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Diversity of intertidal macrobenthic fauna around Ratnagiri and Sindhudurg districts of Maharashtra, west coast of India

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Diversity of intertidal macrobenthic community and environmental parameters namely temperature, salinity, pH and DO were assessed near the proposed nuclear power plant site Jaitapur from 2012 to 2014. Analysis of macrobenthic samples revealed the presence of 54 species belonging to 19 different groups. Highest diversity (14 groups) was observed during the post-monsoon (2014) season. At sandy and rocky shores, polychaetes were dominant followed by crustaceans like amphipod, isopod, penaeid shrimps and decapod larvae. Among all inshore stations, diversity was found to be maximum at Ganeshgule (N SW30 kms). Shannon-Weiner diversity index (2.259) and Margalef's species richness index (2.502) indicated rich diversity at rocky habitats (N SW30 kms). The present study suggests the stable environmental parameters around the Jaitapur Nuclear Power Plant (NPP) sites and is responsible for the rich benthic community. The outcome of the present study may be useful as baseline information on macrobenthos around the proposed Jaitapur NPP site.

[**Keywords**: Environmental parameters, Macrobenthos, Margalef's species richness index, Shannon and Wiener diversity index]

Introduction

The sessile and sedentary nature of macrobenthos is identified to be the reason for their use as the indicator of time-integrated environmental status[1]. Since the macrobenthic organisms are dependent on their ambiances; they serve as a biological indicator and reflect the overall ecosystem functions[2]. Ecosystem functioning brings up to the properties shaping and processes the energy flow through abiotic and biotic constituents of ecosystems, controlling the goods and services delivered to humanity[3]. The diversity and abundance of macrobenthos known to vary with environmental parameters like water temperature, depth, salinity, latitude, nature of the substrates and ecological states like competition and predation. Physical, chemical and biological potentials of marine water influence the composition of species, species richness and productivity[4,5]. Benthos serves as potential food source for higher trophic level organisms directly and acts as an ecological engineer through recycling of the debris and organic matter[6]. Further, macrobenthos also play an important role in the aquatic community including sediments mixing, oxygen enrichment in the sediments and developments of mineralization in bottom, recycling of organic matter[7] and evaluation of water quality[8]. In the tropical environment, benthic faunal organisms plays a major role by creating a significant link in the transfer of energy and by making the food availaibility in the sediments[9,10]. Sediment parameters such as particle size, food availability, and organic content are vital factors for the distribution of benthic community[11-14].

Due to the fast expansion of the agricultural and industrial sectors, the demand for electric power has increased in the developing countries, especially in India. For the establishment of nuclear power plants, coastal regions are considered as best sites because of easy access to water required for the power plants. Maharashtra is considered suitable for setting up multi-unit NPPs (Nulcear Power Plant site), hence proposed the same at Jaitapur village. In view of this, the baseline information on the ecological status at spatial and temporal scales, of the region, is essential. Further, this information would be useful in assessing the environmental impacts and to determine the management regimes for biodiversity conservation. Macrobenthos supports the nutrients recycling, which is useful for the major productivity of a region. In addition, soft bottom macrobenthic communities are also a significant components that affect productivity in coastal and marine ecosystems[15,16]. Though acquaintance of the benthic faunal organisms is essential for the purpose of productivity[17], it also helps in the evaluation of variety of the habitats on ecological scales. Therefore, present investigation was carried out to generate the baseline data on diversity of macrobenthos and their relationships between the habitats with reference to seasons at proposed NPP site at Jaitapur, Maharashtra.

Materials and Methods

Study area and sampling design

The lighthouse of the Jaitapur was considered as a reference point for this study. From this reference point, 30 kms North and South, 7 different stations *viz*. Ganeshgule-N SW30 kms, Vetye-N SW15 kms, Ambolgad-N SW10 kms, Vijaydurg-S SW5 kms, Purel-Gyre-S SW10 kms, Padwanae-S SW15 kms and Devgad-S SW30 kms, were selected. At each station, two sampling locations were identified based on the habitat (sandy and rocky beaches) (Fig. 1 & Table 1) and 8 sample collections were done between March 2012 and February 2014, during pre-monsoon (March to May), monsoon (June to August), post-monsoon (September to November), and winter (December to February).

Physico-chemical parameters

The physico-chemical parameters, namely temperature, salinity, dissolved oxygen (DO) and pH were measured following the methods described by Strickland & Parsons[18]. Sediment samples were analyzed following the method of Krumbein & Pettijohn[19] and % composition of clay, silt and sand was determined according to Sheppard[20].

Intertidal macrobenthos

Samples of macrobenthos were collected from rocky and sandy habitats of intertidal areas. At sandy areas, macrobenthic organisms were sampled in triplicate from smaller quadrats and at the rocky area was sampled with large quadrats[21]. After collection, the samples were washed separately through a 500 µ mesh sieve, and preserved with rose bengal solution prepared from 5 % formaldehyde in seawater. All the collected samples were labeled and transferred to the Aquatic Radioecology laboratory, Central Institute of Fisheries Education, Mumbai for further identification. The macrobenthos were identified by

