalassina anomala</i> Herbst, 1804	+	-	+
			Dotillidae	<i>Dotilla intermedia</i> de Man, 1888	-	-	+
				<i>Dotilla blanfordi</i> Alcock, 1900	+	+	+
				<i>Dotillopsis brevitarsis</i> (de Man, 1888)	+	+	+
			Sesarmidae	<i>Sesarmoides</i> sp.	-	-	+
			Sesarmidae	<i>Sesarmops impressus</i> (H. Milne Edwards, 1837)	-	-	+
				<i>Parasesarma bidens</i> (De Haan, 1835)	++	+	+
				<i>Episesarma mederi</i> (H. Milne Edwards, 1853)	+	+	+
				<i>Sesarmoides longipes</i> (Krauss, 1843)	++	++	
				<i>Parasesarma plicatum</i> (Latreille, 1803)	+	+	+
			Varunidae	<i>Metaplex intermedia</i> de Man, 1888	+	++	+
			Diogenidae	<i>Clibanarius padavensis</i> de Man, 1888	++	++	++
			Portunidae	<i>Scylla serrata</i> (Forsk., 1775)	++	++	++
		Stomatopoda	Squillidae	<i>Squilla</i> sp.	-	-	+
		Maxillopoda	Sessilia	<i>Balanus</i> sp. Brown, 1844	++	+	+
Arthropoda Subphylum Chelicerata	Merostomata	Xiphosurida	Limulidae	<i>Carcinoscorpius rotundicauda</i> (Latreille, 1802)	+	+	+
Cnidaria	Anthozoa	Actiniaria	Actinidae	<i>Sea anemone</i>	+	-	-
Chordata	Actinopterygii	Perciformes	Gobiidae	<i>Boleophthalmus boddarti</i> (Pallas, 1770)	+	+	+

W: Western zone, C: Central zone, E: Eastern zone

+ = Rare (Species represented in 1 - 7 quadrats), ++ = Common (Species represented in 8 - 14 quadrats), +++ = Very common (Species represented in 14 - 21 quadrats)

Table 3. Mangrove associated molluscs and crabs of India reported by other researchers

Authors	Species reported	Study area
Molluscs		
Rao <i>et al.</i> (1983)	21 species	River Muriganga around Kakdwip and Namkhana Sagar Island, West Bengal
Dey <i>et al.</i> (2005)	37 species (24 gastropods and 13 bivalves)	Sundarban, West Bengal
Dey (2006)	56 species (31 gastropods and 25 bivalves)	Gulf of Kachchh, Gujarat
Saravanakumar <i>et al.</i> (2007)	33 species (17 gastropods and 16 bivalves)	Brackishwater wetlands, West Bengal
Roy <i>et al.</i> (2008)	35 species (26 gastropods and 9 bivalves)	Pondicherry mangroves
Satheeshkumar and Khan (2012)	37 species (21 gastropods and 16 bivalves)	North-east coast of India
Paul <i>et al.</i> (2014)	63 species (31 gastropods and 32 bivalves)	Indian Sundarban, West Bengal
Present study	12 species (9 gastropods and 3 bivalves)	
Crabs		
Chakraborty <i>et al.</i> (1986)	26 species	Sundarban, India
Pandya and Vachhrajani (2013)	10 species (dominant ones were <i>Uca lactea annulipes</i> , <i>Macrophthalmus depressus</i> , <i>Macrophthalmus brevis</i> and <i>Dotilla intermedia</i>)	Mahi Estuary and surrounding areas
Present study	18 species (dominant species was <i>Tubuca rosea</i>)	Indian Sundarban, India

Such variation could be attributed, firstly, to geographical variations of the study area, sampling design and duration of the investigation. Secondly, to the fact that the present study was aimed at recording the rapid diversity inventory based on quantitative samples collected from quadrats taken randomly at fixed depth without taking into account the specimen inhabiting outside the demarcated area. Contrary to this, other workers recorded all specimens occurring in wide habitats for a longer period.

In the present study, *Cerithidea obtusa*, *Telescopium telescopium*, *Pirenella* (= *Cerithidea*) *cingulata* and *Nerita balteata* (= *Nerita articulata*) were the most frequent species. Among molluscs, *Telescopium telescopium* was the most frequent species whereas *Platevindex tigrinus* was the least frequent one. Among crustaceans, *Tubuca rosea* was the most frequent one. The present findings are corroborated with the earlier findings of Roy *et al.* (2008) from the brackishwater wetlands of West Bengal who recorded *Pirenella cingulata* as the most dominant species in all the stations surveyed, whereas *Cerithidea obtusa* was dominant only in the lower littoral zone of the Matla River bed. Anbuezhian *et al.* (2009) also observed that out of the 54 macrobenthic fauna in south-east coast of India, only a single species of gastropod *P. cingulata* dominated in all the stations surveyed, whereas, Das and Nandy (1999) have noted *Littoraria scabra* as the most abundant species in higher part of Sundarban mangroves.

