Distribution of Ostracoda in marine and marginal marine habitats off Tamil Nadu and adjoining areas, southern east coast of India and Andaman Islands: Environmental implications

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Ostracods successfully inhabit almost all types of aquatic environment, from deep oceans to brackish water lagoons, estuaries and even freshwater streams, lakes, etc. The major controlling factors governing ostracod population and distribution in estuarine environments and continental shelf zones are water temperature, salinity and substrate. In this paper, the distribution and ecology of marine ostracoda in relation to the environmental parameters such as temperature, salinity, dissolved oxygen of the bottom waters, organic matter, and CaCO$_3$, along with the sand-silt-clay ratio of sediments from the inner shelf sediment region off Karikkattukuppam (near Chennai), off Rameswaram, off Tuticorin and Andaman Islands is discussed. Additionally, similar studies on the brackish water ostracods from the Adyar estuary, Pitchavaram mangroves and Tamiraparani estuary have also been presented. The work pertaining to the statistical parameters of ostracoda such as carapace/valve ratio, ornamentation and grain size to infer the environment of the study area, from the Indian region is also discussed.

[Key words: Ostracoda, Tamilnadu coast, Andaman Islands, ecology, environmental implications]

Introduction

Ostracods are successful inhabitants of almost every aquatic environment, including marine (from deep oceans to shallow seas), brackish water lagoons, estuaries/creeks, mangroves and even freshwater streams, lakes, etc. It is evident from the literature that ostracods from the Recent marine and marginal marine water (brackish water habitat such as estuaries, lagoons, salt marshes, mangroves, etc) off India, are not fully described. India has about 8129 km long coast line, in addition to the estuarine, intertidal, lagoonal and marshy zones, which provide a vast scope for ostracod studies. Despite the fact that there are several papers on the taxonomic studies of Ostracoda from the shelf sediments of east and west coasts of India$^{1-17}$ and sporadic reports$^{18-26}$ from brackish waters of India, no detailed study has yet been carried out to describe distribution and ecology of ostracods from the Indian coastal waters. Hence, this work was carried out to explore the distribution and ecology of ostracoda along the Tamil Nadu coast and Andaman Islands (Fig. 1).

Materials and Methods

A common methodology was adopted for a detailed ecological and systematic study of Recent marine Ostracoda. The bottom sediment and water samples were collected from different localities along the Tamil Nadu coast by using mud grab while water samples were collected from the same locations from the sediment-water interface. The depth of sample collection ranged up to 50 m. The sampling was done once in every three months, for a period of one year, representing the four seasons - October (north-east monsoon), January (winter), April (summer) and July (south-west monsoon). The collections were made every kilometre in a single transect approximately perpendicular to the coastline. The classification proposed by Hartmann & Puri$^{27}$ has been followed for identification and systematic representation. The standard procedures were adopted for the determination of sedimentological (Organic matter, CaCO$_3$ and sand-silt-clay ratio) and water (salinity and dissolved oxygen) parameters.

Distribution of Recent benthic Ostracoda from off Karikkattukuppam (near Chennai)

The area under investigation is off the coast of Karikkattukuppam, near Chennai (Lat. 12°50’ N; Long. 80°16’ to 80°24’ E), in the Bay of Bengal, Chennai-Chingleput District, Tamil Nadu, east coast of India (Fig. 1B). A total of 56 sediment samples...
were collected during four different seasons from water depth range of 4 to 40 m and these were analysed. Mohan et al.\textsuperscript{14} have identified 51 ostracod taxa belonging to 40 genera, 22 families, 3 superfamilies, and 2 suborders of the order Podocopa, off Karikattukuppam. Among these, 2 species belong to suborder Platyopoda and the remaining to suborder Podocopa. They reported four new species namely, \textit{Hemitrachyleberis siddiquii}, \textit{Puricythereis whatleyi}, \textit{Neocythromorpha reticulata} and \textit{Pterigocythereis chennaiensis}. They\textsuperscript{15} have also observed that salinity, water depth and calcium carbonate content control the overall abundance and distribution of ostracode populations in this region. They further noticed that living/total population sizes are found to be more during April than July which is attributed to the high temperature, salinity, and dissolved oxygen of the bottom waters.

