Spatial variations in recent ostracode assemblages and bottom environments in Trincomalee Bay, northeast coast of Sri Lanka

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Spatial variations in recent ostracode assemblages and bottom environments in Trincomalee Bay, northeast coast of Sri Lanka

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ABSTRACT: Trincomalee Bay is situated on the northeast coast of Sri Lanka. This is the first study to report the recent ostracode assemblages in this bay. As a result, at least 36 ostracode taxa were identified from surface sediments in the bay. Many of them are typical tropical-water species that have been reported from inner bays and shallow marine areas around the coast of the Indo-Pacific region. We compared the species composition of ostracodes in the study area with that in adjacent seas. The result clearly showed that ostracode assemblages from Sri Lanka have strong connection with those along the coast of the Indian subcontinent. Moreover we evaluated the bottom environment in Trincomalee Bay on the basis of statistical analyses of ostracode assemblages combined with grain size, and total organic carbon (TOC) and total nitrogen (TN) contents. The results showed that the TOC content is related to grain size and is relatively high in the inner part of Inner Harbor and Koddiyar Bay, where fine-grained sediments are distributed. Four biofacies were recognized based on Q-mode cluster analysis using ostracode data for 36 taxa. Biofacies I is consistent with distributions of fine-grained sediments with moderate TOC contents (0.30%–0.49 %). Biofacies II is collected from relatively deep water areas with sediments of low TOC contents (0.22%–0.41 %) in Inner Harbor. Biofacies III and IV are characterized by euryhaline species and are influenced by fresh water and shallow depth with low TOC contents (0.14%–0.37%) in sediments. The ostracode distribution in Trincomalee Bay is depend on natural environmental factors such as water depth, grain-size, TOC contents of sediments, and water salinity.

INTRODUCTION

Trincomalee Bay lies on the northeast coast of Sri Lanka and has a large semi-enclosed opening toward the Bay of Bengal (text-fig. 1). In this study, we focus on recent ostracode (small bivalved *Crustacea*) assemblages, which have not yet been studied in Trincomalee Bay.

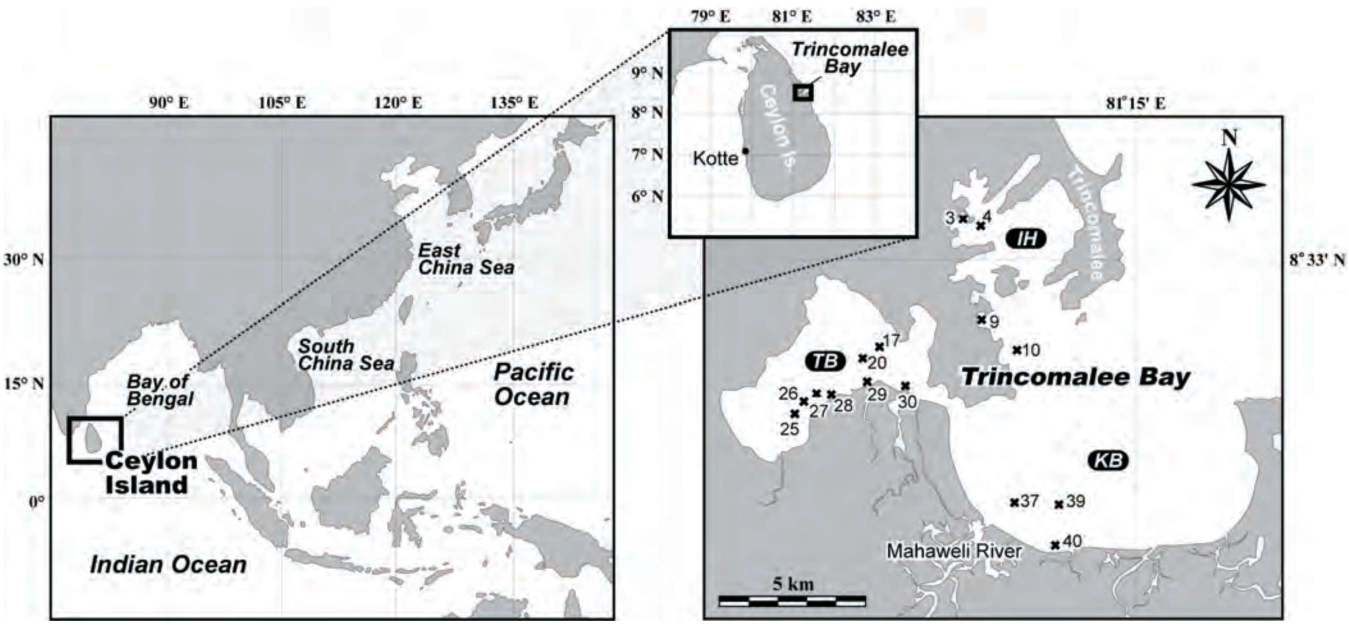
Thirteen ostracode zoogeographical provinces have been recognized in the Indo-Pacific region based on the geographical distribution of ostracode species (Titterton and Whatley 1988). Sri Lanka is situated in the Bengal province, and the recent ostracode fauna in this area is not fully understood (Titterton and Whatley 1988). Several studies have been conducted on these faunas around the Indian subcontinent (Hussain 1998; Hussain and Mohan 2000, 2001; Mohan et al. 2002; Sridhar et al. 2002; Hussain et al. 2006, 2007, 2010; Gopalakrishna et al. 2008). However, only a few taxonomic investigations of marine Ostracoda from Sri Lanka were conducted in the 19th and early 20th centuries (Brady 1886; Scott 1905). Therefore, it is important to investigate these tropical-water ostracode faunas as a contribution toward the understanding of spatial variations in ostracodes in the Indian Ocean. This is the first report on recent marine ostracode assemblages from Trincomalee Bay in Sri Lanka.

