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# RECENT OSTRACOD BIODIVERSITY FROM SHELF TO SLOPE SEDIMENTS OF GULF OF MANNAR, INDIA: ECOLOGIC AND BATHYMETRIC IMPLICATIONS

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## ABSTRACT

The present study has been focused to create the baseline data for the distribution and biodiversity of Ostracoda from the continental shelf to slope sediments of Gulf of Mannar. For the purpose, 5 short core samples were collected through multi-corer, ranged in water depth from 58 m to 1887 m (shallow to deep-marine water) during Cruise SSD-004 (ORV Sindhu Sadhana). A total of 4355 ostracod specimens were recovered, belonging to 82 species and 51 genera. Of these, 14 species were recorded for the first time from the Indian waters. Bathymetric distribution of Ostracoda in all the five multi-core samples are studied, in which *Propontocypris bengalensis,* a species that is dominantly present in shallow water region (MC-8). Species of *Krithe* recorded only in deeper water regions (MC-2 and MC-60). *Xestoleberis* sp. and *Paracypris* sp. are the only species which were present from the continental shelf to slope sediments of Gulf of Mannar. The faunal carapaces are fresh, shiny, and not pyritised. The ornamentation on the carapaces changes gradually in accordance with the sediments that grades from coarse to fine towards the deeper water and the population of ostracod also varies from shallow to deeper water sediments. Core-wise distributions of ostracods species, ecological implications and species diversity have also been discussed.

**Keywords:** Recent Ostracoda, Biodiversity, Bathymetry, Gulf of Mannar.

## INTRODUCTION

Deep-sea ostracods are distinctly different from the shelf and marginal marine taxa. In recent years, a lot of research works on taxonomy, distribution and ecology of Ostracoda have been carried out in the International marine environment including Atlantic, Pacific, Indian and Arctic Oceans (Gengo, 2016; Luz and Coimbra, 2015; Yasuhara *et al*., 2014; Hokuto *et al*., 2014; Dewi, 2014; Stepanova and Lyle, 2014; Noraswana *et al*., 2014; Piazza *et al*., 2014; Andrei and Gabriel, 2014; Yasuhara *et al*., 2012; Julio and Francisco, 2012; Lili *et al*., 2012; Theodora, 2012; Jessica *et al*., 2007; Mostafawi *et al*., 2005; Yasuhara and Irizuki, 2001). Comparatively, similar research works are few in number from the Indian sub-continental region (Mohammed *et al.,* 2017; Hussain and Kuleen, 2016; Mohammed *et al.,* 2015; Baskar *et al.*, 2015; Baskar *et al*., 2013; Hussain *et al.,* 2009; Gopalakrishna *et al*., 2007; Hussain *et al.*, 2006; Sridhar *et al.,* 2002; Hussain, 1998). The available literature reveals that only a few research works on ostracods from marginal marine and shelf environments have been carried out to understand the faunal diversity, their relationship to the substrate, and also with other ecological parameters. Also, the literature available on ecology and taxonomy of deep-sea Ostracoda from the Indian sub-continent is insufficient. Hence, the present work has been carried out in a different point of view, namely, horizontal and vertical distribution of ostracods from the shallow to deep marine environmental conditions of Gulf of Mannar which provides a baseline data for the study area.

## REGIONAL SETTING

Gulf of Mannar is made up of an alternative series of horst-graben structures resulting in ridges and basins with a trend NNE-SSW to NE-SW, EW and N-S directions. These faults were clear evidence of neotectonism due to strike-slip and vertical movements (Gopalakrishnan *et al*., 2008). The ocean currents possess tidal amplitude about half a meter in the Gulf of Mannar (Ramesh *et al*., 2008). Prevalence of monsoons are well experienced in the Gulf of Mannar, especially the higher intensity of Northeast monsoon. There are two courses of drift in water currents seen in Gulf of Mannar, between April to September the movement is from South to North and vice-versa in October to December (Chacko, 1950). Throughout the coast occurs, a 10 to 12 km wide narrow band of Cenozoic sedimentary formations such as Tertiary carbonates and recent sediments. Domination of riverine processes marked the southern part of the Gulf of Mannar (Stoddart and Gopinatha, 1972; Rajamanickam and Loveson, 1990; Banerjee, 2000).

## MATERIALS AND METHODS

In the present study, 5 multi-core samples were collected at various water depths (Fig. 1) such as 58 m, 215 m, 510 m, 1235 m and 1887 m during Cruise SSD004 (ORV Sindhu Sadhana). The multi-corer with transparent tubes (50 cm in length) was used to collect sediment samples. In addition to sediments, sufficient clear undisturbed water was recovered on the top of the multicorer tubes. The water was syphoned off and the water parameters such as temperature, salinity and dissolved oxygen were measured immediately onboard by using scientific probes (Table 1). All the five core samples are sub-sampled at an interval of 3 cm and thus, totally 61 sub-samples were obtained. Ten gram of each sub-sample was taken for micropaleontological studies. Samples were washed through ASTM 63 sieve and studied under a stereo-binocular microscope. The observed specimens were then sorted at the species level to determine adult and juvenile