Mangrove associated crustaceans, mainly represented by brachyuran crabs is considered not only as vital components influencing the structure and function of tropical mangrove forests, after bacteria and trees but also as bioindicators owing to their huge diversity, density and

their unique preference to micro habitats (Lee, 1998; Arya *et al.*, 2014).

In the present study, 20 species of crustaceans were reported out of which 18 species were crabs (Table 2). A comparison of the diversity of crabs reported by other researchers in Indian waters is given in Table 3. Sesarmids play an important role in the ecology of the mangroves through their selective destruction of propagules and huge consumption and breakdown of leaf litter (Robertson, 1986; Smith, 1987; Macintosh and Ashton, 2002). Other crustaceans include the portunids, hermit crabs, penaeid shrimps and a variety of burrowing species such as the mud lobster *Thalassina*, amphipods and isopods (Macintosh and Ashton, 2002).

Ocypodidae is dominated by the fiddler crabs *Uca* spp., the density of which could be as high as 80 m⁻² (Macintosh, 1984). Fiddler crabs also play an important role in the mangrove ecosystem as a food source for numerous predators (Macintosh and Ashton, 2002). Some mangrove crustaceans like the mud crab *Scylla serrata* which has considerable commercial value was also recorded in the present study. Some crustaceans can cause significant damage to mangroves, for example the barnacles (*Balanus* sp). Barnacles can damage or kill mangrove seedlings if in very high abundance (Macintosh and Ashton, 2002). Mudskippers, semi-terrestrial fish, are common representatives of teleosts in mangroves. In the present study *Boleophthalmus boddarti* was the only fish species recorded.

Abundance and composition of macrobenthos vary in the sampling stations due to the prevailing abiotic and biotic factors (Ramamurthy, 1953; Weyl and Peter,

1970). However, an increase in marine invertebrate faunal diversity with the increase in number of plant species has also been well documented (Hutchings and Recher, 1983). Chakraborty (2013) has observed interactions of environmental variables determining the biodiversity of coastal-mangrove ecosystem of West Bengal, India. In fact, detritus provided by the mangrove vegetation charges the ambient water with nutrients, which trigger the growth of plankton and supplies food for the molluscan species. This may explain the relatively higher diversity value in the mangrove dominated stations.

In the present study, density of the species varied from 1.587 m⁻² to 747.619 m⁻². *P. cingulata* (747.619 m⁻²) and *T. rosea* (119.048 m⁻²) were the most dense mollusc and crustacean respectively (Fig. 4). Frequency of the species fluctuated between 1.587 and 90.476 (Fig. 5). The quantitative studies on the benthic macrofauna of Sagar Island was done by Nandi and Choudhury (1983) and the estimated faunal density varied from 82.8 m⁻² to 328.95 m⁻². Roy *et al.* (2008) revealed the highest population density of macrozoobenthic molluscs at Canning (2014.81 m⁻²) in

post-monsoon season and at Matla Char (507.41 m⁻²) in monsoon season. The present findings were corroborated with the earlier findings of Roy *et al.* (2008) and Islam *et al.* (2013) with respect to the frequency of the species.

Results of the present study revealed a comparatively higher density of species in the Western zone which decreased gradually towards the Eastern zone. Among the three zones, Western zone contributed the maximum number of individuals (748) followed by Central (612) and Eastern zones (511) (Fig. 6). Conversely, the maximum number of species was represented by Eastern zone (34), followed by Western zone (29) and Central zone (28) (Fig. 7). Benthic molluscan assemblages showed almost similar pattern of distribution in each zone (Eastern, Central and Western) except for *P. tigrinus*, which was not found in the Western zone. However, frequent occurrences of crustaceans were recorded. The species *T. acuta*, *Dotilla intermedia*, *Sesarmoides* sp. *Sesarmops impressus* and *Squilla* sp. were found only in the Eastern zone. Sea anemone was found only in the Western zone and absent in Central and Eastern zones. Likewise, *Thalassina anomala*