Trincomalee Bay is well known for its deep-water natural harbor and for fish resources and tourism (Rajasuriya et al. 2005). In the mid-1900s, the population in the district of Trincomalee increased rapidly. However, in 2012, it reached approximately 380,000 (Department of Census and Statistics, Sri Lanka 2012). The environment there is predicted to change because of the further development of sightseeing and commercial uses. Till date, only a few studies have been conducted on the bottom environments in this bay (Rajasuriya et al. 2005). Ostracodes serve as an effective environmental indicator, especially in enclosed brackish lakes, estuaries, and bays (Yasuhara et al. 2003, 2007; Ruiz et al. 2005, 2006; Irizuki et al. 2008, 2011; Lili Fauzielly et al. 2013). This study evaluates the bottom environments in Trincomalee Bay because of the statistical analyses of ostracode assemblages combined with data on grain size, total organic carbon (TOC) content, and total nitrogen (TN) content.

STUDY AREA

Sri Lanka is an island country surrounded by the Indian Ocean, which is separated from the southeast coast of the Indian Subcontinent by the Palk Strait. The climate of Sri Lanka can be characterized as tropical monsoon (Malmgren et al. 2003). It has two monsoon and two inter-monsoon periods during a year. The mean annual temperature in the coastal plane is 26–28°C (Dassanayake 1984). In addition to possessing considerable endemic species, Sri Lanka exhibits a remarkable species diversity considered to be the richest per unit area in the Asian region (Ministry of Environment, Sri Lanka 2011).

The study area is Trincomalee Bay, which is located on the northeast coast of Sri Lanka. Trincomalee Bay is divided into three areas: Tambalagam Bay, Inner Harbor, and Koddiyar Bay (text-fig. 1). Tambalagam Bay is situated in the innermost part



TEXT-FIGURE 1
Maps showing the study area. TB: Tambalagam Bay, IH: Inner Harbor, KB: Koddiyar Bay.

and is mostly enclosed. Inner Harbor is surrounded by the Trincomalee Peninsula. Koddiyar Bay is the largest area in Trincomalee Bay, and is widely opened northward. An extremely deep submarine canyon, named Trincomalee Canyon, exists in Koddiyar Bay and the offing of Inner Harbor. It is over 40km long and 500m deep even in Trincomalee Bay (Wijayananda 1985).