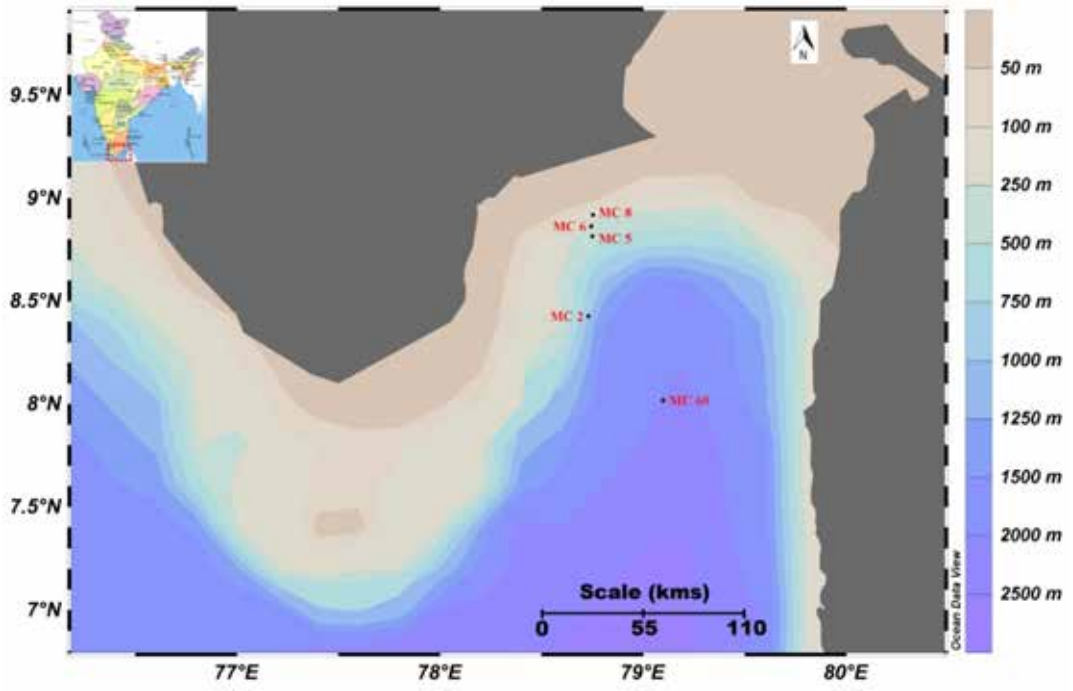


Fig. 1. Map showing sample locations from Gulf of Mannar, India.

Table 1. Core details with water parameters for the sampling locations.

| Multicore | Water Depth (m) | Core Length (cm) | BW Temp (ºC) | BW Salinity (psu) | BW DO (mg/l) |
|---|---|---|---|---|---|
| MC-8 | 58 | 26 | 25.20 | 35.66 | 4.07 |
| MC-6 | 215 | 45 | 18.70 | 35.07 | NA |
| MC-5 | 510 | 30 | 16.10 | 35.14 | NA |
| MC-2 | 1235 | 45 | 13.70 | 35.20 | 2.35 |
| MC-60 | 1887 | 35 | 13.00 | 34.26 | NA |

*BW- Bottom water
NA- Data not available

assemblages. A detailed account of the bathymetric distribution of ostracod and its biodiversity are discussed in the following content.

## RESULTS AND DISCUSSION

### Bathymetric distribution of Ostracoda

The purpose of the distributional study is to unravel meaningful patterns of any organisms in association with the surrounding environment. Ostracod species distribution in an area is controlled primarily by ecological parameters such as salinity, temperature, oxygen availability and substrate type (Horne and Boomer, 2000). In addition to ecological parameters, water depth also plays a significant role in ostracods distribution. In the present study, a total of 51 genera and 82 ostracod species have been recorded from 61 sub-samples. The following 14 species were recorded for the first time from the Indian sub-continent (Plate I) namely, *Caudites exmouthensis, Cytherella posterotuberculata, Cytherelloidea excavata, Cytherois paratubipensifora, Cytheropteron miurense, Cytheropteron volantium, Hemicytheridea ornata, Lankacythere elaborata, Loxoconcha abdicostata, Loxoconcha paiki, Paradoxostoma caudatum, Paranesidea conulifera, Phlyctocythere pellucida* and *Stigmatocythere parakingmai.* Bathymetric occurrence of ostracods from all five multi-core samples is discussed in the following content (Table 2).

The continental shelf sediments include MC-8 and MC-6 records more population than the other 3 continental slope cores. In MC-8, a total of 1828 ostracod specimens belong to 68 species and 44 genera were numerically counted from 9 sub-samples. Out of 68 species, the following 24 species viz., *Bythoceratina mandviensis, Caudites exmouthensis, Caudites javana, Cytherella hemipunctata, Cytherelloidea excavata, Cytherelloidea leroyi, Cytheropteron miurense, Hemicytheridea reticulata, Keijella reticulata, Leptocythere* sp., *Loxoconcha abdicostata, Loxoconcha paiki, Loxoconcha* sp., *Mutilus pentoekensis, Mutilus splendideornatus, Neocytheromorpha reticulata, Neonesidea elegans, Paracytheridea pseudoremanei, Paranesidea conulifora, Paranesidea fracticorallicola, Propontocypris bengalensis, Propontocypris crocata, Spinoceratina spinosa* and *Xestoleberis variegata* were encountered persistently in all the sub-samples of MC-8. Of these,

## EXPLANATION OF PLATE I

Figs. 1, 1a. ***Caudites exmouthensis,*** RV external view, Figs. 2. ***Cytherella posterotuberculata,*** RV external view, Figs. 3. ***Cytherelloidea excavata,*** RV external view, Figs. 4. ***Cytherois paratubipensifora,*** LV external view, Figs. 5. ***Cytheropteron miurense,*** dorsal view, Figs. 6. ***Cytheropteron volantium,*** LV external view, Figs. 7. ***Hemicytheridea ornata,*** RV external view, Figs. 8. ***Lankacythere elaborata*** LV external view, Figs. 9. ***Loxoconcha abdicostata,*** LV external view, Figs. 10. ***Loxoconcha paiki,*** LV external view, Figs. 11. ***Paradoxostoma caudatum,*** RV external view, Figs. 12. ***Paranesidea conulifera,*** LV external view, Figs. 13. ***Phlyctocythere pellucida,*** RV external view, Image 14. ***Stigmatocythere parakingmai*** LV external view.

