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# Sediment geochemistry with population of recent benthic ostracoda in Palk Bay, southeast coast of India

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**ABSTRACT: Seasonal observation on trace elements of shallow inner shelf sediments and their correlation with the population of recent benthic ostracoda off Rameswaram, Ramanathapuram District, Tamil Nadu, Southeast coast of India is the aim of this study. The sediments were analysed for trace elements Al, Fe, Mn, Zn, Cu, Pb, Cd, Ni, Co and Cr and being correlated with the population of benthic ostracoda for four different seasons. Cu has a positive correlation, and Fe, Mn, Zn, Pb, Cd, Ni, Co and Cr have negative correlation with the total population of ostracoda. Al has no considerable correlation with the total population of ostracoda. In the middle segment plenty of corals were found in the study area and their effect being discussed.**

**Key words:** trace elements of sediments, recent benthic ostracoda, seasonal correlation

## 1. INTRODUCTION

Few studies reported the comparison of the occurrence of trace metals and other carapace components in ostracod valves from recent sites of varying contamination levels, with the nature of the contaminant discharges. Carapaces of *Cyprideis* sp. have significant differences in Mn, Fe and rare earth element contents between the unpolluted and polluted lagoon of Africa and Europe, whereas Cd and Pb did not have this distinction (Palacios-Fest et al., 2003). A surface sample includes living individuals and dead specimens belonging to a variable number of previous ostracod generations depending on the individual species ontogeny and the local sedimentation ratios. Their faunal composition, population density, and diversity are variable, depending on various environmental factors such as water temperature, salinity, water depth, grain size, dissolved oxygen, nutrient concentration, or heavy metal content (Bodergat et al., 1998). In recent years, much attention has been paid to the chemical composition of marine sediments in coastal regions near large industrial and urban areas because it is linked to deterioration of oceanic ecosystems (Jonathan et al., 2004). Bodergat and Ikeya (1988) reported from Ise and Mikawa Bays in Japan, where the population of ostracod is lowest but the concentrations of Zn, Pb, Cr, or Cu are found to be highest, as far as the species *Cytheromorpha acupunctata*, is concerned. The present paper is focused on the relationship between the geochemical composition of the sediment and environmental variables and being correlated with the population of ostracoda.

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## 2. STUDY AREA

The area under present investigation is a tropical region situated off Rameswaram, in the Palk Bay, Southeast coast of India. The study area is represented in the Survey of India toposheet Nos. 57 O/7 and 57 O/8. It lies between the coordinates of latitude from 9°16′N and longitude from 79°18′E to 79°25′E which is the eastern transect off Rameswaram Island. The region is a shallow inner shelf, with a topography having a gentle slope towards the sea. Plenty of coral reefs are seen, especially, in the middle segment of transect. The location map of the study area is shown in Figure 1.

## 3. MATERIALS AND METHODS

The bottom sediment samples were collected for four different seasons, namely, northeast monsoon (October 2010), winter (January 2011), summer (April 2011) and southwest monsoon (July 2011). The sediment samples were collected by Petersen grab sampler onboard in a motor launch. The total trace elements, regarding Al, Fe, Mn, Zn, Cu, Pb, Cd, Ni, Co and Cr were determined after preliminary treatment and total decomposition of sediments following the procedure of Tessier et al. (1979). The final solution was analyzed using Atomic Absorption Spectrophotometry (AAS – Perkin Elmer AA700 AAS) equipped with a deuterium background corrector, in the Department of Applied Geology, University of Madras. Further standard reference material MESS1 was used to ensure the quality control and accuracy of the analysis. Average values of trace elements concentration during different seasons are given in the Table 1.