MATERIALS AND METHODS

In August 2010, a total of 43 surface sediment samples were collected from Trincomalee Bay by using an Ekman-Berge grab sampler. Since many of them were very coarse sand, ostracodes were rarely found.

Thus, in this study, we selected 15 samples composed of relatively fine-grained surface sediments, which contain many ostracode individuals and seem to reflect a spatial distribution of ostracode assemblages in the study area (text-fig. 1).

Grain size analysis

Fifteen samples, whose organic matter was decomposed by 30% hydrogen peroxide water solution, were used for the grain size analysis. The integrated value of grain size was then measured using a laser diffraction particle size analyzer (SALD-3000S Shimadzu Co., Ltd.) at the Department of Geoscience, Interdisciplinary Faculty of Science and Engineering, Shimane University.

CN analysis

For CN analysis, part of each dried sample was powdered in an agate vessel. The total organic carbon (TOC) and total nitrogen (TN) contents of the powdered sediment samples (approximately 10 mg) were determined using a FISONS 1108 elemental analyzer, after treatment with 1M HCl added to the sediment weighed in a cup and dried to remove the carbonate fraction. The errors (coefficient of variation) inherent in this analysis are within ±3%.

Ostracode analysis

For ostracode analyses, approximately 20g of dried sediment samples were weighed and washed through a 0.063mm sieve. The residues were divided using a sample splitter, each with approximately 200 specimens to be picked from residues coarser than 0.125mm. The number of specimens refers to both valves and carapaces. One carapace was counted as two valves.

