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Impact of mangrove defoliation by *Hyblaea puera* on diversity of associated crustaceans in the Dharamtar Estuary, Maharashtra, India

Chennuri Sathish[1,2*], B. Sivaiah[1], K. Srinivasu[1], Vidya Shree Bharti[2], A. K. Jaiswar[2], Sudheer Joseph[1] and Geetanjali Deshmukhe[2]

[1]Indian National Centre for Ocean Information Services, Hyderabad - 500 090, Telangana, India
[2]ICAR-Central Institute of Fisheries Education, Mumbai - 400 061, Maharashtra, India

Abstract

Mangrove defoliation, caused by teak defoliator moth (*Hyblaea puera*), has been reported in India and other countries. However, research on its impact on the associated fauna remains limited. We observed extensive mangrove defoliation from August to October 2019 in the Dharamtar Estuary, Maharashtra, India. Consequently, a study was conducted to assess the impact of this defoliation on the diversity of crustaceans within the mangroves and the surrounding estuarine waters. A total of 27 crustacean species were recorded in the mangrove region exhibiting reduced species richness and abundance during the mangrove defoliation period. Whereas, a total of 32 species of crustaceans were recorded from the estuarine region, where both species richness and abundance were higher during the defoliation period. These findings indicate that the crustaceans on the mangrove floor and in the estuarine waters responded differently to the changing environmental conditions caused by defoliation.

*Correspondence e-mail:
sathishchennuri22@gmail.com

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Introduction

Crustacean fauna comprises a significant portion of the macrofauna which predominantly plays a role in shaping the structure and function of the mangrove ecosystems (Aveline, 1980; Cannicci *et al*., 2008). Crustacean species in this ecosystem occcupy diverse niches; some species dwell on the sediment surface, while others reside in burrows, crevices, tree holes or on pneumatophores and prop-roots. Some burrow into decaying wood and others dwell on tree canopies (Sasekumar, 1974; Ashton, 1999; Nagelkerken *et al*., 2008). Crustaceans associated with mangroves can be categorised into two types, *viz*., Permanent mangrove dwellers (burrowing or sessile organisms, which include mud lobster, fiddler crabs, mud crabs, sesarmid crabs, grapsid crabs, hermit crabs, mud lobsters, pistol shrimps and barnacles) and Mangrove visitors (free swimmers, which include penaeid shrimps, non-penaeid shrimps, swimming crabs, mysid shrimps, lobsters, squilla, some crab species and isopods).

Mangrove defoliation caused by the teak defoliator moth (*Hyblaea puera*) poses a significant threat to mangrove ecosystems. This has been reported from India (Arun and Mahajan, 2012; Rishi and Sundararaj, 2020; Sathish *et al*., 2021) and many other countries (West *et al*., 1981; Whitten and Damanik, 1986; Murphy, 1990). However, studies on its implications on crustaceans are limited. Hence, this study was carried out to assess the impact of defoliation on the diversity of dominant mangrove-associated fauna specifically crustaceans, in the mangrove forest (permanent dwellers) and in the adjacent estuarine waters (temporary visitors of mangroves). A taxonomic survey of crustacean diversity in the estuarine ecosystem is crucial to understanding the community structure. Effective scientific management is urgently needed for the well-being of as well as for preserving coastal biodiversity.

Materials and methods

Study area

The study was carried out in the mangroves of Dharamatar creek, located in Raigad District of Maharashtra, near Mumbai, along the Eastern Arabian Sea. The estuary receives freshwater from the river Amba as well as form the Patalganga and Karanja creeks, before opening into the Arabian Sea between Uran and Rewas.

Sampling of crustaceans from the mangrove forest floor

Crustacean samples (only macro-crustaceans) from the mangrove forest floor were collected during the low tide. All the different habitats starting from the seaward fringes at the mouth region to the upstream limit of tidal influence were targeted. The crustacean samples were collected from 12 different sites (Fig. 1), six sites (A1, B1, C1, D1, E1, F1) near the main creek and the other six sites (A2, B2, C2, D2, E2, F2) near to the periphery of mangroves far from the main creek. At each site, two transects were laid perpendicular to the waterfront, each in different periods of the same season with at least 20-days gap. Quantitative data on crustaceans were collected by laying quadrats (1 x 1 m) along the line transects, five quadrats on each transect with a 10 m gap between each quadrat.