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Plate I

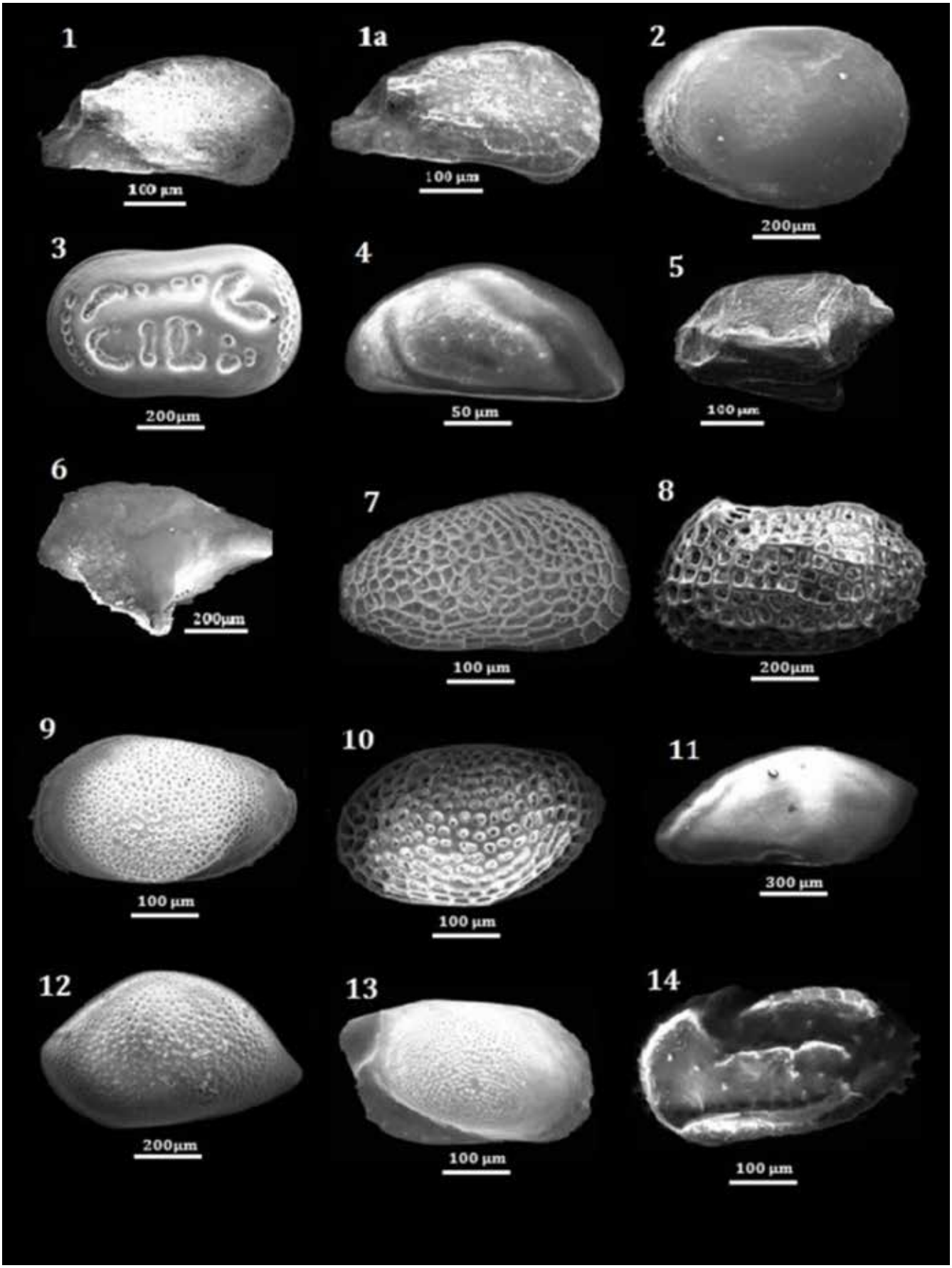

Table 2. Bathymetric occurrence of Ostracod species from the study area.