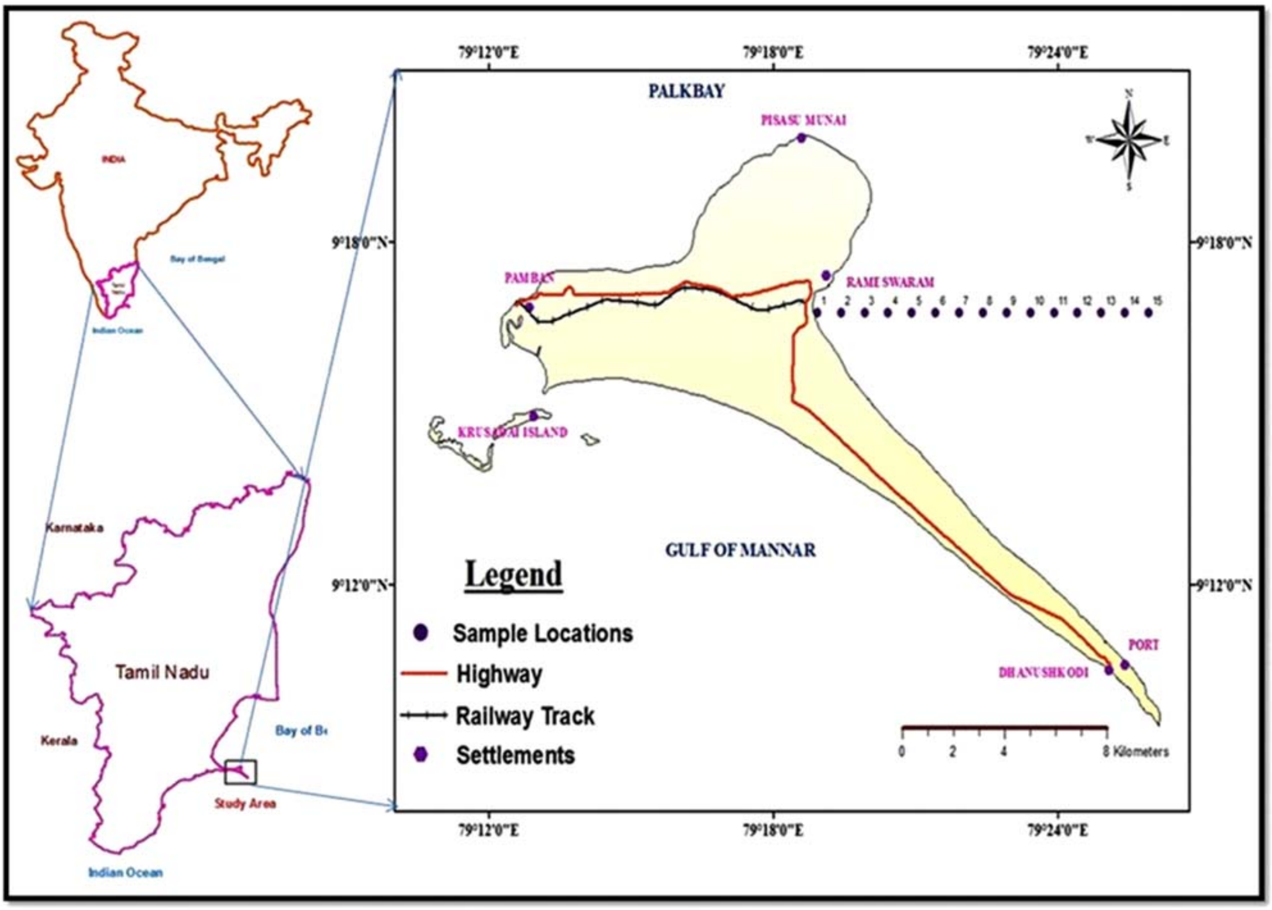


**Fig. 1.** Location map with sampling stations of the study area.

**Table 1.** Average value of trace elements during different seasons

| Eastern transect | | | | |
|---|---|---|---|---|
| Trace elements mg/L | NE monsoon | Winter | Summer | SW monsoon |
| Al | 76380.2 | 75109.6 | 73102.7 | 74206.4 |
| Fe | 7480.0 | 7428.5 | 7611.6 | 8134.0 |
| Mn | 293.0 | 273.1 | 275.3 | 275.0 |
| Zn | 18.5 | 17.9 | 17.0 | 16.7 |
| Cu | 20.0 | 20.4 | 17.9 | 19.4 |
| Pb | 12.4 | 11.8 | 10.6 | 11.3 |
| Cd | 7.2 | 7.1 | 7.0 | 6.9 |
| Ni | 23.0 | 22.5 | 19.5 | 19.8 |
| Co | 17.0 | 16.3 | 15.9 | 16.6 |
| Cr | 60.3 | 78.9 | 66.6 | 63.6 |

## 4. RESULT AND DISCUSSION

### 4.1. Total Population of Ostracoda

Sridhar et al. (1998) inferred that the congenial substrate is siltysand and sand for the samples collected three decades ago for the same location, but Baskar et al. (2013) reported for the same location that the substrate is Sand in all the stations during all the seasons. They (op. cit.) observed that higher the silt content higher the population of ostracoda. Baskar et al. (2013) reported the total population of ostracoda in the eastern transect for four different seasons that exist. They (op. cit.) reported that the total population is highest during summer and lowest during winter and moderate during other two seasons as shown in Figure 2. Baskar (2014) has reported that the middle segment has higher population of ostracoda irrespective of any season due the presence of plenty of corals which contribute $CaCO_3$ that facilitate the survival and congenial environment for the abundance of ostracod in the eastern segment where the present study is done for trace elements. The present study deals with the correlation of total population of ostracoda with the concentration of trace elements identified and quantified. Corals are vulnerable to the accumulation of high concentrations of heavy metals, such as, Pb, Ni, Mn, Cd, except Cu and Zn, within the skeletal part (Jayaraju et al., 2009) is being confirmed in the observed heavy metals of the sediments while correlation the population of ostracoda.

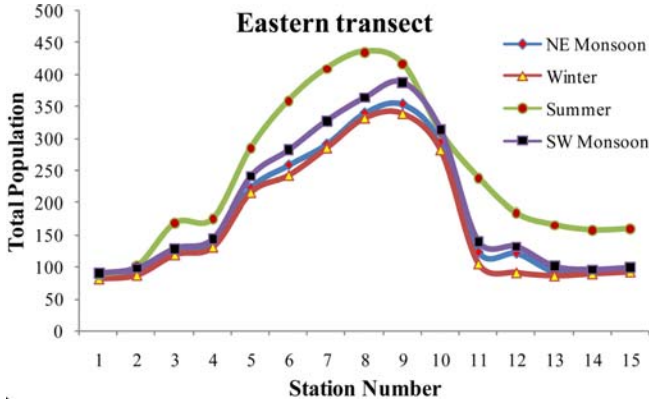


**Fig. 2.** Total population of ostracoda during different seasons against the sampling stations (after Baskar et al., 2013).