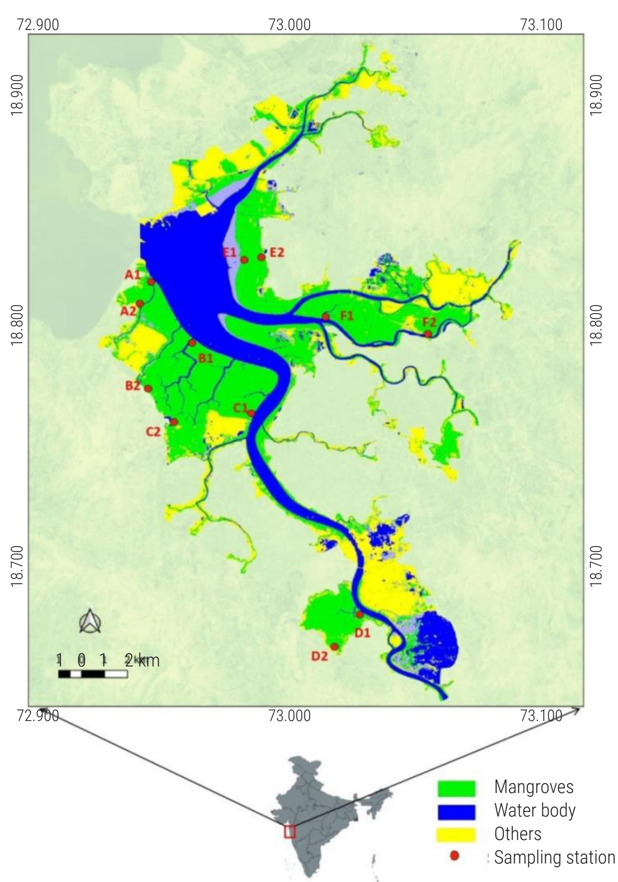

Fig. 1. Study site showing sampling stations

Twenty-four transects were laid and 48 quadrats were sampled from all the sites. The organisms were collected from the surface of mud, burrows, mangrove stems, leaves and roots. Burrowing organisms were collected by digging with shovels and sieving. The collected organisms were brought to the laboratory, photographed, and preserved in 70% alcohol for subsequent identification. The specimens obtained were stored carefully to ensure that no appendages were lost due to stress. Identified organisms in the field were released safely. All specimens were deposited at the Fisheries Harvest and Post Harvest Management (FRHPHM) Division, ICAR-Central Institute of Fisheries Education (ICAR-CIFE), Mumbai. Two samplings were conducted during each season, during pre-monsoon (March and April 2019), monsoon (June and July 2019) and post-monsoon (October and November 2019).

Sampling of crustaceans from the estuary and creek waters

Samples of crustaceans in the estuarine water were collected from the catches of traditional fishing gear (dol net and stake net). Two sampling stations were chosen, one station where stake nets are operating near the edge of mangroves in the shallow waters below the level of mudflat and the other station where dol nets are operating in the deeper waters near the mouth of the estuary. The entire catch of crustaceans of each fishing gear was identified and the individuals of each species were enumerated. Unknown specimens were brought to the laboratory for identification. Samplings were conducted once in every season, pre-monsoon (March), monsoon (July) and post-monsoon (October). Samples of all species were preserved in the FRHPHM Division of CIFE, Mumbai.

Data analysis

The collected data was pooled and divided according to the three seasons. Spatial and temporal species abundance data were used as input for the calculation of biodiversity indices such as species diversity: Shannon-Wiener index (H'), species richness: Margalef index (d), species evenness: Pielou's index (J'), Dominance plot and Bray Curtis similarity by using PRIMER V6 (Plymouth Routine in Multivariate Ecological Research) software (Clarke and Gorley, 2006).

Species diversity: Shannon-Wiener index $(H') = 3.3219\ (N \log - \sum ni \log ni) / N$

Species richness: Margalef index $(d) = (S-1) / \log e\, N$

Species evenness: Pielou's index $(J') = H' / \log_2 S$ or $H' / \ln_2 S$

Species diversity: Simpson index $(D) = 1 - (\sum n(n-1) / N(N-1)$

Results

Crustacean diversity in the mangroves

Species composition

A total of 27 species were recorded from the study area, which includes 22 species of brachyuran crabs *viz.*, *Tubuca alcocki* Shih, Chan and Ng, 2018, *Austruca annulipes* (H. Milne Edwards, 1837), *Gelasimus hesperiae* (Crane, 1975), *Parasesarma persicum*

Naderloo and Schubart, 2010, *Parasesarma plicatum* (Latreille, 1803), *Parasesarma bengalense* (Davie, 2003), *Parasesarma* sp., *Episesarma versicolor* (Tweedie, 1940), *Pseudosesarma glabrum* Ng, Rani and Nandan, 2017, *Nanosesarma sarii* Naderloo and Turkay, 2009, *Leptarma* sp., *Clistocoeloma lanatum* (Alcock, 1900), *Neosarmatium smithi* (H. Milne Edwards, 1853), *Neosarmatium malabaricum* (Henderson, 1893), *Metopograpsus thukuhar* (Owen, 1839), *Metopograpsus latifrons* (White, 1847), *Grapsus albolineatus* Latreille in Milbert, 1812 *Metaplax distincta* H. Milne Edwards, 1852, *Neorhynchoplax octagonalis* (Kemp, 1917), *Scylla olivacea* (Herbst, 1796), *Scylla serrata* (Forskal, 1775), *Ilyoplax gangetica* (Kemp, 1919), under seven families (Sesarmidae, Ocypodidae, Grapsidae, Portunidae, Varunidae, Hymenosomatidae and Dotillidae), one species of anomuran crab *Clibanarius padavensis* de Man, 1888, under the family *Diogenidae*, one species of mud lobster *Thalassina anomala* (Herbst, 1804), under family Thalassinidae, one species of pistol shrimp *Alpheus* sp., under the family Alphiedae and two species of barnacles *Chthamalus barnesi* Achituv and Safriel, 1980, *Amphibalanus amphitrite* (Darwin, 1854) under two families Chthamalidae, Balanidae, respectively.