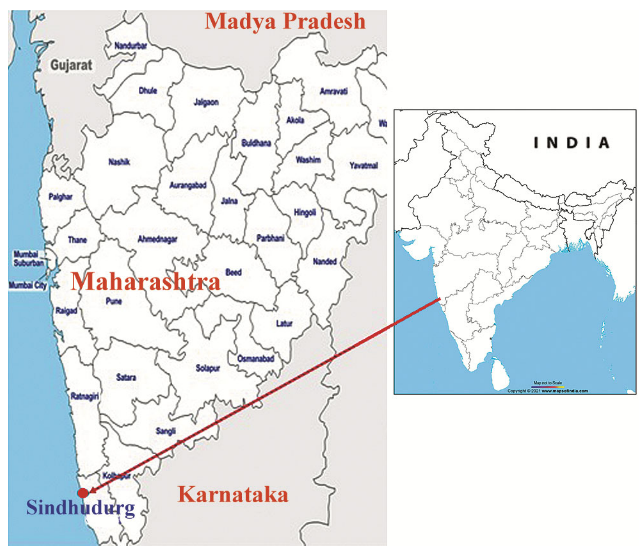

Fig. 1 — Geographical map of sampling location

Table 1 — Details of sampling locations of the proposed Jaitapur nuclear power plant site

Station name	Latitude	Longitude	Station code	No. of samples
		Sandy Shore		
Ganeshgule (GG)	16°52'17'' N	73°17'55'' E	N SW30	8
Vetye (VT)	16°41'38'' N	73°19'61'' E	N SW15	8
Ambolgad (AG)	16°37'68'' N	73°20'47'' E	N SW10	8
Vijaydurg (VD)	16°33'42'' N	73°19'96'' E	S SW5	8
Gyre – Pural (GP)	16°28'51'' N	73°20'52'' E	S SW10	8
Padavane (PW)	16°24'64'' N	73°21'95'' E	S SW15	8
Devgad (DG)	16°22'44'' N	73°22'28'' E	S SW30	8
		Rocky Shore		
Ganeshgule (GG)	16°52'23'' N	73°17'51'' E	N SW30	8
Vetye (VT)	16°41'40'' N	73°19'60'' E	N SW15	8
Ambolgad (AG)	16°37'61'' N	73°20'39'' E	N SW10	8
Vijaydurg (VD)	16°33'38'' N	73°19'92'' E	S SW5	8
Gyre – Pural (GP)	16°28'47'' N	73°20'54'' E	S SW10	8
Padavane (PW)	16°24'51'' N	73°21'97'' E	S SW15	8
Devgad (DG)	16°22'31'' N	73°22'32'' E	S SW30	8

using standard keys, such as Guide to Identification of Marine and Estuarine Invertebrates by Gosner[22] under stereo zoom microscope. The density was expressed as the number of individuals per m^2.

Data analysis

The diversity indices like *H'* $\log^2$ (Shannon-Wiener diversity index), *d* (Margalef's richness index), and *J'* (Pielou's evenness index), graphical representation of *k*-dominance curve and cluster analysis (based on Bray-Curtis similarity) were perfomed using Primer 6.1 and Origin 6.0.

Result and Discussion

Environmental parameters

At selected stations, water temperature varied between 25.2 and 30.1 °C. The maximum temperature (30.1 °C) was noted at station S SW5 in post-monsoon season (Fig. 2a). The DO varied between 5.7 and 8.1 ml l^{-1} with the highest value (8.1 ml l^{-1}) during pre-monsoon at station S SW10, while minimum (5.7 ml l^{-1}) at S SW5 station during the post-monsoon (Fig. 2b). The wide variation during different seasons is due to variations in the influx of freshwater