Of the 51 ostracod species identified off Karikkattukuppam, 8 (\textit{Actinocythereis scutigera} (Brady), \textit{Bairdopipilata} (B.) aclyonica Maddocks, \textit{Callistocythere flavidofusca intricatoides} (Ruggeri), \textit{Cytherelloidea leroyi} Keij, \textit{Keijella reticulata}, \textit{Loxoconcha gruendeli} Jain, \textit{Loxoconcha mandviensis} Jain, \textit{Tanella gracilis} Kingma) are regarded as widespread and abundant species, since they have been reported from \( \geq 75\% \) and more number of samples (i.e. \( \sim 42 \) samples out of the 56) out of the 56 samples. These 8 species were present during all the four seasons.

**Distribution of Recent benthic Ostracoda from off Rameswaram**

The area under investigation is off the coast of Rameswaram (Lat. 9°15’ - 9°17’ N; Long. 79°19’ to 79°35’ E), in the Palk Bay, Tamil Nadu (Fig. 1C). Sridhar et al.\textsuperscript{16} have illustrated 48 Ostracode species from Palk Bay, off Rameswaram and studied their ecology and observed that siltsand and sand are the favourable substrates for the ostracodes to thrive in the sediments of Palk Bay, off Rameswaram. They also deduced a relatively faster rate of sedimentation in the inner-shelf off Rameswaram based on the occurrence of carapace to valve ratio (Carapaces 80.45% and Open valves 19.55%, out of 8264 specimens). Further, they also recorded three species namely \textit{Kotoracythere inconspicua}, \textit{Neocytheretta snellii} and \textit{Paradoxstoma subtile} for the first time from this region. Out of 48 taxa recorded from off Rameswaram, six (\textit{Loxoconcha illjeborgii}, \textit{Mutilus pentoeakensis}, \textit{Neocytheretta murilineata}, \textit{Neomonoceratina iniqua}, \textit{Tanella gracilis} and \textit{Xestoleberis variegata}) are abundant. The population size of all these six species exceeds 62\% of the total population size during the seasons namely,
January: 63.65%, April: 65.28%, July: 62.62% and October 63%.

**Distribution of Recent benthic Ostracoda from off Tuticorin**

Hussain\(^{11}\) for the first time gave a detailed systematic account of 52 ostracod species along with their ecological preferences, from the sediments of Gulf of Mannar, off Tuticorin, along the east coast of India. He (op. cit.), after making a seasonal study of different environmental parameters and ostracod population size, discussed the ostracode distribution in relation to ecological factors. Hussain et al.\(^{12}\) reported two new species namely, *Triebelina tutitcorensis* and *Hemicytheridea khoslati* from off Tuticorin. Hussain et al.\(^{33}\) discussed the temporal and spatial distribution of the following 8 persistent taxa and presented the ecology: *Carinocythereis hamata*, *Cytherelloidea leroyi*, *Loxocorniculum tilljeborgii*, *Mutilus pentoekensis*, *Neocytheretta murilineata*, *Neomonoceratina iniqua*, *Tanella gracilis* and *Xestoleberis variegata*. This paper is considered to be a significant contribution towards the beginning of ecological studies of ostracodes from the coast off Tamil Nadu.