Distribution of samples along the sampling sites of the study area

A total of 1007 individuals were captured, the highest number of individuals recorded from C1 (n=180) followed by B1 (n=157) and the lowest number from E2 and F1 (n=37). The highest number of species were observed from B1 and C1 (16 species) and the lowest from E2 (6 species). Brachyuran crabs contributed 81% of all crustaceans in the mangroves and other crustaceans like anomuran crabs, mud lobsters, pistol shrimps and barnacles together contributed 19%. The highest number of individuals was of *P. plicatum* (n=215) followed by *E. versicolor* (n=99) and the lowest number of individuals by *C. barnesi, Parasesarma* sp. and *Leptarma* sp. Sesarmid crabs were best represented in species richness (11 species) and the most abundant (56.4%). Varunidae (8.7%), Grapsidae (7.4%), Ocypodidae (6.2%), Portunidae (5.8%), Thalassinidae (3.8%), Dotillidae (3.7%), Alpheidae (3.7%), Diogenidae (2.2%), Hymenosomatidae (0.7%), Balanidae (0.6%) and Chthamalidae (0.09%) were represented with 1, 3, 3, 2, 1, 1, 1, 1, 1, 1 and 1 species respectively.

Diversity indices

Distinct variations in crustacean diversity in the study area were observed in the present investigation. The highest Shannon-Weiner index values were observed at station C1 (2.48) and the lowest at F1 (1.4). The highest and lowest Margalef species richness index was observed from B1 and C1 (3.2) as well as E2 (1.08), respectively; Pielou's evenness (J') was in the range of 0.77 (B2) to 0.91 (F1) (Table 1). Inside these stations, the community was well diversified and few species were better represented. The lowest values were recorded from station E2, with a low number of species and individuals. A temporal study found that post-monsoon had a high Shannon-Weiner index (2.7) and Pielou's evenness (0.90) but a lower Margalef species richness index (4.56). Monsoon showed a higher Margalef index (5.21) (Table 2).

Table 1. Diversity indices of crustaceans in the different sampling sites in the mangrove

	S	N	d	J'	H'(loge)	1-Lambda'
A1	12	130	2.389	0.8297	2.062	0.8512
A2	10	53	1.954	0.8799	2.026	0.8494
B1	16	160	3.257	0.8619	2.39	0.8934
B2	8	45	1.52	0.7739	1.609	0.7261
C1	16	182	3.257	0.8949	2.481	0.9106
C2	11	52	2.171	0.8888	2.131	0.8682
D1	13	46	2.606	0.8994	2.307	0.8869
D2	7	37	1.303	0.8628	1.679	0.788
E1	13	104	2.606	0.9098	2.333	0.8926
E2	6	37	1.086	0.8266	1.481	0.7098
F1	13	72	2.606	0.9155	2.348	0.8998
F2	12	115	2.389	0.8385	2.084	0.8388

s = No. of species; N = Total individuals; d = Margaleff's species richness; J' = Pieolov's evenness; H'(loge) = Shannon weiner; 1-Lambda' = Simpson's index

Table 2. Variation of diversity indices among different seasons

	S	N	d	J'	H'(loge)	1-Lambda'
Pre-monsoon	24	66	4.994	0.8526	2.709	0.9113
monsoon	25	96	5.212	0.8391	2.701	0.9158
Post-monsoon	22	75	4.56	0.9009	2.785	0.9321

s = No. of species; N = Total individuals; d = Margaleff's species richness; J' = Pieolov's evenness; H'(loge) = Shannon weiner; 1-Lambda' = Simpson's index)

K-dominance

The k-dominance plot showed, dominance of crustacean species at stations B1 and C1, while E2 showed the lowest dominance. Monsoon recorded dominance over other seasons and lowest in post-monsoon (Fig. 2).

Bray-Curtis similarity

Cluster analysis showed a higher similarity between B1 and C1 (85.8%), B2 and E2 (70.0%) as well as D1 and D2 (47.8%). D1, D2 and F2 were outliers (Fig. 3). The network plot based on the correlation between the stations showed clear discrimination of D1, D2 and F2 sites from other sites in the study area.