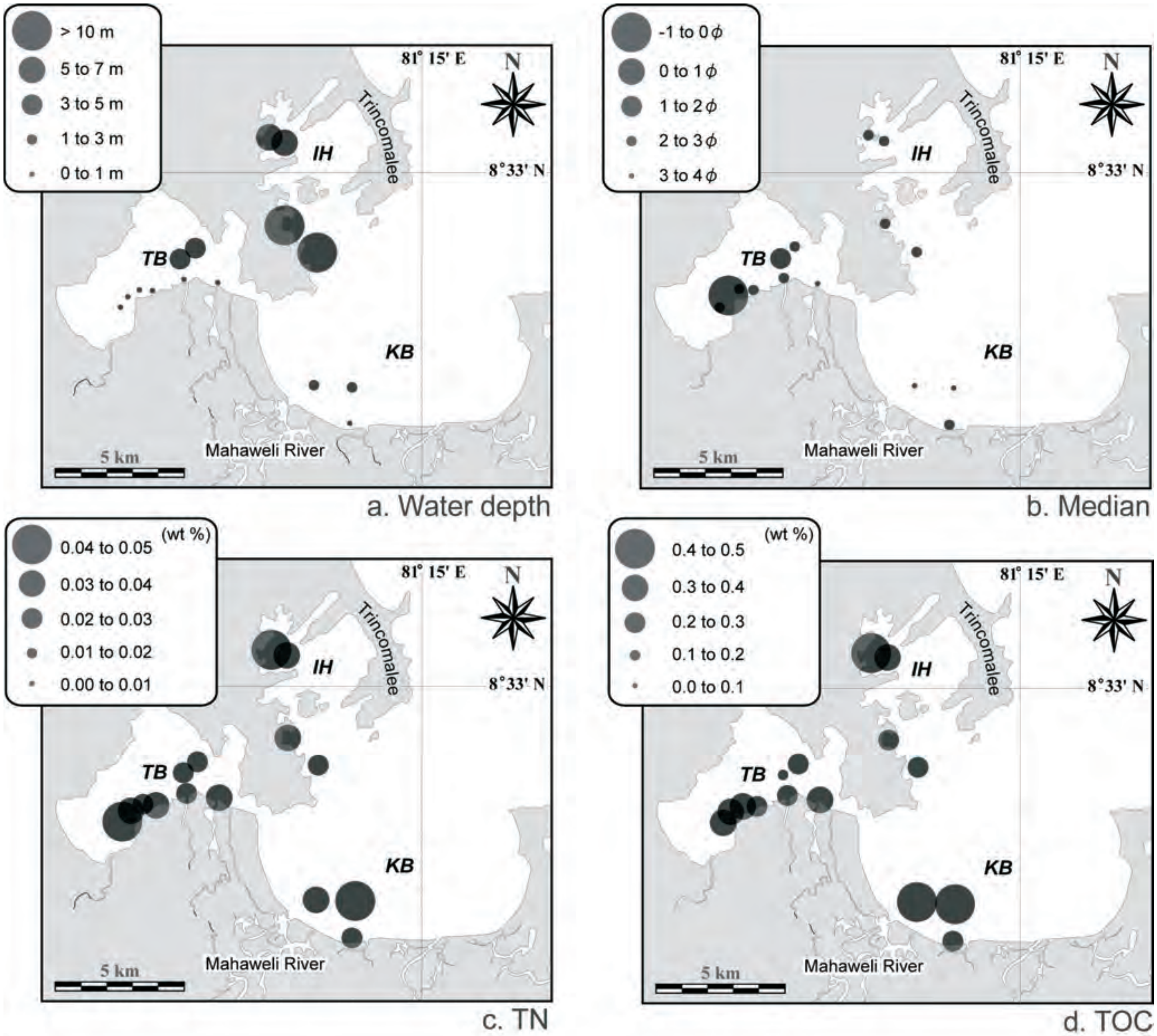
RESULTS

Grain size

We calculated four grain size parameters (median grain size, sorting, skewness, and kurtosis) using the equation of Folk and Ward (1957) (Table 1). As per the result, the median grain size ranges between -0.30 and 3.99φ (average 2.47φ) (text-fig. 2), sorting ranges between 0.39 and 2.34 (average 1.34), skewness ranges between 0.10 and 0.79 (average 0.47), and kurtosis ranges between 0.69 and 3.15 (average 1.80). Thus, poorly- to well-sorted fine-grained sand, very poorly- to well-sorted very fine- to very coarse-grained sand, and very poorly to poorly sorted very fine- to fine-grained sand are distributed in Inner Harbor, Tambalagam Bay, and Koddiyar Bay, respectively.

TOC and TN contents

The concentration ranges of TOC and TN are 0.14%-0.49% and 0.02%-0.05%, respectively (Table 1). TOC is relatively high in the inner part of Inner Harbor and Koddiyar Bay (text-fig. 2). TN shows similar distribution with TOC and relatively high values at around the inner part of each Bay with the exception of Koddiyar Bay. Distributional patterns of TOC are concordant to



TEXT-FIGURE 2
Distribution of water depth (a), median grain size (b), total nitrogen content (c), and total organic carbon content of surface sediments in Trincomalee Bay. TB: Tambalagam Bay, IH: Inner Harbor, KB: Koddiyar Bay.

those of sediment grain size: TOC is high in fine-grained sediments (text-fig. 2). C/N ratios in this area (Table 1) is not useful, because all TOC contents are lower than 0.5% (Sampei and Matsumoto 2001).

Ostracode assemblages in Trincomalee Bay

At least 36 ostracode taxa were identified from 13 of the 15 samples selected in the study site, and two samples did not contain ostracodes (Table 2).

Indices of species diversity, equitability, and density

To reconstruct the bottom-water environment of the study site, nine samples, each of which contained more than 100 specimens, were selected and evaluated by quantitative analyses (Table 2). Four samples with less than 100 individuals were omitted. To reconstruct the structure of ostracode assemblages in the study site, the following three indices were used: species diversity {$H(S)$}, equitability (*Eq.*), and density. The species diversity index was determined by the following Shannon–Wiener function: $H(S) = -\Sigma\, pi \ln pi$, where pi is the proportion of i-th species in a sample. The equitability index was calculated using the equation of Buzas and Gibson (1969): $Eq. = e^{H(S)}/S$, where S is the number of species. In this study, ostracode density was expressed by the number of ostracodes per gram of dried sediment. As per the result, the species diversity ranges between 0.65 and 2.76. In Tambalagam Bay, diversity is clearly low in comparison with that in Inner Harbor and Koddiyar Bay. The equitability ranges between 0.50 and 0.96 and is high at the

TABLE 1
Sample information and results of grain size and CN analyses. TB: Tambalagam Bay, IH: Inner Harbor, KB: Koddiyar Bay.