**Distribution of Recent benthic Ostracoda from the coast of Andhra Pradesh coast**

Naidu et al.\(^{10}\) presented the diversity and distribution of Recent Ostracoda from the shelf sediments off Pentakota and Kalingapatnam, near Visakhapatnam. Varma et al.\(^{26}\) recorded 25 ostracod taxa from the Tekkali Creek, east coast of India, which included three new species - *Hemicytheridea bhatiai*, *Loxoconcha tekkaliensis* and *Neomonoceratina jaini*. They (op. cit.) recorded *Neosinocythere dekrooni* and *Paijenborchella (Eopaijenborchella) malaiensis* for the first time from Indian waters. Shyam Sunder et al.\(^{21}\) reported 33 species of Recent Ostracoda from the Goguleru Creek and adjacent beaches of the east coast of India. These included 5 new species: *Copytus coromandalensis*, *Loxoconcha guhai*, *Neocytheromorpha gaguleruensis*, *Paijenborchella keiji* and *Paradoxostoma bhatiai*. They (op. cit.) also recorded *Keijia demissa* for the first time from Indian waters. Bhandari and Singh\(^{7}\) recorded 24 ostracod species belonging to 14 genera from the Krishna river estuary and Gautami-Godavari estuary and discussed the ostracode abundance and diversity in the upper and lower estuaries. Very little work has been carried out on the marine and marginal water Ostracods from the coast off Andhra Pradesh.

**Distribution of Recent benthic Ostracoda in Adyar river estuary and Pitchavaram mangroves area**

A preliminary study has been carried out on the brackish water ostracodes of Tamil Nadu. A review of the same has been given here. Hussain & Mohan\(^{23,24}\) have reported 26 species from the Adyar river estuary. Further, they inferred the fast rate of sedimentation in the estuary using the carapace to valve ratio. Kumar & Hussain\(^{22}\) reported for the first time 10 ostracod species from Pitchavaram mangroves, Tamil Nadu. A total of twenty-nine species have been diagnosed and illustrated from the sediments of Pitchavaram mangroves along with its ecological conditions by Arul et al.\(^{25}\).

**Distribution of Recent benthic Ostracoda in Tamiraparani estuary, near Tuticorin**

Samples were collected twice in a year representing pre-monsoon (July, 2003) and post-monsoon (January, 2004) periods from the Tamiraparani river estuary (8°36′37″ - 8°40′00″ N and 78°06′28″ - 78°08′37″ E), near Tuticorin, Tamil Nadu (Fig. 1D). In each season, 22 estuarine samples were collected. Simultaneously, water samples have also been collected for water analysis.

**Brackish water ostracods of Tamiraparani estuary**

Various sedimentological parameters such as organic matter, CaCO\(_3\) and bottom water parameters like temperature, salinity and dissolved oxygen have been measured (Tables 1, 2). The total ostracode population vary from 2922 to 3850, the minimum during premonsoon while the maximum has been witnessed during the postmonsoon (Fig. 2). This is attributed to lower and higher values of organic matter during pre-monsoon and post-monsoon periods, respectively. Similar trend is noticed for the population in relation to calcium carbonate content in the estuary as well as shelf. Population size in the estuary is generally found to be directly proportional to the calcium carbonate content. The sand-silt-clay ratios were estimated and siltysand, sandy substrates have been found in the study area. In the Tamiraparani estuary, it was observed that the population of living as well as total ostracod specimens are on the higher side when the temperature is more. From the overall distribution of
the fauna in the present area, it may be observed that the temperature condition is within the tolerance limit for the fauna throughout the year.

The organic matter content in the sediments of Tamiraparani estuary shows a range from 0.33 to 4.68%. In the estuary, the lowest value was recorded at station 7 during pre-monsoon and the highest value at station 16 during pre-monsoon. In the present area, it has been found that the calcium carbonate percentage in the estuarine sediments vary from 0.5% to 10.8%, the maximum at station 6 during pre-monsoon, and the minimum at station 2 during pre-monsoon. The relative abundance of sand, silt and clay in the sediments from each of the 22 stations for the two seasons of the year has been estimated. Taking into consideration the 12 possible sediment types of Trefethen, the substrate of the estuarine samples for the year under study consists mainly of sand, followed by siltsand, sandsilt and silt. The temperature range observed at the 38 stations during both seasons in the estuary are as follows: Premonsoon, 2003, 28 to 31°C; Postmonsoon, 2004, 25.6 to 29.5°C. Salinity has proved to have a direct effect on the number of species and abundance of specimens in marine and marginal marine environments. The salinity values of the estuarine water range from 19.82 to 31.3‰. Here, the salinity values do not show any appreciable variation amongst the stations during a season. The average salinity value is higher during premonsoon (summer), which is very similar to that during postmonsoon. In the present area, it has been observed that the living Ostracoda population is more during premonsoon