Crustacean diversity in the estuarine water

Species composition

A total of 32 species belonging to 20 genera under 11 families *viz*., *Penaeus monodon* Fabricius, 1798, *Penaeus indicus* H. Milne Edwards, 1837, *Metapenaeus dobsoni* (Miers, 1878), *Metapenaeus brevicornis* (H. Milne Edwards, 1837), *Metapenaeus monoceros* (Fabricius, 1798), *Metapenaeus affinis* (H. Milne Edwards, 1837), *Parapenaeopsis stylifera* (H. Milne Edwards, 1837), *Mierspenaeopsis hardwickii*, *Mierspenaeopsis sculptilis* (Heller, 1862), *Solenocera crassicornis* (H. Milne Edwards, 1837), *Acetes johni* Nataraj 1949, *Acetes indicus* H. Milne Edwards 1830, *Exhippolysmata ensirostris* (Kemp, 1914), *Palaemon styliferus* H. Milne Edwards, 1840, *Macrobrachium idella* (Hilgendorf, 1898), *Macrobrachium rosenbergii* (De Man,1879), *Charybdis feriata* (Linnaeus, 1758), *Charybdis lucifer*

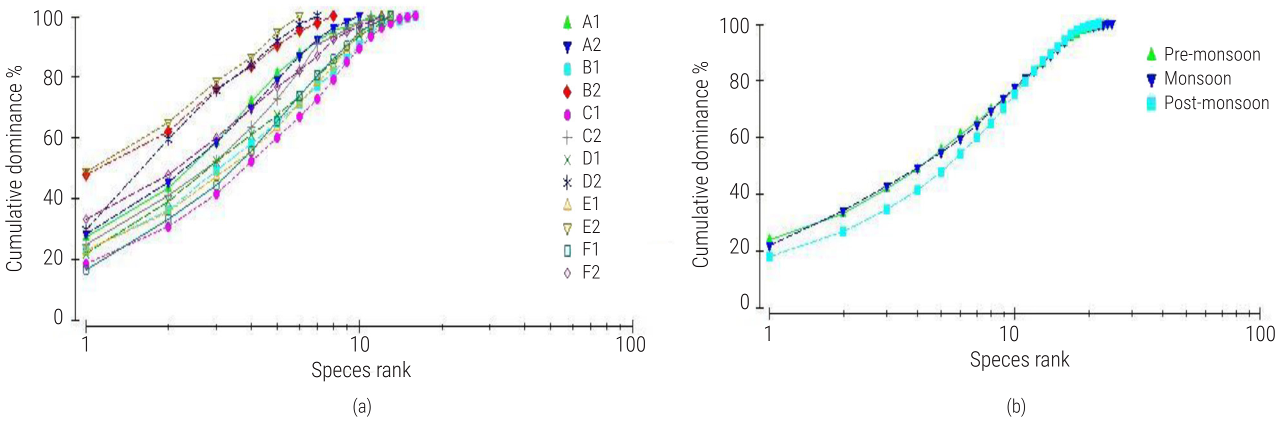

Fig. 2. K-dominance plots (a) station-wise and (b) season-wise

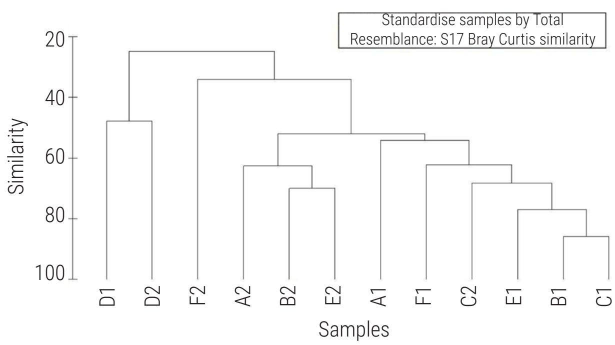

Fig. 3. Bray-Curtis similarity plot (between sampling stations)

(JC Fabricius, 1798), *Charybdis callianassa* (Herbst, 1789), *Portunus reticulatus* (Herbst, 1799), *Portunus sanguinolentus* (Herbst, 1783), *Portunus pelagicus* (Linnaeus, 1758), *Scylla serrata*(Forskål, 1775), *Xiphonectes hastatoides* (JC Fabricius, 1798), *Ashtoret lunaris* (Forskal, 1775), *Matuta planipes* JC Fabricius 1798, *Neodorippe callida* (JC Fabricius, 1798), *Panulirus polyphagus* (Herbst, 1793), *Rhopalophthalmus* species, *Harpiosquilla* sp., *Cloridina ichneumon* (Fabricius, 1798) and *Squilla* sp. were recorded from the waters of Dharamtar Estuary. Nine species belonging to the family Penaeidae, two species belonging to Sergestidae, three species belonging Palaemonidae, eight species belonging to Portunidae, two species under the family Matutidae, three species of Squillidae, one species each belonging to the families Solenoceridae, Lysmatidae, Dorippidae, Palinuridae and Mysidae were recorded.