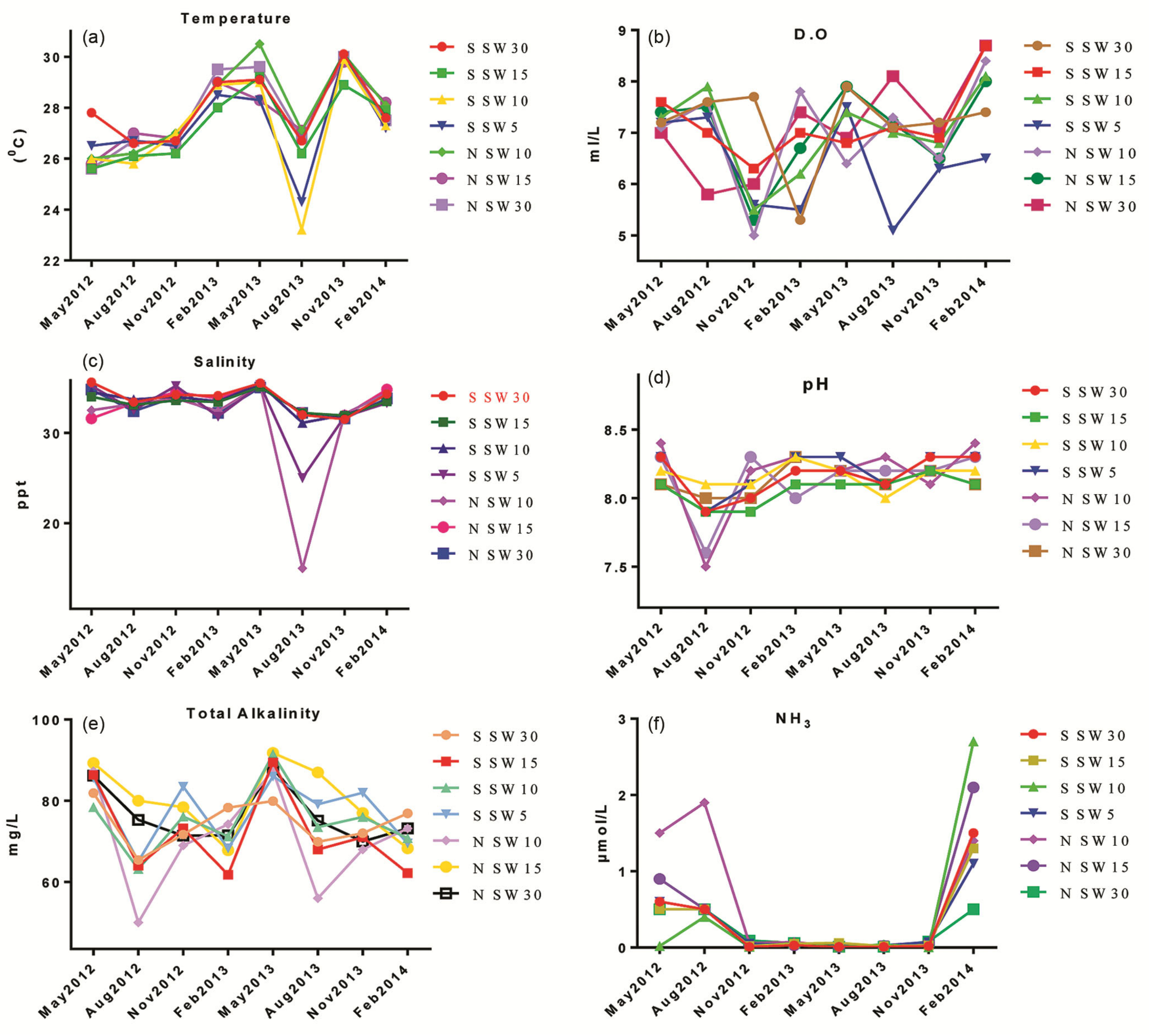

Fig. 2 — a-f: Water quality parameters at inshore stations during May 2012 to Feb 2014; Ganeshgule (N SW30 kms), Vetye (N SW15 kms), Ambolgad (N SW10 kms), Vijaydurg (S SW5 kms), Gyre-Purel (S SW10 kms), Padwanae (S SW15 kms), and Devgad (S SW30 kms)

from Rajapur and Vijaydurg creeks. However, the maximum dissolved oxygen (8.2 ml l^{-1}), noticed during winter (Feb 2013), was result of the phytoplankton bloom. Water temperature ranged between 23.2 °C and 30.5 °C with the highest value (30.5 °C) in pre-monsoon at station N SW10 (Fig. 2a). Similarly, DO ranged from 5.0 to 8.7 ml l^{-1} (Fig. 2b) and the highest DO value was observed in monsoon at station N SW15, N SW10, and S SW5 because of the fresh water influx at these stations from nearby villages. Minimum DO of 2.5 mg l^{-1} was noted in post-monsoon, it may be considered hypoxic[23].

The salinity is known as a regulating factor for the distribution of living organisms in marine ecosystems[24-26]. Temperature and salinity disturb the dissolution of oxygen[27,28] and affect the scattering of living animals in the intertidal area/ zone[14,29]. In present study, salinity ranged between 31 to 35.6 ppt with the highest value during September-Novevember 2013 at Devgad, while lower salinity was recorded at Ambolgad followed by Vijaydurg during June-August 2013 (monsoon) due to the rainwater inflow. However, recolonization of benthic communities was observed during high salinity indicating positive influence of higher salinity on the benthic population[30].

The overall values of physico-chemical parameters of sediments were more or less similar at all the stations. The analysis of sediment compostion revealed 95.98 – 97.74, 2.16 – 3.56 and 0.02 to 0.73 % of sand, silt and clay, respectively (Fig. 3a-c). Sediment texture influences the colonization of different benthic invertebrates in the ecosystem[11]. In the present study, the sediment texture was composed of sand and clay followed by silt at 7 inshore stations; however, the composition varied due to the occurrence of silt and clay particles in different percentages along with macrobenthic species. Generally, the pelagic larvae of macrobenthos, while settling down at the bottom, face different hurdles and every type of bottom substances will fascinate certain set of species[31]. A basic perception in macrobenthic orgnaims and sediment relation are based on feeding type[32]. Debris feeders frequently dominate the macrobenthic invertebrate community[33].

Diversity of macrobenthos

Total of nineteen benthic groups, comprising 54 species, were identified from seven intertidal stations (Table S1). The macrobenthic diversity is presented based on values of Margalef's species richness (*d*), Shannon-Weiner diversity (*H'* $\log^2$) and Evenness (*J'*) indices (Figs. 4, 5). Among inshore stations, diversity was found to be maximum at Ganeshgule (N SW30 kms). *H'* (2.259) and *d* (2.502) indicated rich diversity at the rocky habitats (Fig. 4). Maximum groups of macrobenthos (14) were recorded during September-November 2014 (post monsoon). At sandy as well as rocky shores, polychaetes were dominant group followed by crustaceans like amphipod, isopod, penaeid and decapods larvae. Ascidia (Urochordata) was recorded during the post-monsoon seasons (September-November 2013). Seasonal variations in biodiversity were observed at sandy and rocky habitats. Moreover, the highest diversity indices (2013-2014) in sandy shore were observed at Vetye (N SW15 kms) (Fig. 5) and highest value of Shannon – Weiner diversity index (1.667) was recorded at Ganeshgule. In case of rocky shore, the maximum number of macrobenthic