### 4.2. Aluminium

The present study reveals that the Al concentration ranges from 58918 to 86781 mg/L; the lowest value being recorded during summer season at 2nd station and the highest value being recorded during winter season at 15th station. The average Al concentration in NE monsoon 76380.2 mg/L, winter season 75109.6 mg/L, summer season 73102.7 mg/L and SW monsoon 74206.4 mg/L. Aluminium remains the most successful and widely used normative and component states for variation in grain size and composition, because it represents the quality of aluminosilicate, which is the most important carrier of absorbed metals in near shore sediments. Moreover, in the crust, metal to the aluminium ratios are less affected by human activities (Schropp et al., 1990). According to Salomons and Forstner (1984), the contamination in an area can be inferred from the enrichment factor, which is the ratio between metal/Al in the sample and metal/Al in the average shale or crust and this provides an effective tool to evaluate sediment quality and aids in making comparisons between different areas. Jonathan and Ram Mohan (2003) reported Al concentration as 5.39% in the Gulf of Mannar, Tuticorin, east coast of India. Using the median value from the frequency distribution of box and whisker plot drawn for Al in Figure 3, it is inferred that northeast monsoon has higher concentration distribution in the study area. Based on correlation of matrix, NE monsoon and summer season shows positive correlation and winter and SW monsoon shows negative correlation with the total population of ostracoda as shown in Tables 2a–d. It is inferred that Al has no considerable correlation with the total population of ostracoda. As the concentration of element Al increases from the shore to shallow inner shelf, the higher population in the middle segment cannot be correlated here in this study.

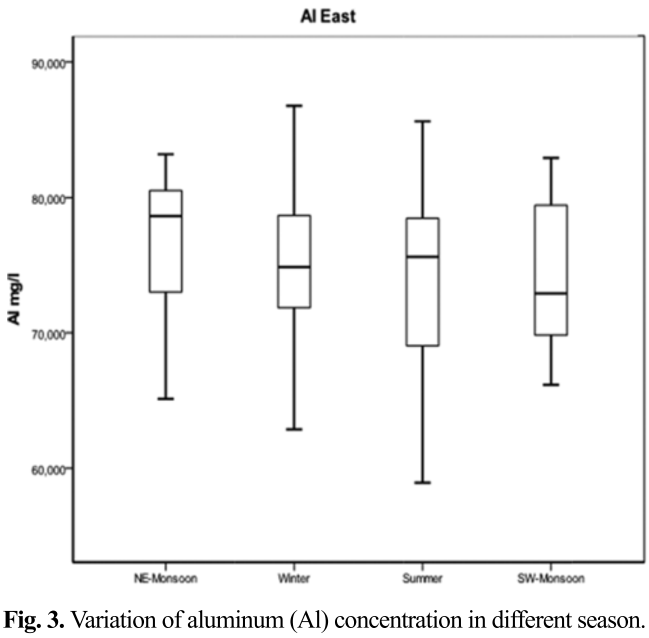


**Fig. 3.** Variation of aluminum (Al) concentration in different season.

### 4.3. Iron

Concentration of Fe ranges from 1337 to 19520 mg/L; the lowest and highest values being recorded during summer season at 10th and 14th station, respectively. The average Fe concentration during NE monsoon 7480 mg/L, winter season 7428.5 mg/L, summer season 7611.6 and SW monsoon 8134 mg/L. Iron can be combined with a wide variety of anions to from complexes and minerals. The common minerals being silicates, oxides, sulphides and phosphates; silicates and oxides are more favorable forms of iron in oxic coastal environments. Iron changes its oxidation states readily under a variety of natural environmental conditions. The concentration of metal transfer efficiencies varies from tissue to the skeleton (Esslemont, 2000). Oyewo and Don-Pedro (2002) reported from Lagos, Nigeria that the heavy metal pollution from industrial effluents and drainage channels, especially Hg as the most toxic to all test species followed by Cu, Mn and Fe and *Cypris sp.* is the most tolerant species. Using the median value from the frequency distribution of box and whisker plot drawn for Fe in Figure 4, it is inferred that northeast monsoon and southwest monsoon seasons have higher concentration distribution in eastern transect. Based on Tables 2a–d, Fe is found to have a strong negative correlation with the total population of ostracoda during different seasons. This is being supported by the higher population of ostracoda in the middle segment where the concentration of Fe is lower compare to near shore and shallow inner shelf.

### 4.4. Manganese

Mn concentrations in the eastern transect ranges from 159 to 438 mg/L; the lowest and highest values are recorded during summer season, at 6th and 13th stations, respectively. The average Mn concentration in NE monsoon 293.0 mg/L, winter season 273.1 mg/L, summer season 275.3 mg/L and SW monsoon

**Table 2.** (a) Correlation matrix in northeast monsoon season

| | Al | Fe | Mn | Zn | Cu | Pb | Cd | Ni | Co | Cr | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | 1.000 | | | | | | | | | | |
| Fe | .328 | 1.000 | | | | | | | | | |
| Mn | .358 | .549 | 1.000 | | | | | | | | |
| Zn | .313 | .678 | .187 | 1.000 | | | | | | | |
| Cu | –.367 | –.504 | –.181 | –.100 | 1.000 | | | | | | |
| Pb | –.168 | .655 | .418 | .362 | –.073 | 1.000 | | | | | |
| Cd | –.512 | .207 | .013 | –.065 | .227 | .770 | 1.000 | | | | |
| Ni | –.074 | .438 | .607 | .159 | .069 | .739 | .655 | 1.000 | | | |
| Co | –.082 | .438 | .406 | .067 | .076 | .755 | .722 | .863 | 1.000 | | |
| Cr | –.221 | .313 | .377 | .043 | .229 | .718 | .698 | .848 | .935 | 1.000 | |
| Population | .194 | –.722 | –.550 | –.332 | .116 | –.873 | –.642 | –.786 | –.775 | –.733 | 1.000 |