Sample number	Area	Depth (m)	Grain size analysis (Phi scale, and Grain size division by Folk & Ward, 1957)				CN analysis		
			median	sorting	skewness	kurtosis	TN (wt%)	TOC (wt%)	C/N ratio
TR3	IH	6.4	2.76 fine sand	0.41 well	0.27 positive	2.35 very leptokurtic	0.046	0.41	8.86
TR4	IH	5.2	2.93 fine sand	1.87 poorly	0.79 very positive	2.41 very leptokurtic	0.039	0.30	7.68
TR9	IH	13	2.75 fine sand	1.81 poorly	0.49 very positive	2.33 very leptokurtic	0.036	0.24	6.61
TR10	IH	11.5	2.75 fine sand	1.62 poorly	0.38 very positive	2.01 very leptokurtic	0.022	0.22	10.25
TR17	TB	3.9	2.92 fine sand	2.24 very poorly	0.63 very positive	2.31 very leptokurtic	0.028	0.23	8.17
TR20	TB	3.2	1.83 medium sand	0.39 well	0.24 positive	1.34 leptokurtic	0.023	0.14	6.03
TR25	TB	0.5	2.24 fine sand	1.47 poorly	0.66 very positive	3.15 extremely leptokurtic	0.042	0.35	8.45
TR26	TB	0.5	-0.30 very coarse sand	1.39 poorly	0.74 very positive	0.69 platykurtic	0.031	0.32	10.28
TR27	TB	0.5	2.03 fine sand	1.13 poorly	0.57 very positive	2.34 very leptokurtic	0.028	0.37	13.58
TR28	TB	0.5	2.27 fine sand	0.86 moderately	0.45 very positive	0.98 mesokurtic	0.031	0.29	9.40
TR29	TB	0.5	2.22 fine sand	0.72 moderately	0.12 positive	1.24 leptokurtic	0.027	0.23	8.65
TR30	TB	0.8	3.09 very fine sand	1.59 poorly	0.53 very positive	1.42 leptokurtic	0.038	0.34	8.79
TR37	KB	1.5	3.34 very fine sand	1.11 poorly	0.10 positive	1.17 leptokurtic	0.039	0.49	12.59
TR39	KB	2.3	3.99 very fine sand	2.34 very poorly	0.55 very positive	1.86 very leptokurtic	0.040	0.42	10.47
TR40	KB	0.5	2.28 fine sand	1.12 poorly	0.53 very positive	1.38 leptokurtic	0.026	0.26	10.17

mouth of Tambalagam Bay (TR-30). The density of ostracodes varies widely, ranging between 5.65 and 499.20. In Inner Harbor and Koddiyar Bay, it is relatively stable, ranging between 50 and 300. On the other hand, in Tambalagam Bay, the density varies in each locality.