| Sl. no | Species Name | MC-8 (58 m) | | MC-6 (215 m) | | MC-5 (510 m) | | MC-2 (1235 m) | | MC-60 (1887 m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | J | A | J | A | J | A | J | A | J |
| 1. | *Acanthocythereis* sp. | | | 4 | 2 | | | 7 | 5 | | |
| 2. | *Actinocythereis scutigera* (Brady) 1868 | 18 | 8 | 7 | 2 | | | | | | |
| 3. | *Actinocythereis* sp. | 2 | 0 | 4 | 0 | | | 9 | 0 | | |
| 4. | *Alocopocythere kendengensis* (Kingma) 1948 | | | 14 | 1 | | | | | | |
| 5. | *Alocopocythere reticulata indoausralica* Hartmann, 1978 | | | 227 | 19 | 3 | 0 | | | | |
| 6. | *Argilloecia* sp. | 6 | 0 | 10 | 3 | 5 | 4 | 7 | 0 | | |
| 7. | *Bairdoppilata alcyonicola* Maddocks, 1969 | 15 | 13 | 23 | 7 | | | | | | |
| 8. | *Bairdoppilata* sp. | 27 | 5 | 31 | 8 | | | 3 | 0 | | |
| 9. | *Bradleya andamanae* Benson, 1972 | 10 | 2 | 9 | 0 | 5 | 0 | 3 | 0 | | |
| 10. | *Bradleya japonica* Benson, 1972 | | | | | 15 | 13 | 10 | 4 | 6 | 0 |
| 11. | *Bradleya* sp.1 | 20 | 6 | 5 | 1 | 7 | 2 | | | | |
| 12. | *Bradleya* sp.2 | 13 | 1 | 5 | 0 | 13 | 6 | | | | |
| 13. | *Bythoceratina mandviensis* Jain, 1978 | 36 | 9 | 14 | 7 | 0 | 1 | 6 | 1 | | |
| 14. | *Bythoceropteron* sp. | 11 | 5 | 161 | 14 | | | | | | |
| 15. | **Caudites exmouthensis* Hartmann, 1978 | 32 | 4 | 10 | 2 | | | | | | |
| 16. | *Caudites javana* Kingma, 1948 | 42 | 3 | 16 | 1 | | | | | | |
| 17. | *Cytherella hemipuncta* Swanson, 1969 | 38 | 3 | 9 | 0 | 7 | 0 | 3 | 0 | | |
| 18. | **Cytherella posterotuberculata* Kingma, 1948 | 8 | 3 | 3 | 0 | 2 | 1 | | | | |
| 19. | *Cytherella semitalis* Brady, 1868 | 26 | 5 | 11 | 2 | 0 | 1 | 3 | 1 | | |
| 20. | **Cytherelloidea excavata* Mostafawi, 1992 | 35 | 8 | 12 | 6 | | | | | | |
| 21. | *Cytherelloidea leroyi* Keij, 1964 | 49 | 13 | 14 | 1 | | | | | | |
| 22. | **Cytherois paratubipensifora* Whatley and Keeler, 1989 | 8 | 4 | 4 | 2 | 1 | 0 | | | | |
| 23. | **Cytheropteron miurense* Hanai, 1957 | 26 | 8 | 10 | 2 | | | | | | |
| 24. | *Cytheropteron* sp.1 | 16 | 8 | 151 | 21 | 10 | 13 | 3 | 2 | | |
| 25. | *Cytheropteron* sp.2 | | | 6 | 0 | 7 | 12 | 4 | 1 | | |
| 26. | **Cytheropteron volantium* Whatley and Masson, 1979 | 14 | 5 | 76 | 20 | 25 | 0 | 7 | 2 | | |
| 27. | *Echinocythereis* sp. | 4 | 0 | 10 | 1 | | | 3 | 0 | | |
| 28. | *Falsocythere maccagnoi* Ciampo, 1971 | 7 | 2 | 9 | 2 | | | | | | |
| 29. | *Gambiella caelata* Witte, 1985 | 4 | 0 | 23 | 3 | 12 | 5 | | | | |
| 30. | **Hemicytheridea ornata* Mostafawi, 1992 | 23 | 0 | 10 | 0 | 0 | 1 | 0 | 4 | | |
| 31. | *Hemicytheridea reticulata* Kingma, 1948 | 30 | 11 | 13 | 2 | 2 | 0 | | | | |
| 32. | *Hemicytherura* sp. | 8 | 7 | 5 | 2 | | | | | | |
| 33. | *Hemitrachyleberis siddiqui* Mohan *et al*., 2001 | 7 | 1 | 7 | 0 | | | | | | |
| 34. | *Henryhowella* sp. | 0 | 1 | | | 6 | 0 | 11 | 0 | | |
| 35. | *Keijella karwarensis* Bhatia and Kumar, 1979 | 10 | 1 | 11 | 3 | 0 | 2 | 2 | 0 | | |
| 36. | *Keijella reticulata* Whatley and Zhao, 1988 | 28 | 2 | 12 | 5 | | | | | | |
| 37. | *Keijella* sp. | 19 | 2 | 13 | 2 | 14 | 16 | | | | |
| 38. | *Krithe kroemmelbeini* Jain, 1978 | | | | | 4 | 0 | 15 | 3 | 7 | 0 |
| 39. | *Krithe* sp.1 | | | | | | | 22 | 2 | 11 | 0 |
| 40. | *Krithe* sp.2 | | | | | | | 12 | 2 | 7 | 0 |
| 41. | **Lankacythere elaborata* Whatley and Zhao, 1988 | 22 | 5 | 17 | 0 | 2 | 1 | | | | |
| 42. | *Leptocythere* sp. | 19 | 1 | 12 | 0 | 5 | 1 | | | | |
| 43. | **Loxoconcha abdicostata* Hartmann, 1981 | 57 | 6 | 18 | 3 | | | | | | |
| 44. | **Loxoconcha paiki* Whatley and Zhao, 1987 | 43 | 5 | 7 | 4 | | | | | | |
| 45. | *Loxoconcha* sp. | 30 | 7 | 15 | 1 | | | | | | |
| 46. | *Loxoconchella anomala* (Brady) 1880 | 7 | 2 | 4 | 0 | | | | | | |
| 47. | *Macrocyprina* sp. | 11 | 4 | 6 | 0 | 21 | 10 | 4 | 2 | | |
| 48. | *Mutilus pentoekensis* (Kingma) 1948 | 39 | 11 | 14 | 4 | 2 | 4 | | | | |
| 49. | *Mutilus splendideornatus* Hartmann, 1974 | 42 | 9 | 20 | 2 | 3 | 1 | | | | |
| 50. | *Neocytheromorpha reticulata* Mohan *et al*., 2001 | 72 | 8 | 15 | 1 | | | | | | |
| 51. | *Neonesidea cracenticlavula* Maddocks, 1969 | 13 | 7 | 4 | 3 | | | | | | |
| 52. | *Neonesidea elegans* (Brady) 1869 | 25 | 19 | 23 | 4 | | | | | | |
| 53. | *Ornatolebris morkhoveni* Keij, 1975 | 8 | 2 | 11 | 0 | | | | | | |
| 54. | *Pacombocythere* sp. | | | 2 | 0 | 6 | 4 | 6 | 3 | 1 | 0 |
| 55. | *Paijenborchella malaiensis* Kingma, 1948 | | | 8 | 0 | 18 | 12 | 10 | 1 | | |
| 56. | *Paijenborchella* sp. | | | 9 | 0 | 10 | 0 | 6 | 0 | 4 | 0 |
| 57. | *Paijenborchellina prona* Lyubimova *et al*., 1960 | | | 6 | 1 | 0 | 17 | 3 | 1 | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 58. | *Paracypris* sp. | 9 | 1 | 4 | 0 | 5 | 1 | 5 | 2 | 1 | 0 |
| 59. | *Paracytheridea pseudoremanei* Bonaduce *et al.,* 1980 | 21 | 5 | 10 | 2 | 3 | 1 | 5 | 0 | | |
| 60. | *Paradoxostoma bhatiai* Shyam Sundar *et al.*, 1995 | 15 | 3 | 9 | 1 | 3 | 0 | | | | |
| 61. | **Paradoxostoma caudatum* Hartmann, 1974 | | | 6 | 0 | 2 | 0 | | | | |
| 62. | *Parakrithella* sp. | | | | | 1 | 0 | 8 | 1 | 6 | 0 |
| 63. | **Paranesidea conulifora* Bonaduce *et al*., 1976 | 16 | 4 | 6 | 4 | | | | | | |
| 64. | *Paranesidea fracticorallicola* Maddocks, 1969 | 43 | 27 | 12 | 2 | | | | | | |
| 65. | *Paranesidea* sp. | 6 | 2 | 6 | 0 | 3 | 0 | | | | |
| 66. | *Phlyctenophora orientalis* (Brady) 1868 | 10 | 3 | 12 | 2 | 3 | 0 | | | | |
| 67. | **Phlyctocythere pellucida* Mueller, 1894 | 2 | 0 | 3 | 0 | | | | | | |
| 68. | *Pistocythereis* sp. | 21 | 7 | 45 | 9 | 1 | 0 | | | | |
| 69. | *Polycope* sp. | 3 | 0 | 4 | 0 | | | | | | |
| 70. | *Propontocypris bengalensis* Maddocks, 1969 | 57 | 43 | 16 | 2 | 8 | 6 | | | | |
| 71. | *Propontocypris crocata* Maddocks, 1969 | 28 | 29 | 18 | 1 | 2 | 0 | | | | |
| 72. | *Pterygocythereis chennaiensis* Mohan *et al*., 2001 | 14 | 3 | 6 | 0 | | | 5 | 0 | | |
| 73. | *Pterygocythereis* sp. | 9 | 0 | 4 | 0 | | | 3 | 0 | 2 | |
| 74. | *Puricytheris whatlleyi* Mohan *et al*., 2001 | 19 | 1 | 6 | 0 | 2 | 0 | | | | |
| 75. | *Semicytherura contraria* Zhao and Whatley, 1989 | 25 | 7 | 123 | 5 | 5 | 5 | 10 | 0 | | |
| 76. | *Semicytherura* sp. | 8 | 3 | 40 | 2 | | | 2 | 0 | | |
| 77. | *Spinoceratina spinosa* Annapurna and Rama Sarma, 1987 | 72 | 12 | 9 | 1 | | | | | | |
| 78. | *Stigmatocythere kingmai* Whatley and Zhao, 1988 | 19 | 1 | 5 | 1 | | | | | | |
| 79. | **Stigmatocythere parakingmai* Whatley and Zhao, 1988 | 7 | 1 | 7 | 1 | | | | | | |
| 80. | *Tanella gracilis* Kingma, 1948 | 29 | 4 | 13 | 3 | | | | | | |
| 81. | *Xestoleberis* sp. | 5 | 5 | 13 | 1 | 17 | 28 | 0 | 2 | 7 | |
| 82. | *Xestoleberis variegata* Brady, 1880 | 13 | 10 | 21 | 8 | 28 | 35 | 0 | 1 | | |