(b) Correlation matrix in winter season

| | Al | Fe | Mn | Zn | Cu | Pb | Cd | Ni | Co | Cr | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | 1.000 | | | | | | | | | | |
| Fe | .523 | 1.000 | | | | | | | | | |
| Mn | .438 | .656 | 1.000 | | | | | | | | |
| Zn | .489 | .476 | .480 | 1.000 | | | | | | | |
| Cu | –.385 | –.473 | –.026 | .055 | 1.000 | | | | | | |
| Pb | .161 | .699 | .751 | .492 | –.101 | 1.000 | | | | | |
| Cd | –.322 | .359 | .417 | .077 | .076 | .746 | 1.000 | | | | |
| Ni | .248 | .449 | .674 | .423 | .209 | .626 | .506 | 1.000 | | | |
| Co | .310 | .460 | .686 | .284 | .026 | .749 | .592 | .625 | 1.000 | | |
| Cr | –.120 | .138 | .509 | –.155 | .293 | .427 | .641 | .564 | .767 | 1.000 | |
| Population | –.116 | –.726 | –.715 | –.234 | .217 | –.848 | –.711 | –.671 | –.725 | –.594 | 1.000 |

(c) Correlation matrix in summer season

| | Al | Fe | Mn | Zn | Cu | Pb | Cd | Ni | Co | Cr | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | 1.000 | | | | | | | | | | |
| Fe | .394 | 1.000 | | | | | | | | | |
| Mn | .240 | .475 | 1.000 | | | | | | | | |
| Zn | .334 | .200 | .646 | 1.000 | | | | | | | |
| Cu | –.349 | –.479 | .074 | .171 | 1.000 | | | | | | |
| Pb | .106 | .554 | .743 | .441 | .023 | 1.000 | | | | | |
| Cd | –.293 | .365 | .388 | .162 | .001 | .585 | 1.000 | | | | |
| Ni | .120 | .377 | .819 | .510 | .187 | .745 | .602 | 1.000 | | | |
| Co | .028 | .234 | .557 | .309 | .189 | .810 | .670 | .651 | 1.000 | | |
| Cr | –.464 | .056 | .291 | –.196 | .420 | .523 | .550 | .455 | .643 | 1.000 | |
| Population | .239 | –.610 | –.564 | –.184 | .104 | –.763 | –.857 | –.633 | –.684 | –.630 | 1.000 |

(d) Correlation matrix in southwest monsoon season

| | Al | Fe | Mn | Zn | Cu | Pb | Cd | Ni | Co | Cr | Population |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | 1.000 | | | | | | | | | | |
| Fe | .633 | 1.000 | | | | | | | | | |
| Mn | .424 | .516 | 1.000 | | | | | | | | |
| Zn | .352 | .207 | .617 | 1.000 | | | | | | | |
| Cu | –.360 | –.460 | –.037 | .248 | 1.000 | | | | | | |
| Pb | .054 | .578 | .665 | .326 | –.019 | 1.000 | | | | | |
| Cd | –.476 | .087 | .188 | –.270 | .111 | .622 | 1.000 | | | | |
| Ni | .226 | .521 | .784 | .649 | .171 | .736 | .359 | 1.000 | | | |
| Co | .036 | .234 | .366 | .178 | –.095 | .660 | .428 | .384 | 1.000 | | |
| Cr | –.323 | .111 | .379 | .016 | .320 | .659 | .639 | .441 | .567 | 1.000 | |
| Population | –.083 | –.697 | –.623 | –.164 | .162 | –.907 | –.670 | –.716 | –.512 | –.640 | 1.000 |