Diversity

A distinct variation of crustacean catches of two different gears was observed in the estuarine waters. The Shannon-Weiner index, Simpson index and Pielou's evenness index were observed to be higher at sampling site 2 (stake net) (1.77) than at sampling site 1 (dol net). The Margalef species richness index was observed to be higher at sampling site 1 (dol net) than site 2 (stake net) (Table 3). Season-wise study found that monsoon had a high Shannon-Weiner index (3.17) and Pielou's evenness (0.98). The pre-monsoon showed a higher value for the Margalef species richness index (6.57) and the lowest in the pre-monsoon (6.03) (Table 4).

K-dominance

Dol net revealed dominance over stake net and post-monsoon showed dominance over other seasons (Fig. 4).

Bray-curtis similarity

Cluster analysis showed a higher similarity between pre-monsoon and post-monsoon (90.6%), monsoon-formed outlier (Fig. 5).

Discussion

Diversity of crustaceans associated with mangrove forest floor

Investigation of the crustacean fauna in the mangroves (floor and canopy) of the present study recorded 27 crustacean species. Several authors reported crustaceans from the mangrove forest floor of India *viz.*, Satheeshkumar (2012) reported 22 species of brachyuran crabs (nine species of portunidae, seven species of ocypodidae, four species of grapsidae and 1 callappidae and gecarcinid each) from Pondicherry mangroves; Sravanakumar *et al*. (2007) reported 13 species of brachyuran crabs (4 grapsids and ten ocypodids species) in the mangroves of Gulf Kachchh; Khan *et al*. (2005) reported 38 species of brachyuran crabs in both natural Pichavaram and artificially developed mangroves of Vellar Estuary (18 species of grapsids and seven species of ocypodids

Table 3. Crustacean diversity indices (in the water) of different sampling sites of Dharamtar Estuary

Sample	S	N	d	J'	H'(loge)	1-Lambda'
Dol net	29	57	6.08	0.3601	1.212	0.4628
Stake net	23	40	4.777	0.5661	1.775	0.6671

Table 4. Crustacean diversity (in the water) among different seasons

	S	N	d	J'	H'(loge)	1-Lambda'
Pre-monsoon	23	38	6.033	0.965	3.026	0.9699
monsoon	25	39	6.556	0.9864	3.175	0.9815
Post-monsoon	27	52	6.576	0.9579	3.157	0.9686

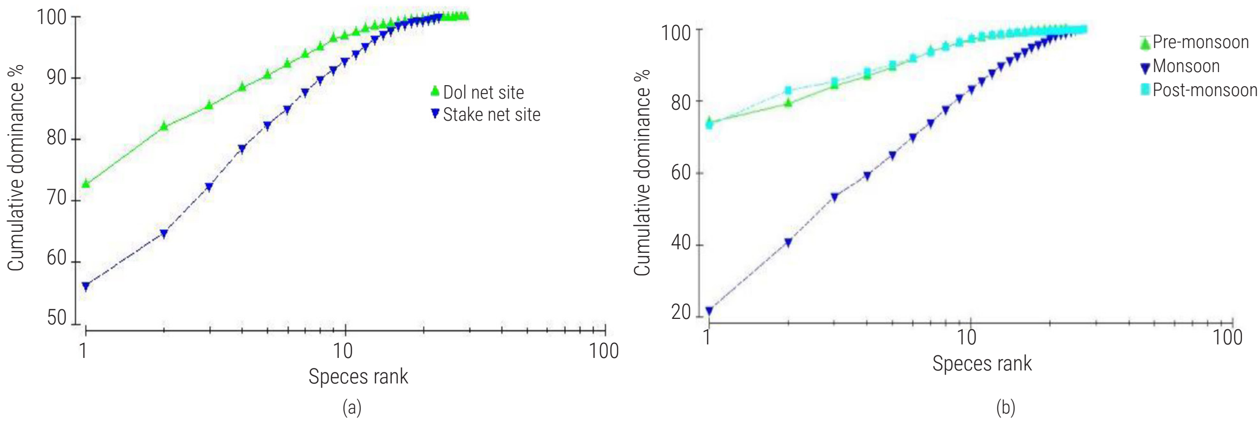

Fig. 4. K-dominance plot, (a) between dol net and sake net and (b) between seasons

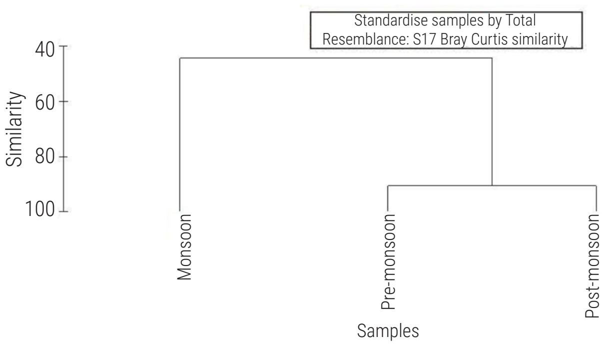

Fig. 5. Bray-Curtis similarity plot (between seasons)

at Pichavaram mangroves, while eight species of grapsoids and three species of ocypodids at Vellar mangroves); Pawar (2017) recorded 31 species of crabs in 3 different sites from mangrove and estuarine waters of Uran, Navi Mumbai, but few of them were misidentified (Trivedi *et al*., 2018).