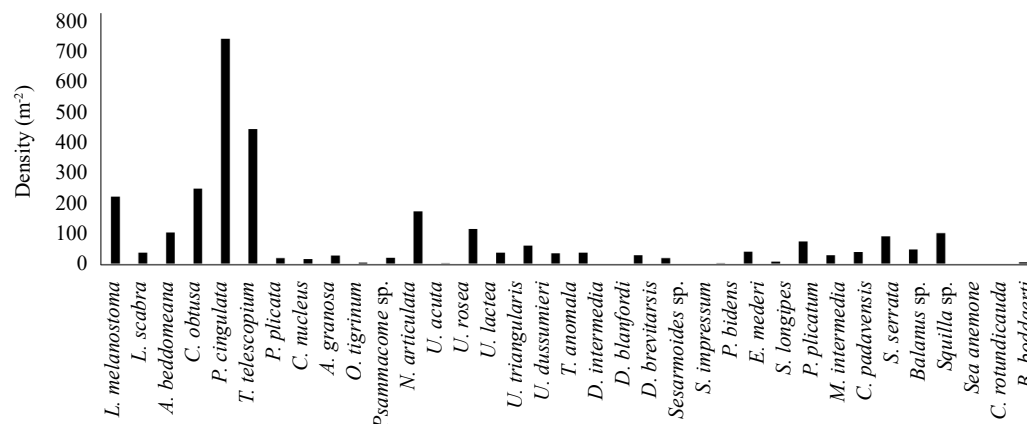


Fig. 4. Density of species in the Indian Sundarban

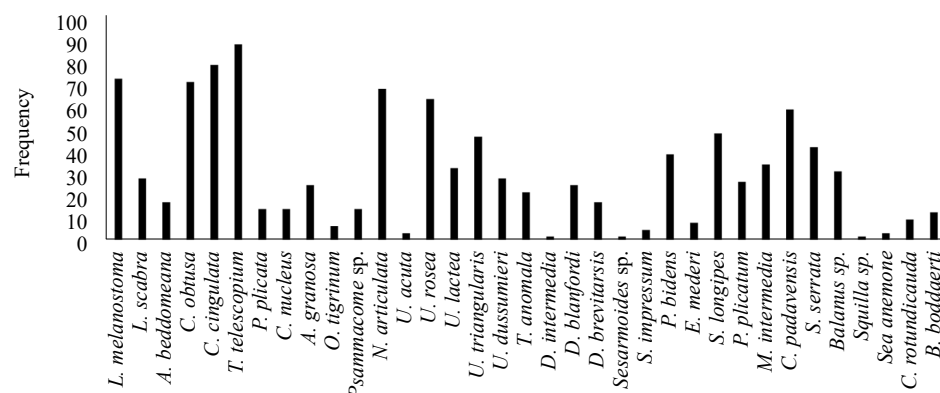


Fig. 5. Frequency of species in the Indian Sundarban

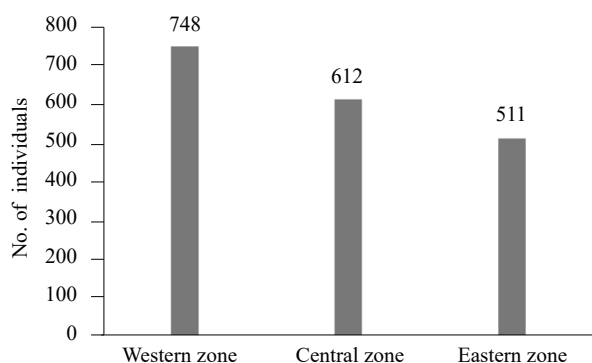


Fig. 6. Number of individuals recorded in different zones of Indian Sundarban

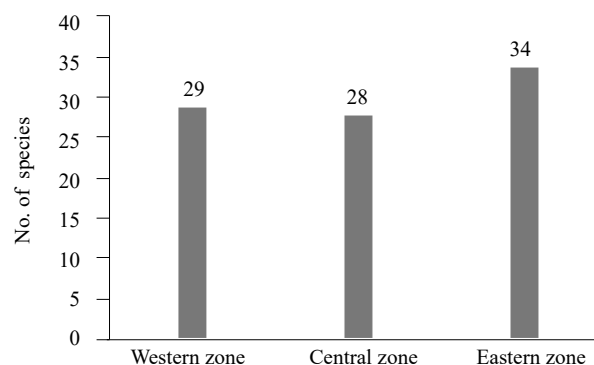


Fig. 7. Number of species recorded in different zones of Indian Sundarban

was not recorded in the Central zone of Indian Sundarban (Table 2) during the present study. The higher frequency of crustaceans in the Western zone indicated that the mangroves of this region are rich in organic food material thereby providing suitable habitats for them. The other main environmental factors affecting the distribution and structure of macrobenthic organisms reported by most authors are organic matter, salinity and sediment characteristics, especially mud and clay content (Parsons *et al.*, 1984), the vegetation structure and composition (Kissling *et al.*, 2012) and the sediment texture (Sanders, 1958). The most widely accepted model was proposed by Rosenberg (2001), who suggested that as the organic matter content increases, the species diversity decreases and the number of individuals increases. The salinity in Western zone is less compared to the salinities of Central and Eastern zones of Indian Sundarban. This may be one of the reasons for higher population density recorded in the Western zone.