Biofacies in Trincomalee Bay

To define ostracode biofacies, we performed Q-mode cluster analysis using the same samples of the aforesaid analysis and relative abundance data for 36 taxa. We used Horn's overlap index as a similarity (Horn 1966) and UPGMA (unweighted pair group method with arithmetic average) as the clustering method. As a result, four ostracode biofacies (I, II, III, and IV) were discriminated (text-fig. 3). **Biofacies I** comprises three samples (TR-4, 37, and 39) collected from relatively fine-grained sediments in Tambalagam Bay and Inner Harbor (text-figs. 4 and 5). It is characterized by the dominance of *Chrysocythere keiji*, *Hemicytherideα reticulata*, *Keijella* sp. 2, and *Stigmatocythere bona*. According to Hussain (1998), *C. keiji* occurs in Indian coastal areas. *H. reticulata* was first described from the Plio-Pleistocene marls in the Atjeh (North Sumatra) and Southern Kendeng area (East Java) by Kingma (1948). According to Sridhar et al. (2002), this species is found in both brackish and shallow marine environments. Lili Fauzielly et al. (2013) reported that *H. reticulata* lives in an oxic environment in Jakarta Bay, Indonesia. *Keijella* sp. 2 has not yet been described. *S. bona* occurs rarely in the Malacca Strait (Whatley and Zhao1988). **Biofacies II** comprises three samples (TR-3, 9, and 10) collected from relatively deep-water areas in Inner Harbor (text-figs. 4 and 5). This biofacies was dominated by *Keijella reticulata*, *Pistocythereis* aff. *bradyformis*, and *Pistocythereis* aff. *bradyi*. According to Dewi (1997), *K. reticulata* is mainly distributed in the Malacca Strait. The genus *Pistocythereis* lives in fine sand or muddy bottoms in the inner bay areas (Hanai et al. 1977). **Biofacies III** is composed of TR-17 and 26 collected from Tambalagam Bay (text-figs. 4 and 5). This biofacies is characterized by the dominance of *Neomonoceratina iniqua*. This species occurs abundantly in Jason Bay of the Southeast Malay Peninsula at water depths of 0–20 m (Zhao and Whatley 1988). According to Sridhar et al. (2002), this species can thrive in brackish as well as shallow marine habitat with silty-sand and sandy bottoms. Lower values of diversity in biofacies III reflect the dominance of this species. **Biofacies IV** is composed of only one sample, TR-30, which was collected from the estuary of a branch of the Wahawelli River in Tambalagam Bay (text-figs. 4 and 5). It is characterized by the dominance of *Loxoconcha* aff. *tekkaliensis* and *Tanella gracilis*. The former species has not yet been described. According to Sridhar et al. (2002), *T. gracilis* can tolerate wide ranges of salinity and temperature. Lower values of diversity in biofacies IV reflect the dominance of these species.

DISCUSSION AND CONCLUSIONS

The ostracode assemblages of the study area were composed of typical tropical marine species which have been reported from inner bays and shallow-marine areas along the coasts of the

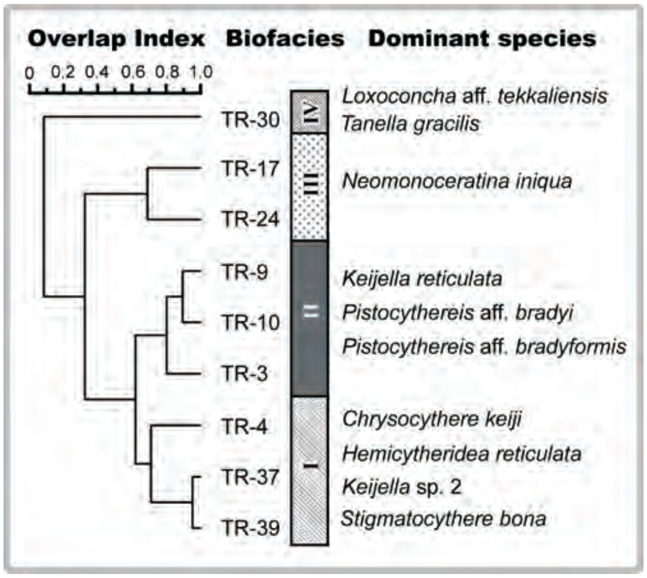
TABLE 2
List of ostracodes from Trincomalee Bay. TB: Tambalagam Bay, IH: Inner Harbor, KB: Koddiyar Bay. Black stars show common species with adjacent provinces. See text for the detailed description of these provinces.