Each crustacean species has its way of living in the mangrove ecosystem; the majority live in the burrows (Sesarmids and Ocypodid crabs), some are arboreal (living on the mangrove branches and leaves like *Metopogapsus latifrons*), few inhabit the crevices (*Grapsus albolineatus*), others are sessile attaching to the mangrove trunk (barnacles). Sesarmis crabs (*P. plicatum, P. bengalense* and *P. persicum*) are the most common species recorded from most stations. Grapsid crabs were recorded only from stations far from the estuary mouth where low salinities persist in the *S. apetala* and *A. officinalis* zones. Mud crabs (*S. serrata, S. olivacea*) were recorded from stations near and far from the mouth; pistol shrimps were found only in the mudflat region, while mud lobsters were common in the *S. apetala* zone, far from the mouth of the estuary. Fiddler crabs were common in the stations close to the mouth region of the estuary where high salinity persists. The distributional trends of the crustaceans in the present study are similar to the findings of other studies; Murugan and Anandhi (2016) found that marsh crabs are common near upper zones and fiddler crabs closer to shore. Jones (1984) observed the zonation of mangrove crabs based on-shore level. The crustaceans associated with the mangrove community also change with the age of the mangrove forest stand (Ashton *et al*., 2003).

In the present study, lower abundance and richness of crustaceans were recorded during the post-monsoon (d=4.56, S=22), while higher abundance and richness were recorded during the monsoon (d = 5.21, S=25). Contrastingly, Satheeshkumar (2012) recorded maximum diversity and richness in post-monsoon at Pondicherry. Harshit *et al*. (2016) recorded a higher H index during post-monsoon (1.6) than monsoon (1.4), from Ratnagiri (Maharashtra), Karhale *et al*. (2017) reported a lower and higher abundance of crustaceans during monsoon (2.7359 no. m^2) and post-monsoon (3.8961 no. m^2) respectively. Saravanakumar *et al*. (2007) also reported higher densities of macrobenthic fauna during post-monsoon and lower during the monsoon from the Gulf of Kachchh mangroves in Gujarat. Lower abundance and richness during post-monsoon in the present study might be due to the peak defoliated condition of mangroves, thus affecting the crustaceans; nevertheless, stable environmental factors (salinity, DO) during post-monsoon might be the reason for higher crab abundances. Since the majority of the crustaceans of the present study area belong to the Sesarmid group, they are dependent on mangrove leaves for their food (Steinke *et al*., 1993; Thongtham and Kristensen, 2005; Thongtham *et al*., 2008), absence or less availability of leaf matter might have caused their migration to less defoliated areas or starved to death. The overall diversity of crustaceans in the mangroves of Dharamtar was high and proper conservation and management measures need to be taken.

Diversity analysis showed variations among different sampling stations and seasons, with the highest species richness from B1 and C1 (16 species each) and the lowest from E2 (6 species). The highest and lowest diversity values of d, H' and 1-Lambda' were recorded from C1 and E2 sites. H' values were observed to vary from habitat to habitat; the H' values of Pondicherry mangroves were in the range of 0.96-2.18 (Satheeshkumar, 2012), Pichavaram mangroves (2.70-3.38), Vellar mangroves (1.66-2.26) (Khan *et al*., 2005). Within the habitat, the diversity of crustaceans' changes depending on several factors (availability of food, physical, chemical characteristics and competition). In the present study, the lowest crustacean diversity (Margalef's richness) was observed from the stations away from the main water body (A2, B2, C2, D2, E2, F2). At the same time, the highest values were recorded from stations close to the main water channel (A1, B1, C1, D1, E1, F1), along the creeks highest values were recorded from the intermediate zone (B1, C1) and lowest from the station (A1) near the mouth of the estuary. The highest and lowest Pielou's evenness index was recorded from F1 (far from the mouth of the estuary) and B2 (station near the landward side of mangroves), respectively. The findings are similar to a study by Prasanna *et al*. (2017) on the diversity of crabs at Chinnapalam Creek found the lowest H' at the mouth of the creek and the highest H' at the intermediate zone of the creek. In the present study, the abundance and diversity of crustaceans in the *A. marina* zone were higher compared to the *S. apetala* and *A. officinalis* zone. This could be due to the increased surface area and increased habitat complexity in mangrove regions and abundance of food from decaying leaves and organic sedimentary material support these large, diverse populations of benthic invertebrates in such ecosystem and establishment of the *A. marina* zone before the establishment of *S. apetala* and *A. officinalis* zones, as mangrove biomass increases with age and it supports higher richness and abundance (Azman, 2021). Bandibas and Hilomen (2015) reported that soil texture affects the distribution of crabs from the mangroves of the Philippines.