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**Table 1—Sediment and bottom water parameters along Tamil Nadu coast**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Study area</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Depth (m)</th>
<th>Substrate</th>
<th>CaCO$_3$ (%)</th>
<th>Org.Mat. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>09°15’N–</td>
<td>72°09’E–</td>
<td>&lt;1 to 43</td>
<td>Sand, silty sand and clay sand</td>
<td>20.5 to 35.5</td>
<td>0.135 to 0.845</td>
</tr>
<tr>
<td>2</td>
<td>Tuticorin</td>
<td>08°47’N</td>
<td>78°10’E–</td>
<td>0.5 to 20</td>
<td>Sand, silty sand, sandy silt, clay sand</td>
<td>18.0 to 32.0</td>
<td>0.103 to 2.72</td>
</tr>
<tr>
<td>3</td>
<td>Tamiraparani estuary</td>
<td>08°36’N–</td>
<td>78°06’E–</td>
<td>0.5 to 24</td>
<td>Sand, silty sand, sandy silt and silt</td>
<td>1.1 to 9.9</td>
<td>0.5 to 4.676</td>
</tr>
<tr>
<td>4</td>
<td>Karikkattukuppam</td>
<td>12°50’N</td>
<td>09°15’– 09°17’N</td>
<td>7 to 55</td>
<td>Sand, silty sand, sandy-silt &amp; silt</td>
<td>2.5 to 7.2</td>
<td>0.36 to 3.5</td>
</tr>
</tbody>
</table>

**B) Bottom water parameters**

<table>
<thead>
<tr>
<th></th>
<th>Temperature (°C)</th>
<th>DO (ml/l)</th>
<th>Salinity (ppt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26.4 to 32.6</td>
<td>3.0 to 6.5</td>
<td>30.0 to 35.2</td>
</tr>
<tr>
<td>2</td>
<td>26.0 to 33.5</td>
<td>6.1 to 7.1</td>
<td>33.7 to 34.9</td>
</tr>
<tr>
<td>3</td>
<td>25.6 to 31.0</td>
<td>3.616 to 8.136</td>
<td>19.8 to 31.3</td>
</tr>
<tr>
<td>4</td>
<td>25.2 to 28.6</td>
<td>2.68 to 8.73</td>
<td>31.11 to 35.81</td>
</tr>
</tbody>
</table>

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**Fig. 2**—Histogram showing the living and total (living+dead) ostracod population in the Tamiraparani estuary, near Tuticorin, Tamil Nadu.
Table 2a—Sedimentological characters and living and total (living+dead) population (actual number of specimens) per unit volume (25 ml wet sediment) in Tamiraparani estuary during pre-monsoon period (2003).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Station No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>2.6</td>
</tr>
<tr>
<td>CaCO₃ (%)</td>
<td>5.2</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>1.50</td>
</tr>
<tr>
<td>Sand content (%)</td>
<td>88.33</td>
</tr>
<tr>
<td>Silt content (%)</td>
<td>10.67</td>
</tr>
<tr>
<td>Clay content (%)</td>
<td>1</td>
</tr>
<tr>
<td>Total population</td>
<td>105</td>
</tr>
<tr>
<td>Living population</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2b—Sedimentological characters and living and total (living+dead) population (actual number of specimens) per unit volume (25 ml wet sediment) in Tamiraparani estuary during post-monsoon period (2004).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Station No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>2.6</td>
</tr>
<tr>
<td>CaCO₃ (%)</td>
<td>5.8</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>1.82</td>
</tr>
<tr>
<td>Sand content (%)</td>
<td>84.17</td>
</tr>
<tr>
<td>Silt content (%)</td>
<td>11.83</td>
</tr>
<tr>
<td>Clay content (%)</td>
<td>4</td>
</tr>
<tr>
<td>Total population</td>
<td>163</td>
</tr>
<tr>
<td>Living population</td>
<td>21</td>
</tr>
</tbody>
</table>
season. Some ostracod species characteristic of brackish water such as *Darwinuala stevensoni*, *Ilyocypris gibba*, *Jankeijcythere mckenziei* and *Kalingella mckenziei* occur in the estuary.