**A-** *Adult form*
**J-** *Juvenile form*
**First time recorded from the Indian water.*

*Neocytheromorpha reticulata* and *Spinoceratina spinosa* are having maximum adult forms and *Propontocypris bengalensis* has more juveniles. In MC-6, 1747 ostracod specimens were encountered. Seventy-six ostracod species belong to 49 genera have been found from all the 15 sub-samples of MC-6, which is retrieved from the Gulf of Mannar. This station encountered maximum ostracod species, compared to other stations. Out of this 76 species, only 5 species namely, *Alocopocythere reticulata indoaustralica, Bythoceropteron* sp., *Cytheropteron* sp.1, *Pistocythereis* sp. and *Semicytherura contraria* were present in the entire core of MC-6. Specimens belong to *Alocopocythere reticulata indoaustralica* and *Cytheropteron* sp.1 has the maximum count of both adult and juvenile forms.

A total of 491 ostracod specimens were recovered from all the 10 sub-samples of MC-5, which belong to 44 species and 31 genera. *Xestoleberis variegata,* the only species which is found to be present in all the sub-samples of MC-5. This station has more juveniles, compared to all the other multi-core samples, of which, juvenile forms of *Xestoleberis variegata* itself is present in more count (35 specimens). In MC-2, 237 ostracod specimens (includes adult and juvenile forms) belonging to 33 species and 23 genera were recovered from the study area. Of these 33 species, only two species namely, *Paijenborchella malaiensis* and *Parakrithella* sp. were found to be present in all the 15 sub-samples of MC-2. A total of 197 adult and 40 juveniles were found in the MC-2, in which, *Krithe* sp. holds the maximum count of adult forms in this station. A total of 52 ostracod specimens belonging to 10 species and 8 genera have been recorded from all the 12 sub-samples of MC-60. *Krithe* sp.1 is the only species present in all the sub-samples of MC-60; no juvenile forms were recorded from this station.

**Distribution of widespread species**

Two species namely, *Xestoleberis* sp. and *Paracypris* sp. are found at all 5 different water depths, viz., 58 m (MC-8), 215 m (MC-6), 510 m (MC-5), 1235 m (MC-2) and 1887 m (MC-60) *i.e., Xestoleberis* sp. and *Paracypris* sp. were present from the continental shelf to slope sediments of Gulf of Mannar. Population and range of this species being comparatively more in MC-5 than the other stations, indicates that this fauna prefers moderate water depth to exist in large number. 28 specimens of *Paracypris* sp. were recorded from all the 5 stations, but the occurrence of this species is not so common in all the sub-samples.