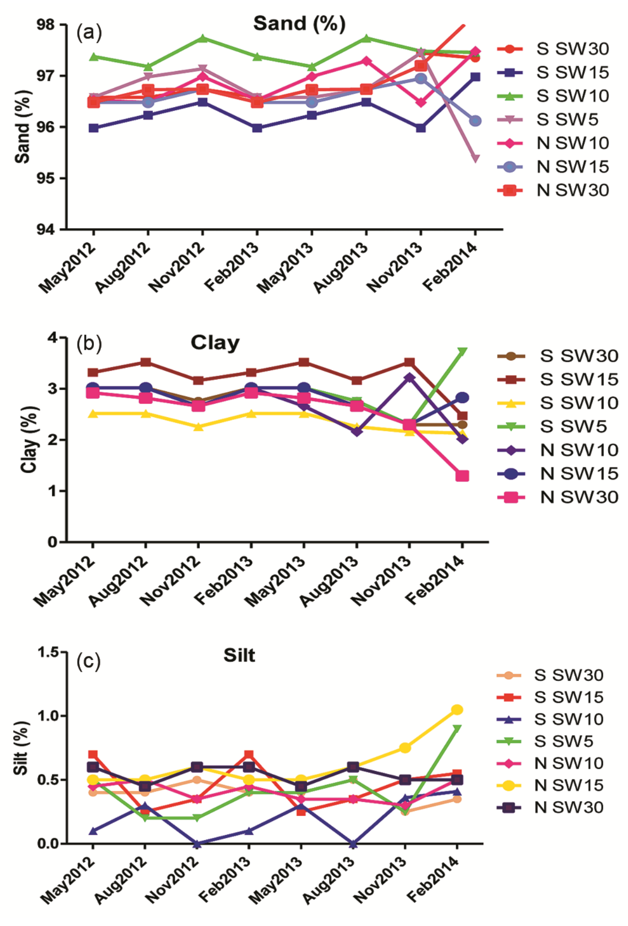

Fig. 3 — a-c: Sediment composition (%) in relation to season and locations during May 2012 to Feb 2014: Ganeshgule (N SW30 kms), Vetye (N SW15 kms), Ambolgad (N SW10 kms), Vijaydurg (S SW5 kms), Gyre-Purel (S SW10 kms), Padwanae (S SW15 kms), and Devgad (S SW30 kms)