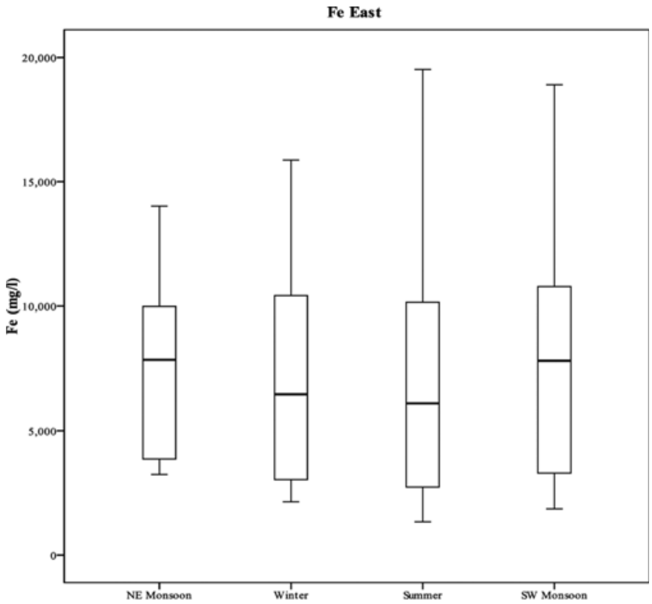


**Fig. 4.** Variation of iron (Fe) concentration in different season.

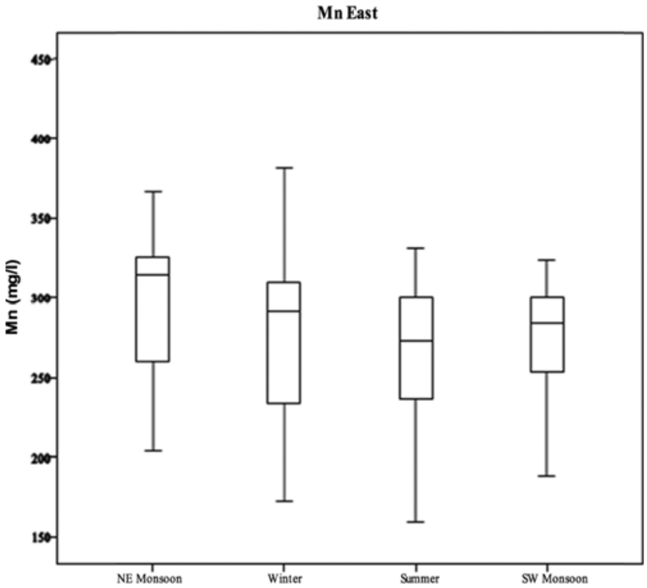


**Fig. 5.** Variation of manganese (Mn) concentration in different season.

275.0 mg/L. The high Mn in the oxidized zone and similar results are consistent with the studies made on the Basaltic sea sediment as reported by Szefer et al. (1995). Palacios-Fest et al. (2003) reported thirty eight trace elements that are anthropogenically induced accumulation, where in the element Mn is being found in the ostracod valves, namely, *Cyprideis sp*. in the following locations: Menorca Island (Spain)–Lee Stocking Island (Bahamas)–Tamiahua Lagoon (Mexico) of brackish-marine environments. Using the median value from the frequency distribution of box and whisker plot drawn for Mn in Figure 5, it is inferred that northeast monsoon season has higher concentration distribution in eastern transect. Mn being correlated with the total population and as in Tables 2a–d, the value is being observed lowest during NE monsoon. But, it has a negative correlation with the total population of ostracoda during all the seasons. In the middle segment, the concentration is found to be lower that supports a negative correlation with the population of ostracoda.

### 4.5. Zinc

Zn concentration in the study area ranges from 10.5 to 30.2 mg/L, the lowest value being recorded during summer season at 7th station and the highest value being recorded during the summer season at 13th station. Average Zn concentration ranges in NE monsoon 18.5 mg/L, winter season 17.9 mg/L, summer season 17.0 mg/L and SW monsoon 16.7 mg/L. zinc and copper are generally good indicators of anthropogenic inputs (Forstner and Wittman, 1979). Kumaresan et al. (1998) studied the distribution of Zn in sediments of corals and seagrass beds of Manali and Hare islands in Gulf of Mannar and it was 20.0 and 21.7 mg/L. Significant values of Zn concentration (31–184 mg/L) have been reported by Jonathan and Ram Mohan (2003) from the Gulf of Mannar. Using the median value from the frequency distribution of box and whisker plot drawn for Zn in Figure 6, it is inferred that the northeast monsoon season has higher concentration distribution in the study area. Even though Zn shows a negative correlation, the values are lower during summer and SW monsoons and it has the highest value during NE monsoon. Based on these facts, it is inferred that Zn has a negative correlation with the total population of ostracoda in the study area (Tables 2a–d). In the middle segment the concentration of Zn decreases where in the population increases.