In addition to *Paracypris* sp. and *Xestoleberis* sp., the following 13 species were present in MC-8 to 4 and devoid in MC-60, of which, *Cytheropteron* sp.1 has more population when compared to the other 12 species. The total population of *Cytheropteron* sp.1 is 224 specimens, which is followed by *Semicytherura contraria* (180 specimens) and *Cytheropteron volantium* (149 specimens). All these species were predominantly presented in MC-6, which is of 215 m water depth with the count of 172, 128 and 96 specimens, respectively and the abundance of these species shows a decreasing trend in shallower and deeper water regions. A total of 114 specimens of *Xestoleberis variegata* has been recorded from the study area. Standing crop of this species shows an increasing trend from MC-8, 6, 5 and decreases in MC-2 and disappeared in MC-60, of all MC-5 records maximum population.

Abundance and population of the following six species namely, *Bythoceratina mandviensis, Cytherella hemipuncta, Cytherella semitalis, Paracytheridea pseudoremanei, Hemicytheridea ornata* and *Bradleya andamanae* show a

decreasing trend towards deeper water depths (MC-8 to 2) and disappeared in MC-60. All these six species prefer shallow water region and records the maximum population in MC-8 of 58 m water depth. A total of 35 and 29 specimens of the following two species, *Argilloecia* sp. and *Keijella karwarensis* were found in MC- 8 to 2, which have their maximum population in MC-6. The distribution and abundance of these species show a decreasing trend from shallower to deeper water regions. On the other side, the abundance and population of *Macrocyprina* sp. doesn't follow a proper trend. *Pterygocythereis* sp. is found in MC-8, 6, 2 and 60 and it has not found in MC-5. The following two species namely, *Paijenborchella* sp. (29 specimens) and *Pacombocythere* sp. (22 specimens) are absent in shallow water region, but present in other regions of the study area i.e., from MC-6 to 60.

**Sediment parameters with ostracod population**

Environmental parameters have been analysed from both the sediment and water samples to understand the ecological conditions in which the ostracod fauna exist. The population of ostracod along with other sediment characteristics such as substrate, calcium carbonate and organic matter were analysed from all the sub-samples and discussed.

All the five cores collected in the study area from different water depth reflects variations in the ostracod population and other environmental parameters. The population of the ostracod is more in MC-8, which shows the fauna prefers to thrive on the sandy silt substrate rather than the silty substrate. The standing crop of ostracod is decreasing towards the deeper stations i.e. decrease in population noticed in a silty substrate. Silt followed by sandy silt is the only substrates found in the study area. By observing the sediment textural results, the sand percentage was comparatively more in the sediments of MC-8 (58 m) than the other stations; this is due to the impact of terrestrial influx and the energy conditions of deposition of sediments in the area. The dominance of silt has taken place in the succeeding stations, which shows the less continental sediment input and also infers low energy conditions of sediment deposition that prevailed in the deeper water environment. The result of calcium carbonate analysis shows that the percentage is high in MC-8 when compared to other cores; the association of sand particles with $CaCO_3$ indicates the major contribution of shell fragments to the sand fraction found in the study area. The calcium carbonate percentage shows decreasing trends towards deeper water level. In addition to the sandy substrate, the presence of calcium carbonate in the silty substrate may be due to the presence of biogenous sediments (tests of planktic, benthic foraminifera and other microfaunas) noticed in the sediment samples of the Gulf of Mannar. The results of the organic matter content show that the percentage is slightly higher in MC-60 (1887 m) than the other multi-core samples. Due to the presence of sandy particles in MC-8, a lower amount of organic matter content is recorded and the percentage of organic matter shows a gradually increasing trend towards the deeper level, because of the presence of mud particles which accumulate organic matter content in the sediments. Organic matter content in the sediments is inversely proportional to the calcium carbonate content and directly proportional to the water depth, in which the core samples have been collected in the study area.

**Water parameters with ostracod population**

Horne (1983) stated that temperature and salinity are important controlling factors for the population of ostracod. Water parameters such as temperature, salinity and dissolved oxygen were correlated with ostracod fauna distributed in the top layer (0-3 cm) of the 5 multi-core samples. However, water depth is also considered as one of the important factors in controlling the population of ostracod in the study area. The population of ostracod is more in the shallow water region whereas it is decreasing towards the deeper water depth, hence a negative correlation with the total ostracod population. The bottom water temperature is found to be inversely proportional to the water depth and directly proportional to the ostracod population. The concentration of salinity in the bottom water samples are positively correlated with the ostracod population and have a negative correlation with the water depth.

In MC-8 the dissolved oxygen content in the bottom water samples and the population of ostracod is comparatively higher than the other stations, indicates DO is considered to be one of the important factors controlling the population of ostracod in the study area. From the measured values, DO content observed at the water depth 1235 m (MC-2) is lower than the DO content at the water depth 58 m (MC-8), shows DO has a negative correlation with the water depth.

**Species diversity**

It is the easiest method to determine the biodiversity/ relation to the number of various species in an area. Multivariate statistical analyses have been performed using the PAST software package (version 3.0) to measure species diversity. Shannon-Weaver index (H) is a popular diversity index used in the ecological related studies and commonly known as Shannon's diversity index. In the present study, the diversity value ranges from 3.55 to 3.9 in MC-8, and has high species diversity than the other 4 multi-core samples. Which is followed by MC-6, value ranges from 2.57 to 3.71; MC-5, value ranges from 2.24 to 2.73; MC-2 value ranges from 1.52 to 2.62 and in MC-60, the diversity values are in the range from 0 to 1.75. The values of Shannon-Weaver diversity index show that species diversity is decreasing towards deeper waters *i.e.,* from the continental shelf to slope sediments of Gulf of Mannar (Fig. 2). Dominance (D) value ranges from 0.02 to 0.04 in MC-8, 0.03 to 0.12 in MC-6, 0.08 to 0.13 in MC-5, 0.09 to 0.23 in MC-2