Production of oxygen by dense extensive patches of benthic algae in shallow environments could be significantly high whereas low oxygen content may occur due to the decomposition of organic matter and comparatively higher percentage of silt content in the bottom sediment. Most of the marine and brackish water organisms are physiologically well adapted to large variations in oxygen concentration.

The range of dissolved oxygen at 22 stations of estuary, during each season, is as follows. Premonsoon: 3.616 to 8.136 ml/l; Postmonsoon: 4.05 to 6.3 ml/l. The increase in the dissolved oxygen content coincides with the total population in the estuary. In this area, the dissolved oxygen content of the bottom water is directly proportional to the total ostracod population size during both the seasons, under consideration. Hence, it is believed that dissolved oxygen content may be one of the important factors governing the standing crop, and it may be concluded that higher dissolved oxygen may be congenial for the ostracode abundance in the study area.

**Distribution of Recent benthic Ostracoda in tsunami sediments along the coast of Andaman Islands**

While presenting the data on ostracodes of Tamil Nadu coast, an attempt has also been made to know the provenance of the tsunamigenic sediments along the coast of Andaman Islands.

The earthquake which occurred on 26th December, 2004 (Sunday), with a magnitude of 9.1 on the Richter scale in the Indian Ocean, triggered a tsunami which damaged and destabilised the coastal areas of Southeast Asia including Indonesia, Sri Lanka, Andaman and Nicobar Islands and East coast of India. These tsunami waves might have transported and redeposited enormous amount of comparatively deep water sediments on the beaches and coasts of these regions.

In order to understand the type of microfauna (foraminifera and ostracoda) which might have been carried along with tsunami sediments deposited on the beaches, estuaries/creeks and mangrove locations of Andaman Islands, a detailed field work has been carried out from these islands and the results were published. A brief outcome of the study is presented here. A total of 87 species belonging to 74 genera of foraminifera and 29 species belonging to 22 genera of ostracoda have been encountered. Among foraminifera, *Assilina ammonoides*, *Amphistegina radiata* and *Calcarina* sp. are widely distributed. Most of the forms are highly to moderately abraded and they are milky white in colour. However, the Ostracod population is scantly, and only *Macrocyprina* sp. is a comparatively deeper dwelling form. Ostracod fauna is reported for the first time from the Recent sediments of Andaman Islands. All the forms recorded in the study area preferably thrive in the shallow inner shelf (neritic) zone. From their distribution, it is inferred that the tsunamigenic sediments deposited on the coastal landforms have been derived from the shallow littoral to neritic region and not from deeper bathyal waters.

**Quantitative (carapace/valve ratio, ornamentation and grain size) studies on Ostracoda**

The carapaces of few ostracods have smooth surface and is devoid of any sculpture. However, in many species, the carapace has simple to complex surface ornamentation. Hence, surface ornamentation serves as direct evidence for ecological interpretations. Few workers studying ostracodes from the Indian regions briefly discussed the relationship between the sculpture in Ostracoda and grain size of the substrate based on direct observations with the help of Scanning Electron Microscope (SEM) photographs of the specimens. The surface sculptures of ostracod carapaces have a direct relationship with the substrate type. In the Bimili backwaters and Balacheruvu tidal stream, near Visakhapatnam, southcentral coast of India, Annapurna and Rama Sarma noticed that the genus *Phlyctenophora* occurs in sand dominated areas and not in muddy areas. They further noticed that the moderately ornamented forms like *Tanella*, *Loxoconcha*, *Paijenborchellina* and *Kalingella* occur in considerable numbers in sandy areas. Vaidya et al. observed more number of ostracod in substrates consisting of medium to fine-grained sand, whereas poor presence was noticed in clean, coarse-grained sand. Sridhar et al. found more number of species in siltsand and sandy substrates, and less in finer materials. They further observed that forms like *Macrocyprina decorata*, *Paracytheroma ventroisinousa*, *Phlyctenophora orientalis*, *Keijella karwarensis* and...
Paracypris sp. occur in considerable numbers in the samples with a mixture of clayey sand and clayey silt, thus indicating that smooth forms occupy fine-grained sediments. Similar observations have also been made from off Karikkattukuppam.