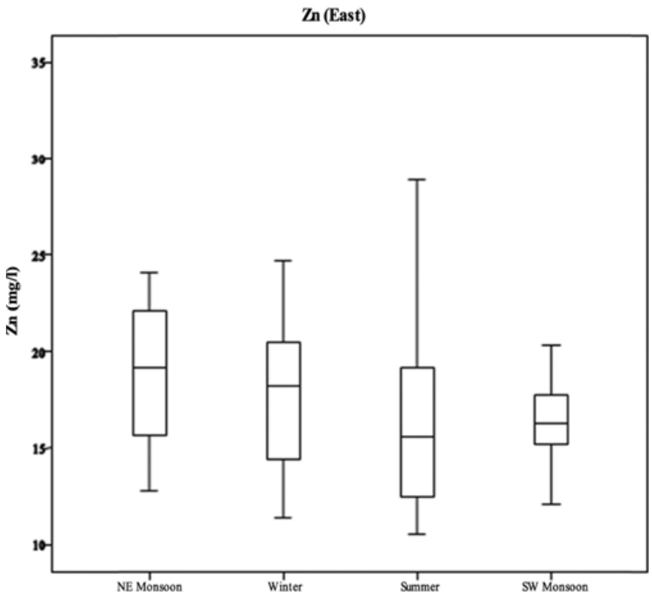


**Fig. 6.** Variation of zinc (Zn) concentration in different season.

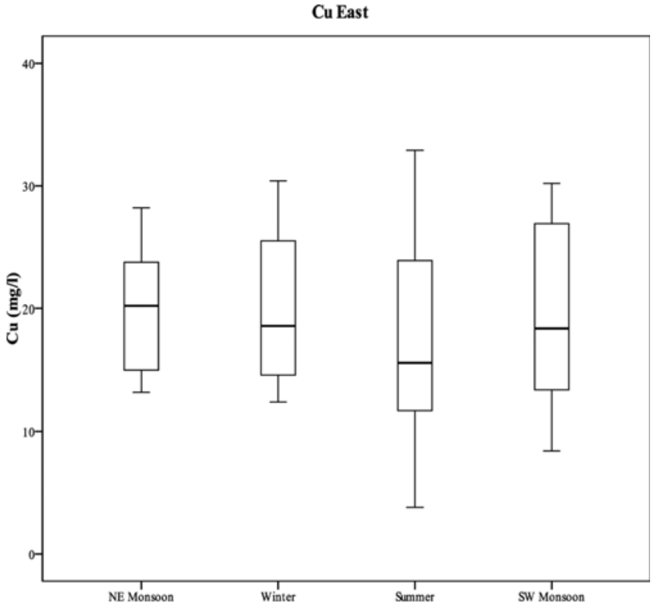


**Fig. 7.** Variation of copper (Cu) concentration in different season.

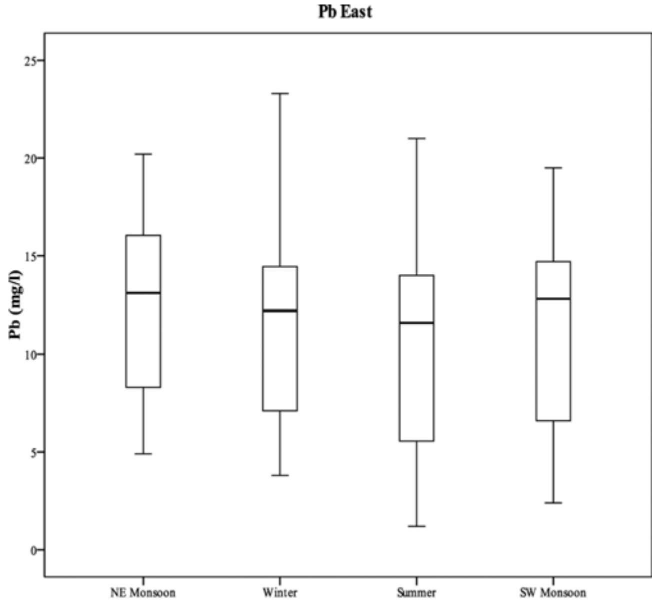


**Fig. 8.** Variation of lead (Pb) concentration in different season.

## 4.6. Copper

The present study reveals that the Cu concentration in the eastern transect ranges from 3.8 to 32.9 mg/L; the lowest and highest values were being recorded during summer season, at stations 6th and 9th, respectively. Average Cu concentration ranges in NE monsoon 20.0 mg/L, winter season 20.4 mg/L, summer season 17.9 mg/L and SW monsoon 19.4 mg/L. Reichelt-Brushett and Harrison (2005) exposed the gametes from a number of coral species to copper. Its weathering products are sulphides, oxides, basic carbonates, sulphate and silicates over chalcopyrite ore and Mn oxides, limonite, organic matter, oxides and carbonates in soils. The ostracod response has been tested statistically for copper (with or without co-occurring organic enrichments) by Lenihan et al. (2003). Using the median value from the frequency distribution of box and whisker plot drawn for Cu in Figure 7, it is inferred that northeast monsoon season has a higher concentration distribution in the study area. Cu has a positive correlation with the total population of ostracoda in the study area as revealed from Tables 2a–d. In the middle segment the higher the concentration of Cu the higher the population of ostracoda.

## 4.7. Lead

Pb concentration in the eastern transect ranges from 1.2 to 23.3 mg/L; the lowest value being recorded during summer season at 8th station and highest value being recorded during the winter season at 3rd station. Average Pb concentration ranges in NE monsoon 12.4 mg/L, winter season 11.8 mg/L, summer season 10.6 mg/L and SW monsoon 11.3 mg/L. Lead is a heavy metal that occurs in nature mainly as lead-sulphide. This metal is extremely insoluble and is readily absorbed by organic matter, especially under reducing conditions. Previously reported in Indian coast at various locations in Palk Bay regions are by Achyuthan et al. (2002); Jonathan and Ram Mohan (2003); Muthu Raj and Jayaprakash (2008); Jayaraju et al. (2009) in the east coast of India. Using the median value from the frequency distribution of box and whisker plot drawn for Pb in Figure 8, it is inferred that northeast and southwest monsoon seasons have higher concentration distribution in the study area. The value in correlation matrix being observed lowest during summer where in the ostracoda population recorded highest. Pb has a negative correlation with the total population of ostracoda during all the seasons. In the middle segment, it is being supported by the lowering of Zn where in the population increases that supports Al-Shawafi et al. (2009) those who inferred that high Cd, Co and Pb in coral reefs sediments will have a negative effects on marine life on the sites.