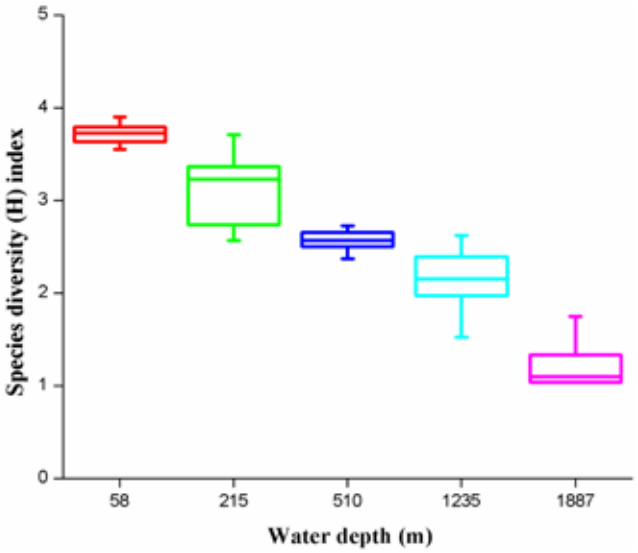


Fig. 2. Box plot shows species diversity index for all the 5 multi-cores of Gulf of Mannar.

and 0.18 to 1 in MC-60. The result shows that the study area is having a low dominance, which means there is no such species that dominates the community completely. Evenness value ranges from 0.73 to 0.85 in MC-8, 0.47 to 0.83 in MC-6, 0.73 to 0.88 in MC-5, 0.76 to 0.97 in MC-2 and 0.90 to 1in MC-60. From the results, MC-8, 5, 2 and 60 are having high evenness values, which shows that the species present in these stations are more or less evenly distributed, whereas, evenness value for MC-6 shows moderate which represents species in this station are moderately distributed.

## CONCLUSION

A research work undertaken to know the biodiversity and bathymetric implication through the ostracod distribution of the core samples collected from the neritic zone (shallow water depth cores at 58 m, 215 m) to bathyal zone (deep water cores at 510 m, 1235 m and 1887 m) during cruise SSD 004 from the Gulf of Mannar reveals a total of 82 ostracod species belonging to 5 genera are distributed along these water depth zones. In the process, 14 species are recorded for the first time from Indian waters. Among these 82 taxa, a typical shallow shelf species assemblage dominated with *Propontocypris bengalensis* and deepwater slope species assemblage with the abundance of *Krithe* spp. are categorized. *Xestoleberis* sp. and *Paracypris* sp. are noticed in all the core samples collected at different water depth. The population, as well as the biodiversity, is more in shallow water sediments than the deeper waters, which is also confirmed from the Shannon-weaver diversity index, in the study area. The occurrence of well preserved, light coloured (pale yellow to white), non-pyritised ostracod carapace reveals the oxic condition of the sediment deposition.

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## REFERENCES

**Andrei, B. and Gabriel, I.G.** 2014. Holocene ostracod and foraminiferal assemblages of the Romanian Black Sea shelf. *Quaternary International*, **345:** 119-129.

**Banerjee, P. K.** 2000. Holocene and Late Pleistocene relative sea level fluctuations along the east coast of India. *Marine Geology*, **167**(3-4): 243-260.

**Baskar, K., Sridhar, S. G. D., Sivakumar, T. and Hussain, S. M.** 2013. Seasonal comparison of recent benthic ostracoda response to sediment type in the Palk Bay, off Rameswaram island, Tamilnadu. *International Journal of Earth Sciences and Engineering*, **6**: 1047–1059.

**Baskar, K., Sridhar, S. G. D., Sivakumar, T., Hussain, S. M. and Maniyarasan, S.** 2015. Temporal Variation of Physico-chemical Parameters and Ostracoda Population, off Rameswaram, Gulf of Mannar, SE Coast of Tamil Nadu, India *Journal of Geological Society of India*, **86**: 663-670.

**Chacko, P. I.** 1950. Marine plankton from waters around the Krusadai Island. *Proceedings: Plant Sciences*, **31**(3): 162-174.

**Dewi, K. T.** 2014. Ostracoda from Subsurface Sediments of Karimata Strait as Indicator of Environmental Changes. *Bulletin of Marine Geology*, **29**(1): 1-10.

**Gengo, T.** 2016. Redescription of two krithid species (Crustacea, Ostracoda) from the Sea of Japan, with a comment on the taxonomic characters of Krithidae. *Paleontological Research,* **20**(1): 31-47.

**Gopalakrishna, K., Hussain, S.M., Mahesh, B. L. and Ayisha, V. A.** 2007. Recent benthic Ostracoda from the inner-shelf off the Malabar coast, Kerala, Southeast coast of India. *Journal of the Paleontological Society of India*, **52**(1): 56-68.

**Gopalakrishnan, K., Badrinarayanan and Subramaniam, K. S.** 2008. Geological and geo-tectonicsettings of Palk-Bay — Gulf of Mannar area between India and Sri Lanka — their relevance to Sethu Samudram shipping canal project. *Journal of Geological Society of India*, **71**: 600–601.

**Hokuto Iwatani, Young, M. Y., Irizuki, T., Sampei, Y. and Ishiga, H.** 2014.Spatial variations in recent ostracode assemblages and bottom environments in Trincomalee Bay, northeast coast of Sri Lanka. *Micropaleontology,* **60**(6): 509-518.

**Horne, D. J.** 1983. Life cycles of Podocopid Ostracoda - A review (with particular reference to marine and brackish water species), pp. 581-590. In: Applications of Ostracoda, (Ed. Maddocks, R.F.), *University of Houston Earth and Atmospheric Science*.