C/V ratio along east and west coasts of India

During the last two decades, the application of statistical data on Ostracoda, such as juveniles and adults, closed and isolated valves, males and females, right and left valves, smooth and ornamented forms etc, besides colour variation, pyritization and predation has attained importance especially with regard to interpretation of the environment of deposition, rate of deposition and assessment of potentiality of sediments as source rocks for hydrocarbons. Guha, while dealing with the prospective of Bombay High and Cambay basins of India for hydrocarbon potential, stressed the need of above mentioned factors to make use of various applications of ostracods.

Pokorny pioneered the application of carapace-valve ratio to yield paleoecological information. Oertli reviewed Pokorny's work and related the carapace-valve ratio as potential tool for the information on hydrocarbons. He summarized that when the ratio is high, sedimentation is rapid, which minimizes disarticulation of carapaces into separate valves. With sufficiently rapid burial, organic matter is not absorbed by mineral particles and so retains potential for conversion into hydrocarbons. Honnappa & Venkatalathathy studied the carapace-valve ratio to interpret the rate of deposition of sediments in the Mangalore harbour area, southwest coast of India. They found that the occurrence of open valves is much more in number than the closed ones (ratio being 24:1). According to them, this is indicative of a slow rate of sedimentation in more agitating waters. While comparing Eocene/Oligocene ostracods from southeastern Australia and India for petroleum potential indicators, a rapid rate of sedimentation is noticed based on high percentage of carapaces. Similarly, rapid rate of sedimentation is observed in Pulicat Lake estuary on the basis of occurrence of more number of closed carapaces. Hussain and Rajeshwara Rao observed more number of closed carapaces than open valves along the east coast of inner shelf sediments, while the number is much less from the sediments off the west coast of India. From this observation, they inferred that the rate of sedimentation is rapid on the east coast but slow on the west coast of India and attributed this to more number of streams/rivers flowing and debouching the sediments into the Bay of Bengal. Hussain et al. studied carapace and valve ratio and noticed faster rate of sedimentation in the inner shelf of Gulf of Mannar, off Tuticorin, southeast coast of India. They counted four-fold occurrence of carapaces to open valves, which was attributed to the inflow of sediments through Tamirabarani river. A moderately slow rate of sedimentation prevails in the inner shelf region off Karikkattukuppam, near Chennai. An analysis of the ratio between the carapaces and valves (10:1) indicates a faster rate of sedimentation that prevailed in Tamiraparani estuary region.

Conclusion

This paper deals with the occurrence of Ostracoda from the marine and marginal environments off Tamil Nadu coast and adjoining areas. The detailed systematic studies of these tiny crustaceans carried out along the coasts of Tamil Nadu and Andhra Pradesh have been reviewed. Ecology of ostracodes has been presented for the Karikkattukuppam, Rameswaram and Tamirparani estuary along the east coast. From the study, it is observed that salinity, water depth and calcium carbonate content control the overall abundance and distribution of ostracode populations in these regions. It is further noticed that living/total population size is found to be more during April collection (summer season) which is attributed to the high temperature, salinity and dissolved oxygen of the bottom waters. The accommodative substrate for the better thriving of the ostracodes in these regions is found to be silty sand. The ecological details of the ostracod fauna will be helpful to study the paleoecological aspects of the older sediments. From the study it is understood that a vast majority of the area is still unstudied with respect to ostracod fauna.

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