Area	IH	IH	IH	IH	TB	TB	TB	KB	KB	Common species		
Species \ Sample number	TR3	TR4	TR9	TR10	TR17	TR26	TR30	TR37	TR39	Arabian	Bengal	ast Indian
Actinocythereis scutigera (Brady)	1		4	2					1	★	★	★
Argilloecia cf. *eburnea* Brady	4	10	1	5				1				
Bairdoppilata alcyonicola Maddocks			11	13						★	★	
Callistocythere sp. 1	5		4	5				1	1			
Callistocythere sp. 2			3	12	2							
Chrysocythere keiji Ruggieri	20	32	7	23	5			11	20	★	★	
Cytherelloidea malaccaensis Whatley & Zhao	7	10	7	8								★
Cytherelloidea sp. 1	8		2					1	1			
Hemicytheridea aff. *khoslai* Hussain et al.						12						
Hemicytheridea cf. *ornata* Mostafawi			3	1		28		4	1			
Hemicytheridea reticulata Kingma	3	5	4	3	7			16	17	★	★	★
Hemikrithe peterseni Jain					6	8				★	★	★
Keijella reticulata Whatley & Zhao	18	19	43	24	5			14		★	★	★
Keijella sp. 1					20	6		22	24			
Keijella sp. 2				4	1			1				
Lankacythere coralloides (Brady)		1			16				4	★	★	
Loxoconcha gruendeli Jain	1	4	4		1			4	11	★	★	
Loxoconcha megapora Benson & Maddocks		5	1	1	2			3		★		
Loxoconcha aff. *tekkaliensis* Varma et al.							40					
Macrocypris cf. *decora* (Brady)	8											
Macrocypris spp.			2		1			9				
Miocyprideis spinulosa (Brady)		4	2	5		2					★	
Mutilus pentoekensis (Kingma)	21	2	13	1				2	2			
Neocytheromorpha sp.		1	4									
Neomonoceratina iniqua (Brady)					46	96		1	2	★	★	★
Neonesidea spp.	16							6	2			
Paijenborchellina prona (Lubimova & Guha)					4			7	10		★	
Paracytheridea pseudoremanei Bonaduce et al.			1		3			1	1	★	★	
Pistocythereis aff. *bradyformis* (Ishizaki)	9	6	14	44				16	11			
Pistocythereis aff. *bradyi* (Ishizaki)	18	1	24	4	1			2				
Ruggieria cf. *darwini* (Brady)			3						2			
Stigmatocythere bona Chen	2	63			23	27		19	17			★
Stigmatocythere cf. *bona* Chen	2	1	3	2								
Tanella gracilis Kingma	2	10	4	3			73	10	7	★	★	★
Xestoleberis spp.	11	3	7	3	1			9	10			
Others (taxa with fewer than five individuals)	14	6	15	13	12			13	13			
No. of speciemens	170	183	186	176	156	179	113	173	157			
No. of species	19	18	25	20	18	7	2	23	20			
Total ostracode(/g)	45.33	292.80	198.40	281.60	499.20	71.60	5.65	69.20	125.60	12	13	8
Shannon_H	2.65	2.20	2.72	2.47	2.27	1.39	0.65	2.76	2.58			
Evenness_e^H/S	0.74	0.50	0.60	0.59	0.54	0.58	0.96	0.69	0.66			

Indo-Pacific region (Jain 1978, 1981; Hussain 1998; Hussain and Mohan 2000; Sridhar et al. 2002; Hussain et al. 2006; Gopalakrishna et al. 2008; Hussain et al. 2010). Titterton and Whatley (1988) recognized 13 ostracode zoogeographical provinces in the Indo-Pacific region based on the geographical distributions of ostracode species. These are the Eastern African, Arabian, Bengalian, East Indian, Kymerian, Japanese, Australian, New Zealand, Southern and Southwestern Pacific, Northern and Central Pacific, Western-North and Central American, Western South American, and Southern Ocean provinces. The ostracode assemblage from the present study area belongs to the Bengal province (the Bay of Bengal). According to Titterton and Whatley (1988), the fauna of the Bengal province shows a comparatively strong connection with that of the East Indian province, with 23 species in common, and the Southern and Southwestern Pacific province, with 24 species in common.