**Horne, D. J. and Boomer, I.** 2000. The role of Ostracoda in saltmarsh meiofaunal communities, pp. 182-202. (Eds. *Sherwood, B.R., Gardiner, B.G., Harris, T.*) *British Saltmarshes.* 182- 202.

**Hussain, S. M.** 1998. Recent benthic Ostracoda from the Gulf of Mannar, off Tuticorin, south- east coast of India, *Journal of the Paleontological Society of India,* **43**: 1-22.

**Hussain, S. M. and Kuleen, E. C.** 2016. Distribution of Foraminifera and Ostracoda in the North Chennai Coast (Ennore to Thiruvanmiur), Tamil Nadu: Implications on Microenvironment. *Indian Journal of Geo-Marine Science*, **45**(3): 416-424.

**Hussain, S. M., Krishnamurthy, R., Suresh Gandhi, M., Ilayaraja, K., Ganesan, P. and Mohan, S. P.** 2006. Micropalaeontological investigations on tsunamigenic sediments of Andaman Islands. *Current Science*, **91**(12): 1655–1667.

**Hussain, S. M., Ravi, G., Mohan, S. P. and Rajeshwara Rao, N.** 2009. Distribution of Recent Ostracoda in the Bay of Bengal, off Karikkattukuppam (near Chennai), southeast coast of India - Implication for Biodiversity. *Gondwana Geological Magazine*, **24**(1): 35-39.

**Jessica, M. R., Chivas, A. R., Garcia, A. and De Deckker, P.** 2007. Palaeoenvironmental change in the Gulf of Carpentaria (Australia) since the last interglacial based on Ostracoda. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **246**(2): 163-187.

**Julio Rodriguez-Lazaro and Francisco Ruiz-Muñoz.** 2012. A general introduction to ostracods: morphology, distribution, fossil record and applications. *Developments in Quaternary Science,* **17**: 1-14.

**Lili, F., Irizuki, T. And Sampei, Y.** 2012. Spatial distribution of recent ostracode assemblages and depositional environments in Jakarta Bay, Indonesia, with relation to environmental factors. *Paleontological Research*,**16**(4): 267-281.

**Luz, N. C. and Coimbra, J. C.** 2015. New species of Xestoleberididae (Crustacea, Ostracoda) from Archipelago of São Pedro and São Paulo, Equatorial Atlantic. *Iheringia, Série Zoologia*, **104**: 470–477.

**Mohammed Nishath, N., Hussain, S. M. and Rajkumar, A.** 2015. Distribution of ostracoda in the sediments of the northwestern part of the Bay of Bengal, India - Implications for microenvironment. *Journal of the Palaeontological Society of India,* **60**(2): 27-33.

**Mohammed Nishath, N., Hussain, S. M., Neelavnnan, K., Thejasino, S., Saalim, S. and Rajkumar, A.** 2017. Ostracod biodiversity from shelf to slope oceanic conditions, off central Bay of Bengal, India, *Palaeogeography, Palaeoclimatology, Palaeoecology*, http://dx.doi.org/10.1016/j.palaeo.2017.05.004

**Mostafawi, N., Colin, J. P. and Babinot, J. F.** 2005. An account on the taxonomy of ostracodes from recent reefal flat deposits in Bali, Indonesia. *Revue de Micropaléontologie*, **48**: 123-140.

**Noraswana, N. F., Ramlan, O. and Norashikin, S.** 2014. Distribution of recent ostracoda in offshore sediment of selected stations in the Sulu sea, Sabah. *Malaysian Applied Biology*, **43**(2): 49-57.

**Piazza Meireles, R., Keyse, D., Borges, P.A., Silva, L., de Frias Martins, A. M. and Avila, S. P.** 2014. The shallow marine ostracod communities of the Azores (Mid-North Atlantic). *Geologica acta*, **12**(1): 53-70.

**Rajamanickam, G. V. and Loveson, V. J.** 1990. Results of radiocarbon dating from some beach terraces around Rameswaram Island, Tamil Nadu. *Sea level variation and its impact on coastal environment*, 389-395.

**Ramesh, R., Nammalwar, P. and Gowri, V. S.** 2008. Database on coastal information of Tamilnadu. Chennai, India: Institute for Ocean Management, Anna University, Chennai. Report submitted to Environmental Information System (ENVIS), Department of Environment, Government of Tamilnadu.

**Sridhar, S. G. D., Hussain, S. M., Kumar, V. and Periakali, P.** 2002. Recent Ostracoda from Palk Bay, off Rameswaram, southeast coast of India. *Journal of the Paleontological Society of India,* **47**: 17-39.

**Stepanova, A. and Lyle, M.** 2014. Deep-sea Ostracoda from the Eastern Equatorial Pacific (ODP Site 1238) over the last 460ka. *Marine Micropaleontology*, **111**: 100-117.

**Stoddart, D. R. and Gopinatha Pillai, C. S.** 1972. Raised reefs of Ramanathapuram, South India. *Transactions of the Institute of British Geographers*, Pub., No. **56**.

**Theodora, T.** 2012. Composition and distribution of recent marine ostracod assemblages in the bottom sediments of Central Aegean Sea (SE Andros Island, Greece). *International Review of Hydrobiology*, **97**(4): 276-300.

**Yasuhara, M and Irizuki Toshiaki.** 2001. Recent Ostracoda from the Northeastern part of Osaka Bay, Southwestern Japan. *Journal of Geosciences,* **44**: 57-95.

**Yasuhara, M., Hunt, G., Cronin, T. M., Hokanishi, N., Kawahata, H., Tsujimoto, A. and Ishitake, M.** 2012. Climatic forcing of Quaternary deep-sea benthic communities in the North Pacific Ocean. *Paleobiology,* **38**: 162–179.

**Yasuhara, M., Stepanova, A., Okahashi, H., Cronin, T. M. and Brouwers, E. M.** 2014. Taxonomic revision of deep-sea Ostracoda from the Arctic Ocean. *Micropaleontology*, **60**: 399-444.

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