Diversity of crustaceans in the estuarine water

Crustaceans in the estuarine waters depend on mangroves for various purposes. Hamilton and Snedaker (1984) report that 60% of commercial catch depends on mangroves in Fiji. A total of 48 prawn species were reported from the mangrove ecosystem of India, with 34 on the east coast, 16 on Bay Islands and 20 on the west coast (Kathiresan, 2000). Crustaceans of the estuarine water caught by dol net and stake net from the present study recorded 32 crustaceans belonging to 11 different families *viz*., Penaeidae, Solenoceridae, Sergestidae, Lysmatidae, Palaemonidae, Portunidae, Matutidae, Dorippidae, Palinuridae, Mysidae and Squillidae. In this study on catch composition analysis, the species richness and abundance were higher at sampling site 1 (dol net) than at site 2 (stake net). Further, high species richness and abundance were recorded during the post-monsoon season than in other seasons and lowest in the pre-monsoon season. Iburahim *et al*. (2017) reported 25 species of crustaceans from the Karanja (Dharamtar Creek) area in dol net from 2016 to 2017 with higher abundance and richness, which was observed during September to November. Pradhan *et al*. (2017) reported 18 species of crustaceans from the Bhayander Creek caught by dol net during 2016-17, with higher abundance and richness observed during September to November.

In intertidal ecology, the lower limit of species distribution is often determined by biotic factors, such as predation pressure and competition for limited resources. In contrast, the upper limit is set by abiotic factors, such as temperature, salinity and water supply (Cannicci *et al*., 2018). The rich crustacean diversity has a significant role in maintaining the ecosystem; hence, maintaining high crustacean species diversity is integral to the health of the mangroves (Tan and Ng, 1994). The brachyuran community composition at a site may indicate the habitat as a stressful environment. Natural and human-induced disturbances pose severe threats to the mangroves and, in turn, pose threats to associated fauna, thus impacting the ecosystem's functioning. Biological and abiological studies need to be done to understand the variation in diversity. Indian mangrove ecosystems have a rich biological diversity; the faunal component is about greater than the floral component (Lalithkumar, 2014). Usually, decapod crustaceans are the primary composition of mangrove forests' invertebrate fauna. These play a crucial role in the mangrove ecosystem dynamics (Aveline, 1980).

Impact of mangrove defoliation on crustaceans of the mangrove forest

The benthic fauna in mangrove forests was dominated by sesarmid, grapsid and ocypodid crabs in the present study and found lower Margalef (d) index (4.56) during the post-monsoon (October and November), which coincided with the mangrove defoliation. Since sesarmid crabs are the dominant group of crustaceans and are dependent on mangrove leaves for their feed, prolonged absence, or reduced availability due to defoliation might cause a reduction in Margalef's richness index of crustaceans. Conversely, the number of crabs was higher during pre- and post-monsoon seasons and lowered in extreme seasons (monsoon and summer) (Kathiresan *et al*., 2016). During the field study, we observed a difference in the crab density among high defoliated and un-defoliated areas on the same day in October 2019, with fewer crabs associated with the high-defoliated regions and *vice versa*. The observed density difference could be attributed to the unavailability of leaf material, accumulation of the high amount of frass beneath the infested trees, which emits an ammonia odour, reduced shade and increased vulnerability to predators (birds) in the high defoliated zones.

In contrast, the presence of mangrove canopies in un-defoliated mangroves shields crabs by providing shade from direct sunlight, restricting the chance of desiccation caused by extreme heat while acting as a visual barrier from predators such as birds and other vertebrates (Nordhaus *et al*., 2009) and provides fresh leaf material upon which few crabs rely on for food (Steinke *et al*., 1993; Thongtham and Kristensen, 2005; Thongtham *et al*., 2008). Hannah and Shuhaida (2017) studied the crab assemblages in different canopies. They found that crabs were not affected by the presence or absence of canopy gaps between the mangrove trees which is likely due to the small canopy gap between the trees. However, they found varying amounts of damaged leaf litter under different canopy conditions, suggesting more crabs preferred to eat under the canopy than under the gap. The number or size of gaps in the canopy depends on the infestation level. The higher the number/size of gaps in the canopy, the higher the light intensity below the canopy. The high light intensity affects the distribution of the crab population in a particular area. A lower burrowing crab population could increase levels of soil sulphide and ammonium concentrations, affecting forest productivity (Smith *et al*., 1991). This suggests that any loss of crustacean biomass will negatively impact soil chemistry and forest productivity. Additionally, a reduction in crustacean species richness may reduce the crab species' specific niche and trophic roles. It is essential to know the behavioural responses of crabs to cope with changes (defoliation) in their surrounding environments, which will be achieved through more studies. High herbivory levels can change the community structure and forest succession patterns (Reiners, 1988).