## 4.8. Cadmium

Cd concentration, in eastern transect ranges from 5.2 to 8.9 mg/L; the lowest value being recorded during summer season at 7th station and highest value being recorded during winter season at 16th station. Average Cd concentration ranges in NE monsoon 7.2 mg/L, winter season 7.1 mg/L, summer season 7.0 mg/L and SW monsoon 6.9 mg/L. Cd and Pb in corals are well known indicators of anthropogenic activity (Shen and Boyle, 1987). Severe contamination of Cd gives rise to itai-itai disease (Yosumura et al., 1980). Jonathan and Ram Mohan (2003), Selvaraj et al. (2004), and Satpathy et al. (2010 and 2011) reported Cd concentration in Palk Bay. Using the median value from the frequency distribution of box and whisker plot drawn for Cd in Figure 9, it is inferred that northeast

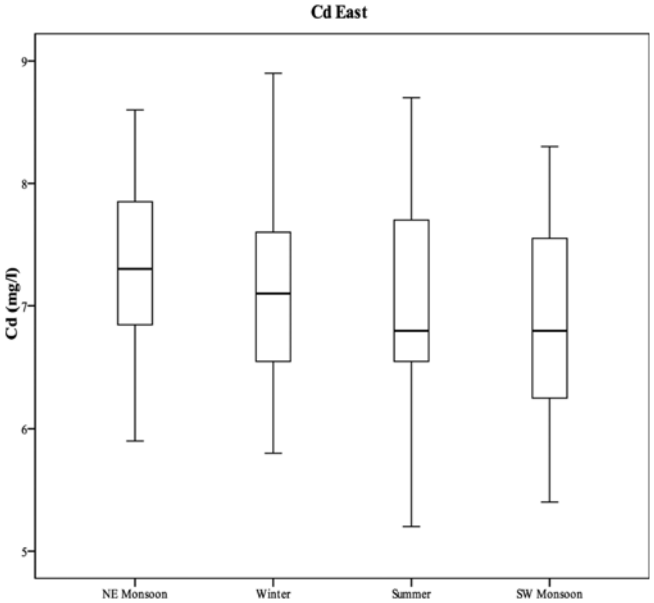


**Fig. 9.** Variation of cadmium (Cd) concentration in different season.

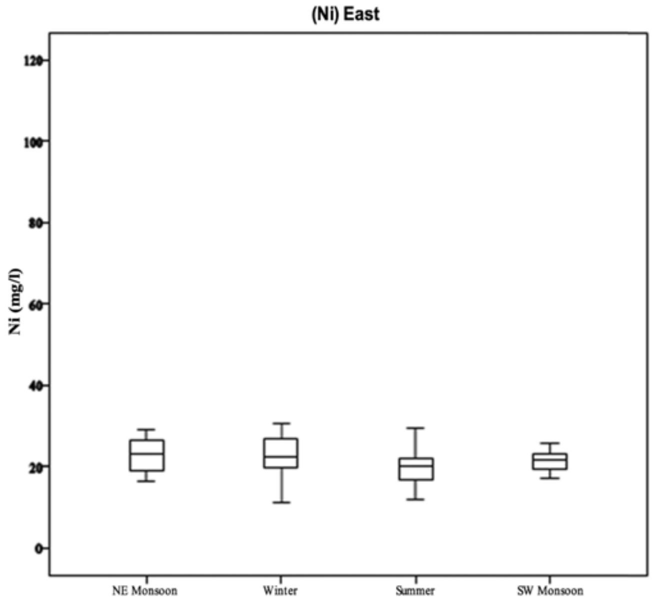


**Fig. 10.** Variation of nickel (Ni) concentration in different season.

monsoon has higher concentration distribution in eastern transect. Cd shows negative correlation with the population of ostracoda in all the season. This is being supported in the middle segment of the study area where corals are plenty in the study area which corroborates with Al-Shawafi et al. (2009). The values are highest recorded in summer season.

### 4.9. Nickel

Ni concentration in the eastern transect ranges from 6.5 to 35.1 mg/L; the lowest and highest concentration being recorded during summer season at 6$^{th}$ and 13$^{th}$ stations, respectively. Average Ni concentration ranges in NE monsoon 23.0 mg/L, winter season 22.5 mg/L, summer season 19.5 mg/L and SW monsoon 19.8 mg/L. The overall distribution pattern of Ni in the surface sediments reveal a moderate concentration, which may be due to its incorporation in the dispersed skeletal fragments. Similar reports are from Mahabalipuram (12–122 mg/L) by Achyuthan et al. (2002); from Gulf of Mannar (14–63 mg/L) by Jonathan and Ram Mohan (2003). Using the median value from the frequency distribution of box and whisker plot drawn for Ni in Figure 10, it is inferred that northeast monsoon has a higher concentration distribution in eastern transect. Ni shows negative correlation with the total population of ostracoda (Tables 2a–d). In the middle segment, the higher the population the lower the concentration of Ni confirms the negative correlation of ostracoda with the observed trace elements.