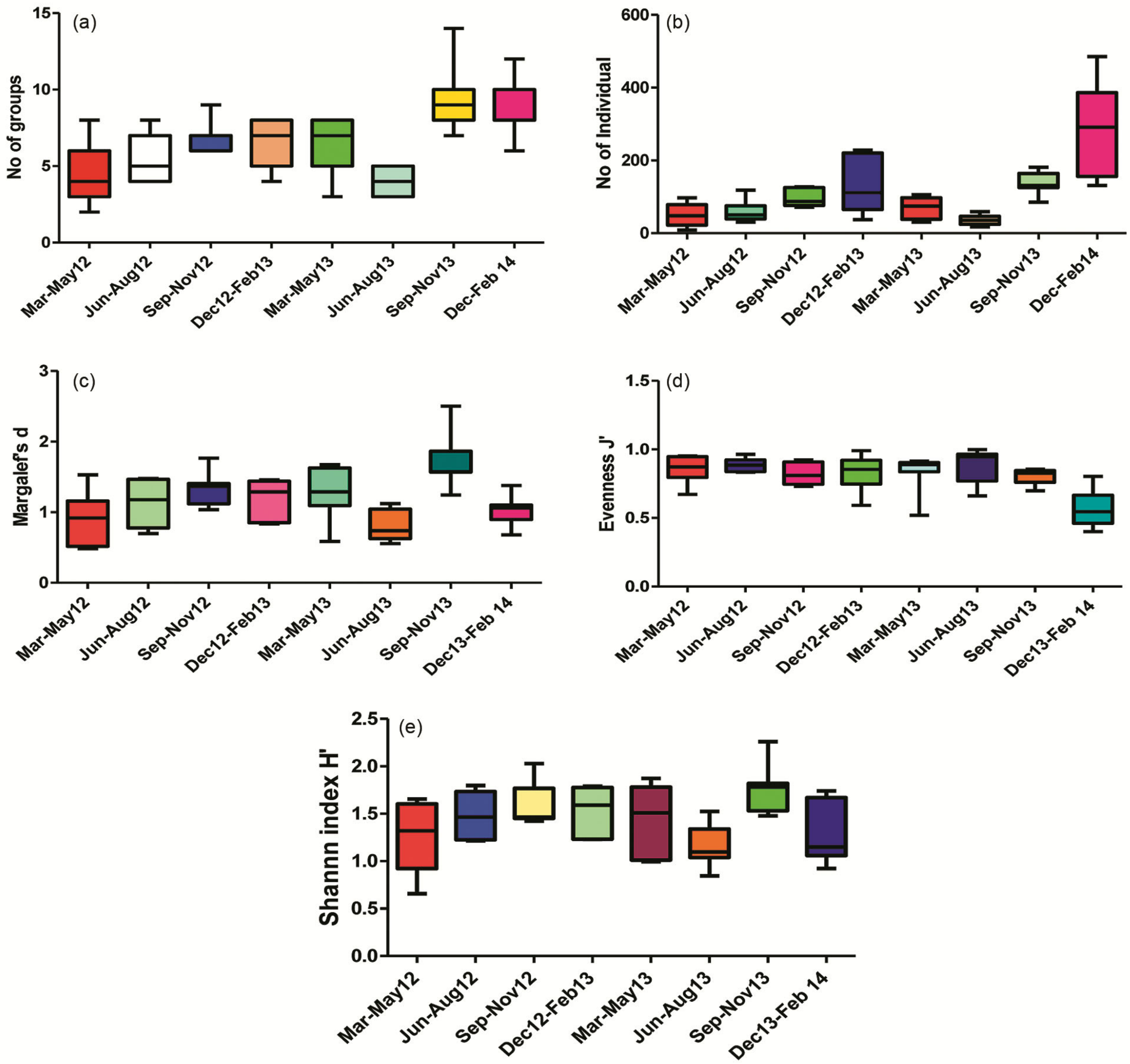

Fig. 4 — Box-plot for inshore macrobenthic diversity at rocky shoreseason wise during May 2012 to Feb 2014. a: Number of groups, b: Number of individuals, c: Margalef's richness, d: Evenness, and e: Shannon-Wiener index

groups (12) were recorded at Ganeshgule (N SW30 Kms) while maximum values of *H*' (1.74) and d (1.379) were recorded at the same station during December-Feberuray 2014 (Fig. 4).

Cluster analysis was conducted for benthos abundance data (no/m^2), representing 7 locations at 4 different seasons such as Dec-Feb, Mar-May, Jun-Aug, and Sep-Nov of 2012-13 (Figs. 6, 7) and 2013-14 (Figs. S1, S2), respectively for two different habitats. It revealed more similarity at sandy habitats (86.01%) in December-Feberuary 2013 and Mar-May 2013 (Fig. 6). In addition, during 2013-14, more similarity (82.05 %) was seen for sandy habitat at GP and PWS SW15 kms followed by 80.04 % by VT kms (Fig. S1). The *k*-dominance plots facilitated the benthic orgnaisms according to the group's comparative impact to representative stock (Figs. 8, 9; Figs. S3, S4). When data, for all stations and different seasons, were plotted together, the curve lying high indicated the lowest diversity while the curve lying low indicated the highest diversity. The *S*-shaped curves obtained for sandy habitat indicated the highest number of groups from Vijaydurg (VD) during Mar-May (pre-monsoon). Gansehgule (NSW30 kms)