Impact of mangrove defoliation on shrimps in the estuarine water

Many shrimp juveniles/ sub-adults (penaeid and non penaeids) were represented in the estuarine catch of dol nets and stake nets during the peak defoliation period of post-monsoon. Mangrove defoliation occurred in many places on the coast, but it remained unreported. However, severe mangrove defoliation was reported in Maharashtra in 2018 and 2019 (Rishi and Sundararaj, 2020) and 2021. While defoliation did not occur, or significantly less defoliation happened in 2015, 2016, 2017 and 2022 (according to local people), it was also confirmed with satellite images. The catch of shrimps using estuarine gear such as dol net, stake net and cast net, has shown an increase in the years of significant mangrove defoliation within the shallow waters of estuaries and creeks in Maharashtra. Conversely, during defoliation period, lower shrimp catches were observed in trawl nets operated in marine waters. (CMFRI, 2015-2020) (Fig. 6). The highest catch per unit was observed in dolnets during 2021, a year of severe mangrove defoliation. Thus, the extensive mangrove defoliation might have led to the ingress of shrimps into the estuaries and creeks, resulting in over-harvest of the shrimps, hence higher catches of dol net and other gears. In addition, higher numbers of juvenile/ sub-adult shrimps were noticed in the dol net and stake nets, which are responsible for recruitment to the shrimp fishery for the same and subsequent years. The overharvest of shrimps with the huge number of juveniles or sub-adults in the estuaries and creeks might have led to reduced stock size. The total shrimp catches in Maharashtra confirmed that the catches were reduced during and after years of severe mangrove defoliation (Fig. 7). As detritus forms an essential component of the shrimp diet, the shrimps located 2 km outside the mangrove swamp depend on mangrove carbon (Gutiérrez *et al.,* 2016). The shrimps migrate to estuaries or lagoons where the defoliation of mangroves results in a substantial amount of detritus, primarily generated by the significant frass production of *H. puera* as it consumes mangrove leaves. However, a combination of factors like temperature, salinity, dissolved oxygen, pH, shelter, currents, sediments and food sources, are also responsible for the distribution and relative abundance of shrimps (Pushparajan *et al*., 2012). Therefore, a comprehensive study on the impact of mangrove defoliation on crustaceans and other fauna is needed.

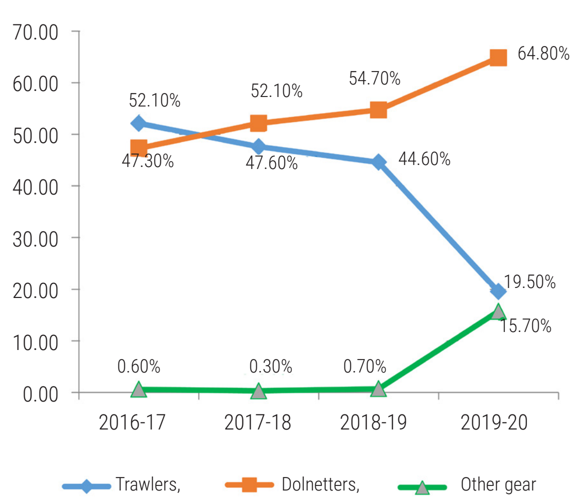

Fig. 6. Fishing gear contribution in shrimp catch of Maharashtra (CMFRI, 2016-20)

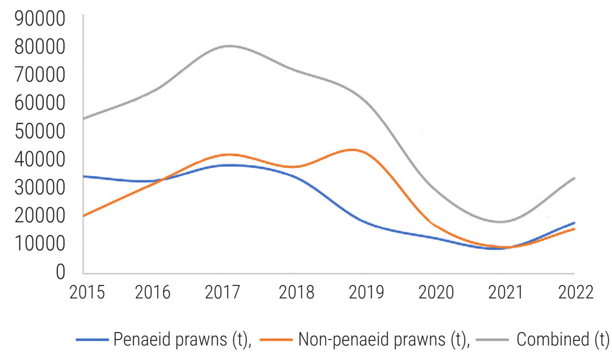

Fig. 7. Landings of penaeid and non-penaeid shrimps (t) in Maharashtra (CMFRI, 2015-20)

This study highlights the valuable biodiversity found in mangrove ecosystems and provides critical baseline information for future studies. This information helps inform and guide mangrove conservation, restoration, and sustainable use within the region. Crustaceans have a significant role in the marine ecosystem, especially in marine food webs, linking high and low trophic levels (Cartes, 1998). Therefore, it is recommended first to follow the status and trends of these communities through faunal monitoring programmes in the area. Specific conservation measures should protect those especially vulnerable benthic habitats. Thus, protecting benthic habitats would involve the conservation of their decapod communities. There is a chance of overexploitation of penaeids and non-penaeids in the estuaries or creeks during periods of high mangrove defoliation; hence proper management measures need to be taken to limit the catch by controlling the number of gears allowed or increasing the size of the mesh. Further research is needed to identify the underlying causes of *H. puera* infestations in mangroves and to understand their impact on the associated flora and fauna. This knowledge is essential for formulating effective management strategies.

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