The value of Shannon-Wiener diversity index in the entire study area varied from 1.322 to 2.928 which was similar to the value (1.80-2.83) previously reported in the Pondicherry mangrove forest by Kumar and Khan (2013). Among the three zones studied, the Western zone showed maximum value of Shannon diversity index (2.756) followed by Eastern zone (2.619) and Central zone (2.573). This indicates that the degree of evenness in species abundance is better in Western zone compared to Eastern and Central zones of Indian Sundarban and also expressed that the interaction of species with ecosystem is better in Western zone.

Wilhm and Dorris (1966) proposed that the values of Shannon diversity index less than 1.0 for estuarine waters indicate heavy pollution, while values between 1.0 and 3.0 indicate moderate pollution, and values exceeding 3.0 indicate that the area is non-polluted. Therefore, it appears that the estuarine area of Western zone is comparatively

less polluted than the Eastern and Central zones of Indian Sundarban. It is also observed that the human settlement and anthropogenic activities are comparatively more in Central and Eastern zones of Indian Sundarban. Human activities have a strong influence on the aquatic environment in the south-east coast of Bay of Bengal (Ananthan *et al.*, 2005).

In the study area, the dominance of macrobenthic fauna ranged between 0.069 and 0.381, which was similar to the previous report by Kumar and Khan (2013) in the Pondicherry mangrove forest. The dominance index of macrobenthic fauna in Central zone (0.131) was more compared to the Eastern (0.123) and Western (0.094) zones. It suggested that the Western zone of Indian Sundarban was more diverse followed by the Eastern and Central zones. It may be due to the diverse and dense mangrove forest present in the Western zone that supply food to the macrobenthic fauna.

The Simpson diversity index of macrobenthic fauna in Indian Sundarban varied from 0.619 to 0.931. Among the three zones, the Western zone showed the maximum value of Simpson diversity index (0.905) followed by Eastern zone (0.876) and Central zone (0.868). It represents the probability that two individuals randomly selected from a sample will belong to different species. So, in the present study, the Western zone represented the maximum species diversity followed by Eastern and Central zones. It may be due to less competition among macrobenthos for space and food and also availability of suitable substrate for settlement in the Western zone compared to the Central and Eastern zones. According to Ramamurthy (1953), the abundance and composition of macrobenthos varied among the stations due to the prevailing abiotic and biotic factors. Biotic factors that affect the living organisms in the intertidal zone are competition for space and food, predation, reproduction substrate and settlement preference. Abiotic factors that affect the living organisms

in the intertidal area are salinity, temperature, air and light exposure, tidal flow, waves and current action, substrate, wind direction and strength, dissolved oxygen, storms and natural disasters (Weyl and Peter, 1970).

The value of Margalef diversity index in the entire study area of Indian Sunderban varied from 0.973 to 5.477, which was relatively more compared to the value (0.450 to 0.720) previously reported in the Pondicherry mangrove forest by Kumar and Khan (2013). The Eastern zone showed the maximum value of Margalef diversity index (5.292), followed by Western zone (4.231) and Central zone (4.208). The Margalef diversity index has no limit value and it shows variation depending upon the number of species and is used for comparison of the sites..

The results obtained for Shanon-Wiener and Simpson indices showed higher values in the Western zone suggesting that this zone is more diverse and have even abundance of species than the other two zones. Low value of dominance (D), the reciprocal of Simpson's Index, recorded for the Western zone further corroborates the above findings. On the other hand, Margalef's species richness index, which is a direct measure of the number of species present at a site, was higher for Eastern zone, as the number of species recorded in Eastern zone was more.

The present study provides baseline information on the distribution, abundance and diversity of macrobenthic fauna in the Indian Sundarban. The findings indicate that the faunal community comprising of variety of species form an integral component of the mangrove ecosystem, but the degree of association and adaptation to such an environment differed from species to species. The information generated in this study will be of much use in formulating an action plan for the conservation and management of this sensitive and biodiversity rich ecosystem.

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