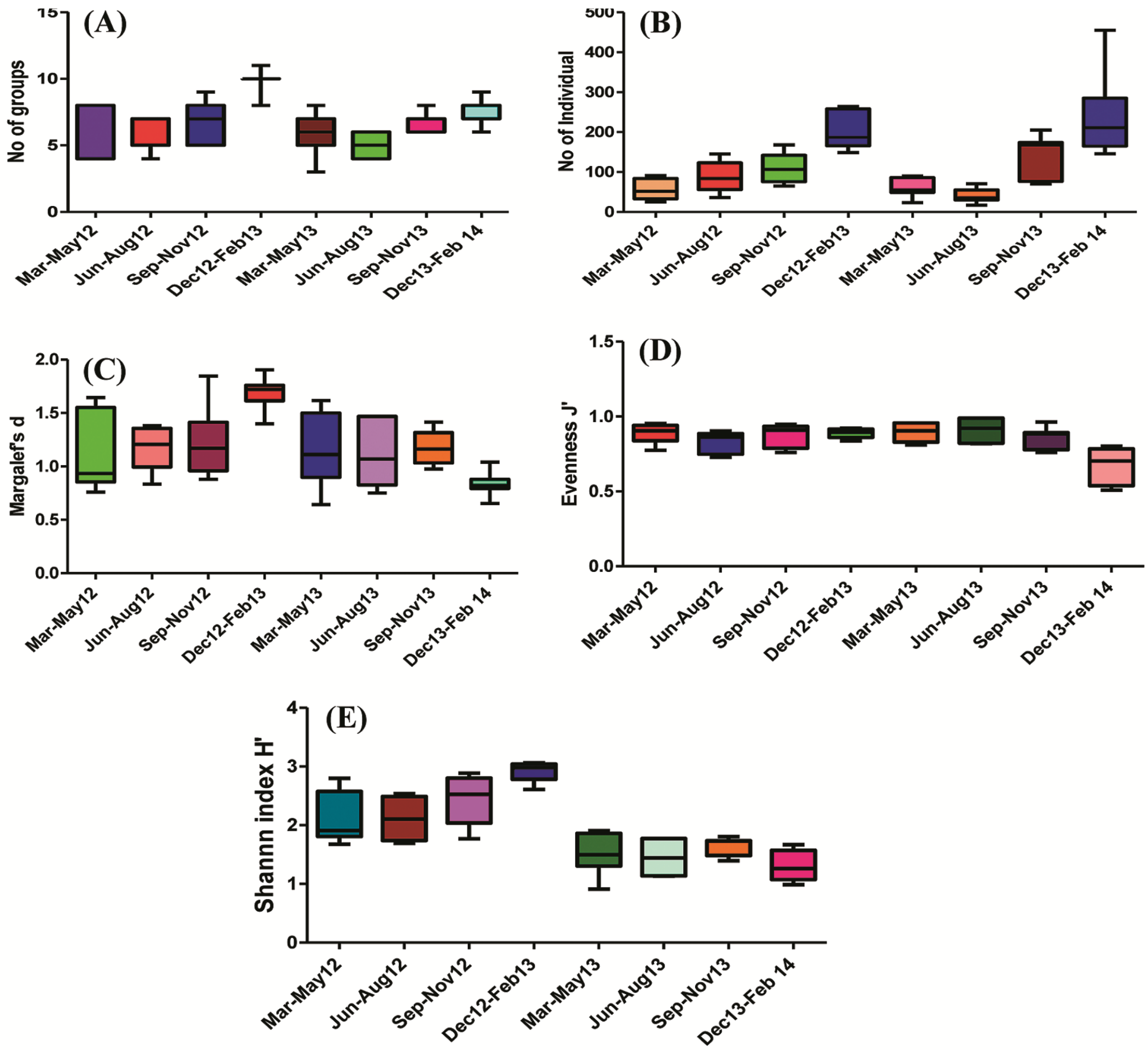

Fig. 5 — Box plot for inshore macrobenthic fauna diversity indices at sandy site season wise during May 2012 to Feb 2014. A: Number of groups, B: Number of individuals, C: Margalef's richness, D: Evenness, and E: Shannon-Wiener index

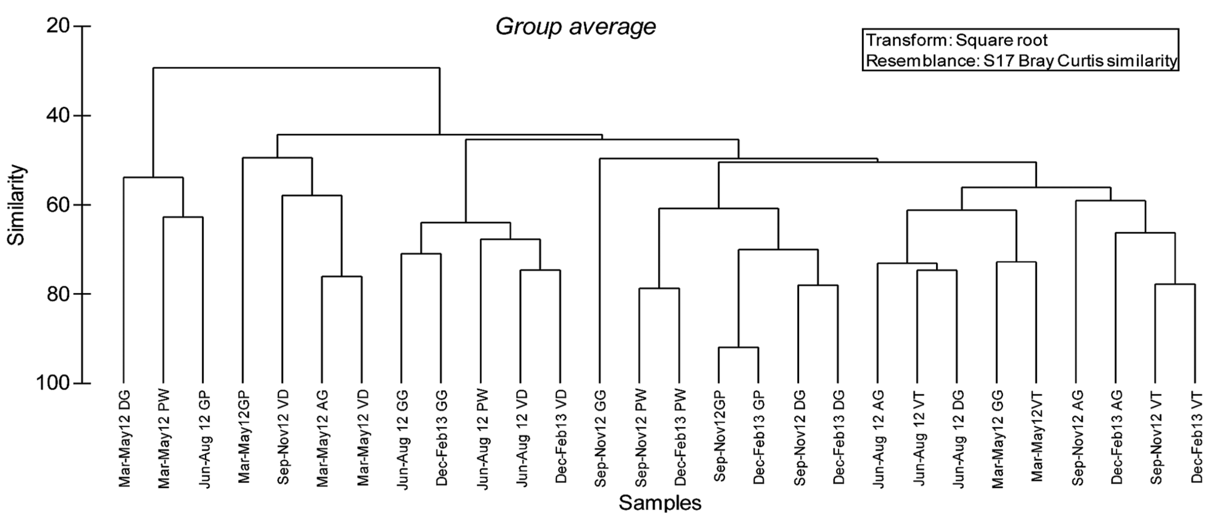

Fig. 6 — Dendrogram for hierarchical agglomerative clustering ofmacrobenthos for sandy shore (2012 to 2013)

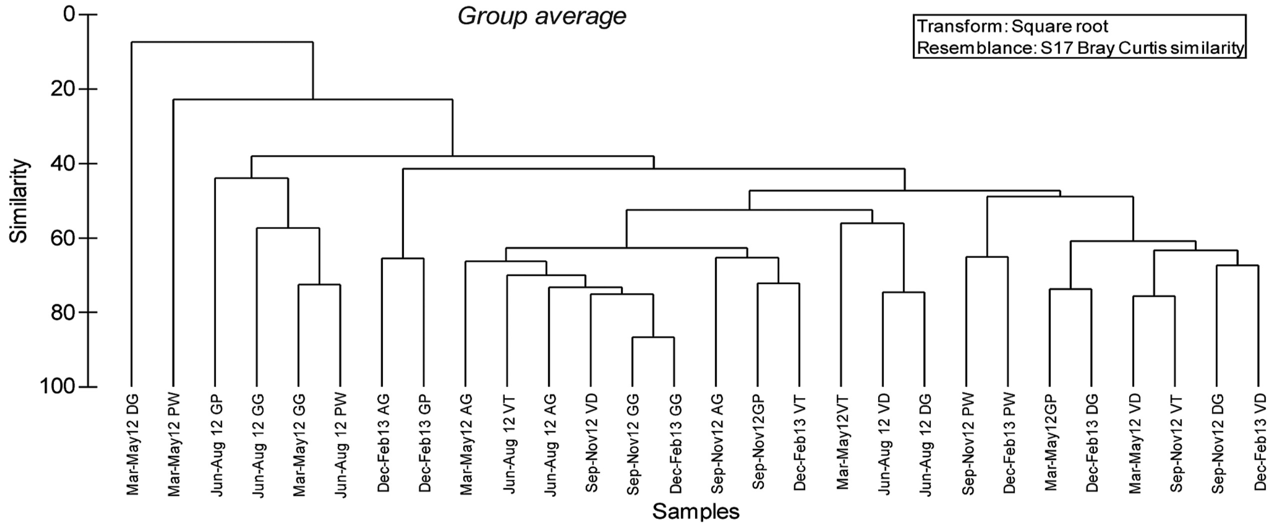

Fig. 7 — Dendrogram for hierarchical agglomerative clustering of macrobenthos rocky shore (2012 to 2013)