### 4.10. Cobalt

The present study reveals that the Co concentration in eastern transect ranges from 10.2 to 22.0 mg/L; the lowest

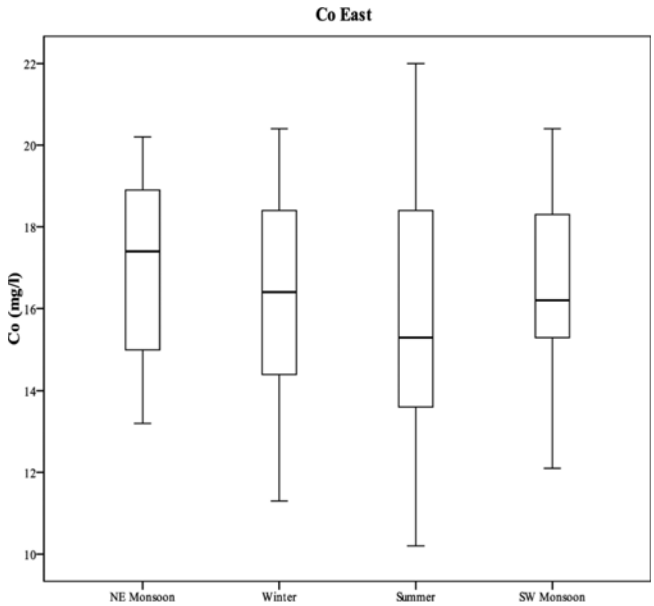


**Fig. 11.** Variation of cobalt (Co) concentration in different season.

and highest concentration being recorded during summer season at 8$^{th}$ and 13$^{th}$ stations, respectively. Average Co concentration ranges in NE monsoon 17.0 mg/L, winter season 16.3 mg/L, summer season 15.9 mg/L and SW monsoon 16.6 mg/L. Cobalt is one of the most important trace elements in animal nutrition. Mobility of Co is intermediate that is controlled mainly by adsorption and co-precipitation with Fe and Mn oxides. Using the median value from the frequency distribution of box and whisker plot drawn for Co as shown in Figure 11, it is inferred that the northeast monsoon has a higher concentration distribution in eastern transect. It is observed that the Co value in the correlation matrix (Tables 2a–d) for four different seasons are in a decreasing order as NE < winter < summer < SW. Overall, it has a negative correlation with the population of ostracoda. In the middle segment, this is being confirmed as per Al-Shawafi et al. (2009).

### 4.11. Chromium

Cr concentration in eastern transect ranges from 0.4 to 224.6 mg/L; the lowest value being recorded during summer season at 8th station and highest value being recorded during winter season at 3rd station. Average Cr concentration ranges in NE monsoon 60.3 mg/L, winter season 78.9 mg/L, summer season 66.6 mg/L and southwest monsoon 63.6 mg/L. Chromium $3^+$ can substitute for $Mg_2^+$ and $Fe_3^+$. However, the distribution of these elements in rock forming minerals is further complicated by its ability to form independent Cr minerals such as chromium member of the spinel group, which often occurs in basic rocks (Rankama and Sahama, 1950). If chromite is present in parent rocks, it occurs along with Fe oxides in normal soils. Previous reports are from Indian coast by Achyuthan et al. (2002) from Mahabalipuram (62–108 mg/L); by Jonathan and Ram Mohan (2003) from Gulf of Mannar (62–108 mg/L). Using the median value from the frequency distribution of box and whisker plot drawn for Cr in Figure 12, it is inferred that the winter season has a higher concentration distribution in the study area. Based on the results of Tables 2a–d, it is inferred that the element Cr shows a negative correlation with the total population of ostracoda during all the seasons. In the middle segment, the concentration of Cr lowers which is being reflected in the abundance of ostracoda.

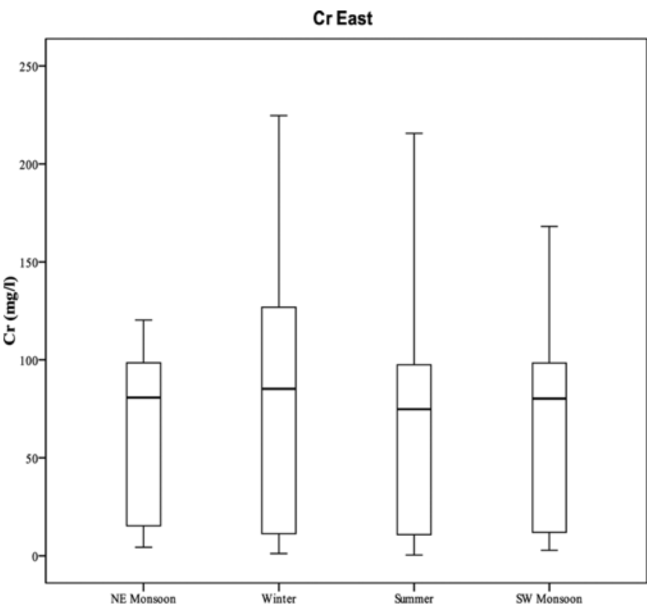


**Fig. 12.** Variation of chromium (Cr) concentration in different season.

## 5. CONCLUSION

The order of abundance regarding the concentration of trace elements in the study area is Al > Fe > Mn > Cr > Ni > Zn > Cu > Co > Pb > Cd. The elements, Al, Fe, Mn, Zn, Cu, Pb, Cd, Ni, Co have higher concentrations during Northeast monsoon and the element Cr has a higher concentration during winter season. All the reported elements have a lower concentration during summer. It is concluded that lower the concentration of trace elements higher the total population of ostracoda. Cu shows a positive correlation, but, Fe, Mn, Zn, Pb, Cd, Ni, Co and Cr show a negative correlation with the total population of ostracoda during all the seasons. Al has no considerable correlation with the total population of ostracoda. The population of ostracoda and their correlation is being confirmed in the middle segment apart from the presence of plenty of Corals in the study area.

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