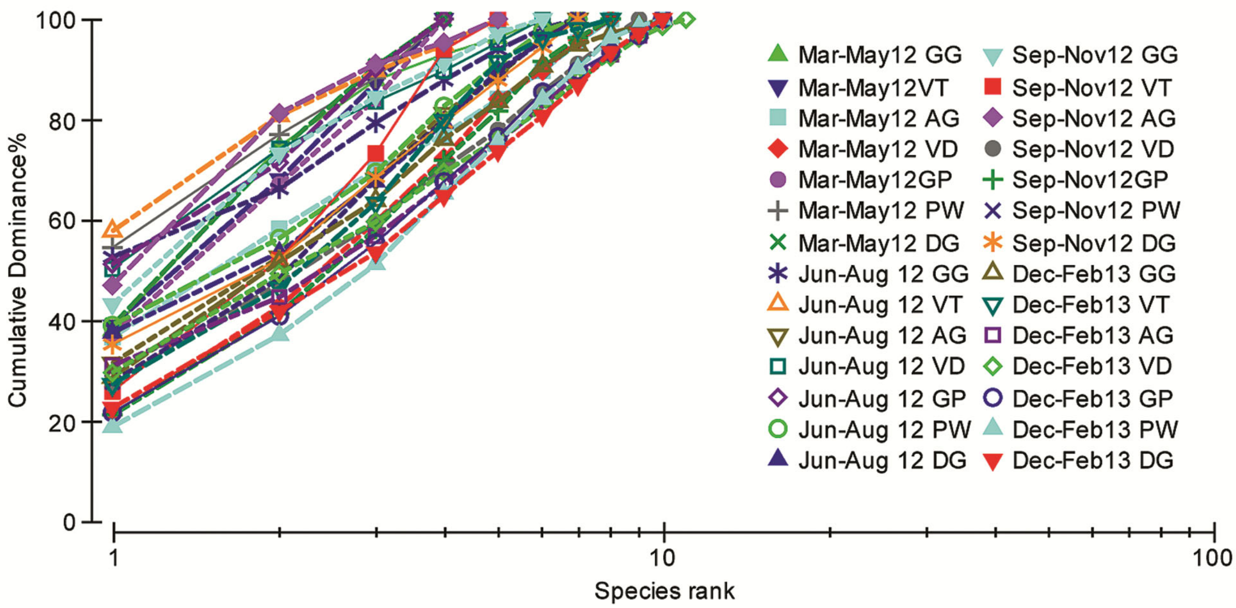

Fig. 8 — k – dominance curve for macrobenthos from sandy shore (2012-13)

harboured 14 groups (Fig. 9). The physico-chemical factors control the faunal assemblages or their distribution. The major goal of benthic diversity has been to recognize the tools of flexibility and associations between the organisms and physico-chemical parameters[34,35]. Further, dissolved oxygen of 4 – 5 mg l^{-1} is important for healthy marine biotic diversity[36], where values below 2 mg l^{-1} characterize the hypoxic condition[37]. However, in the present study, the DO ranged from 5.0 to 8.7 ml l^{-1}; therefore, study area under study can be considered healthy.

The characterstic of sediment is one of the identified dynamic forces in defining the grouping of macrobenthic communities. Silty substrate has always been reported to encourage the epifaunal diversity[38,39]. Sea bottom arrangement of clay, silt and sand have indicated a varied nature of the benthic substratum in study area. Ansari[40] mentioned that high biomass and density of polychaetes are related with sandy substrates. The organic content characterizes direct or indirect food origin for benthic invertebrates and highest organic substances might be responsible for the enhancement of metabolism of benthic organisms[41,42]. Harkantra & Parulekar[43] also reported the clayey-sand and sandy substrate to have a rich faunal abundance. Fine clay particles could influence the congestion of

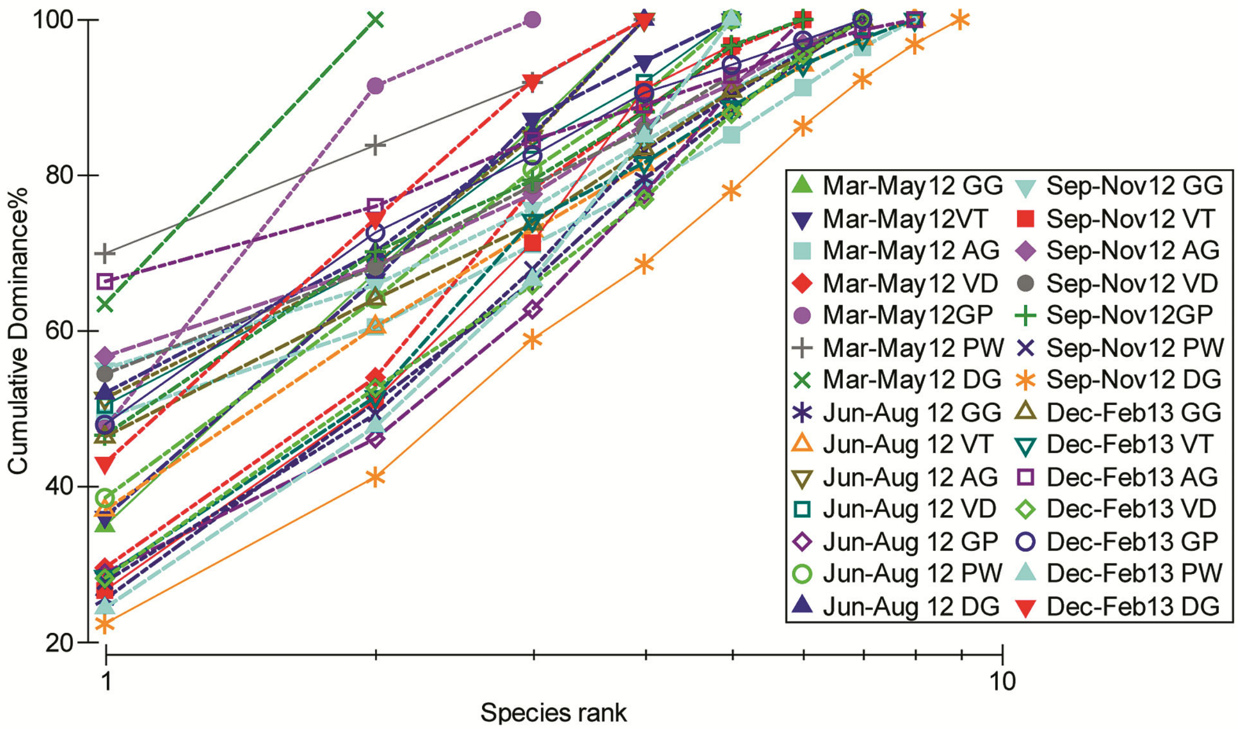

Fig. 9 — k – dominance curve for macrobenthos from rocky shore (2012-13)

the seiving tools of the filter feeders; therefore the fauna avoids very small particle substrate[44].

Palacin *et al.*[45] also reported the maximum availability of benthic organisms in sandy sediment and lowest concentration in larger sedimentation area of Mediterranean Bay. The composition of sediments are very significant to the marine benthic animals that delivers the living environment and food through organic matter[41,46]. Yet, maximum organic substances are considered responsible for decreasing species diversity, abundance, and biomass, probably due to production of toxic substances (ammonia and sulfide) and oxygen depletion[47-49]. Lowest diversity in the shallow region of the upwelling could also be the result of the oxygen depletion by organic matters[11]. The polychaetes density was low in higher organic carbon sediments. Similarly, Jayaraj *et al.*[44] also reported low benthos, especially polychaetes, in habitats with highest organic substances (> 3 %). Harkantra *et al.*[50] also observed that the organic substances beyond 4 % are unfavorable to the macrobenthic assemblage.

For a healthy environment, *H'* and *d* are reported in the range between the 2.5 to 3.5[(ref. 51)]. Redding and Cory[52] observed a highest level of arrangement between the nature of the environment and species diversity. The marine coastal repossession actions, reason for decrease the macrobenthic diversity abundance, has previously been reported by Lu[15]. The Arasaki *et al.*[53] also emphasized about the significance of sediment textures as a main variable defining the scattering of macrobenthos[53]. Thus, the use of diversity indices is advantageous for the explaination of faunal composition in the fluctuating environment[11].

The present study shows a characteristic positive correlation between macrofaunal distribution and temperature as well as pH (r = 0.626 & 0.562; $p < 0.05$) (Table S2). The number of the individual (N) had positive relationship with temperature and pH (r = 0.766 and 0.683; $p < 0.05$). However, salinity showed a negative relationship with richness of species ($r = -0.213$; $p < 0.05$) (Table S3). In addition, a higher macrobenthic density from the sandy (3180 ind m^{-2}) and rocky habitats (2314 ind m^{-2}), at all the stations, were recorded. Present observation of density was higher than the record at Zuari estuary (50 to 1,437 ind m^{-2}) by Parulekar & Waugh[54], and at Andaman seas (80 to 998 ind m^{-2}) Parulekar & Ansari[55], and similar with Harikantra *et al.*[56] who reported the density range of 50 to 3,715 ind m^{-2} at shelf region of west coast of India.

Balachandar *et al.*[14] reported the benthic faunal density between 450-2250 ind m^{-2} around Puducherry coast, India. Yet, present values are lower than the reported density of 5,723 ind m^{-2} at Northwestern Arabian Sea shelf as reported by Parulekar & Waugh[54]. In the present study, species diversity varied between 1.75 (in monsoon season) and 3.36 (in pre-monsoon). The benthic macrofauna was recorded in the order of dominance as polychaetes, molluscs, crustaceans, and other macrobenthos, as also observed by Mohammed[57] and Kumar[58]. The present study shows characteristic positive correlation between temperature as well as pH with macrofaunal distribution in different seasons, which might be due to constant environmental factors, such as pH, temperature and sediment texture, playing major role in faunal distribution.

Conclusions

Present study on the spatial distribution of macrobenthos revealed higher density and more diverse fauna during post-monsoon. Lowest benthic diversity, particularly polychaetes and crustaceans during monsoon, are due to unfavourable environmental factors, especially lower temperature and salinity. Thus, these environmental features play a greater role in the abundance and distribution of benthic organisms. However, the trend in physicochemical parameters of water and soil, in an ecosystem, depends on many natural processes and disturbances, and characters of benthos distribution are likely to change accordingly, apart from human interventions.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at http://nopr.niscpr.res.in/jinfo/ijms/IJMS_51(01)56-66_SupplData.pdf

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Conflict of Interest

Authors do not have any conflict of interest.

Author Contributions

PS: Sample collection, analysis, data interpretation and manuscript writing; MK & AP: Sample collection and data analysis; SKC: Funding support and manuscript correction; AKJ: Funding support, species identification and manuscript correction.

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