Text-figure 6 shows the geographical distributions of six dominant species from the study site. They are mainly distributed along the coasts of the Indian subcontinent (Arabian and Bengal provinces) and off Southeastern Asia (East Indian province). We compared the species composition of the study area with that of the adjacent seas (Arabian, Bengal, and East Indian provinces). The result showed that compared with the species composition off Southeastern Asia, the area around the coast of India resembles Trincomalee Bay. The study area has at least 12 species in common with the Arabian province (west coast of India), and at least 13 species in common with the Bengal province (Table 2). However, the study area has only eight species which occur off Southeastern Asia (Table 2). Thus, the ostracode fauna in Sri Lanka has a strong connection with that in the Indian subcontinent (Arabian and Bengal provinces).

Ostracode biofacies are clearly distinguishable in Trincomalee Bay (text-fig. 5). These biofacies patterns may be related to differences in marine environmental conditions. The relationships between artificial and/or natural environmental factors and ostracodes have been extensively studied (Ishizaki 1968, 1969, 1971; Bodergat and Ikeya 1988; Cronin and Vann 2003; Ruiz et al. 2006, 2008; Yasuhara et al. 2003, 2007; Yasuhara and Yamazaki 2005; Irizuki et al. 2006, 2008, 2011; Lili Fauzielly et al. 2013). Ostracode distribution patterns show a strong relationship with bottom sediment patterns (Ikeya and Shiozaki 1993; Yamane 1998). The results of a cluster analysis combined with grain size analysis showed that biofacies I occurs on very fine- to fine-grained sandy bottoms. Biofacies II corresponds to



TEXT-FIGURE 3
Dendrogram showing the result of Q-mode cluster analysis.

fine sandy bottoms in relatively deep water (> 5m water depth). Biofacies III occurs on relatively shallow coarse-grained bottoms. Biofacies IV corresponds to very fine-grained sand bottoms. In this study, ostracode distributions are concordant with their bottom habitats; thus, ostracode distributions in the study area seem to be hardly affected by postmortem transportation and water currents. Koddiyar Bay has a wide open mouth with a deep-submarine canyon; marine water seems to enter the bay easily. According to Lili Fauzielly et al. (2013), *Hemicytheridea reticulata* is an indicator of oxic conditions, and this species is a representative of biofacies I. Therefore, it is possible that the bottom environment of Koddiyar Bay is controlled by oxic seawater. Biofacies II is collected from relatively deep-water areas with low TOC content (0.22%–0.41%) in Inner Harbor (text-figs. 2 and 5), and there are no large rivers flowing into Inner Harbor (text-fig. 1). Ostracodes in Inner Harbor are influenced by low TOC and relatively deep marine water. Conversely, Tambalagam Bay is a shallow, inner bay into which there is an inflow from some rivers (text-fig. 1), where TOC content is low (0.14%–0.37%). Biofacies III and IV in this bay are characterized by euryhaline species. Therefore, the bottom environment in Tambalagam Bay is strongly influenced by fresh water and the shallow depth, with coarse-grained sediments and low TOC content. We conclude that the ostracode distribution in Trincomalee Bay depends on natural environmental factors such as water depth, grain size, TOC content of sediment, and water salinity.

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TEXT-FIGURE 4

Scanning electron micrographs of ostracodes from Trincomalee Bay used for the Q-mode cluster analysis.
All are left valves. Scale bar is 0.1mm.

1–3 *Chrysocythere keiji* Ruggieri. 1, female, sample TR-10; 2, male, sample TR-4; 3, juvenile, sample TR-17.

4 *Hemicytheridea reticulata* Kingma, juvenile, sample TR-37.

5,6 *Keijella* sp. 2. 5, adult, sample TR-37; 6, juvenile, sample TR-37.

7,8 *Stigmatocythere bona* Chen. 7, female, sample TR-17; 8, juvenile, sample TR-4.

9,10 *Keijella reticulata* Whatley and Zhao. 9, female, sample TR-4; 10, juvenile, sample TR-10.

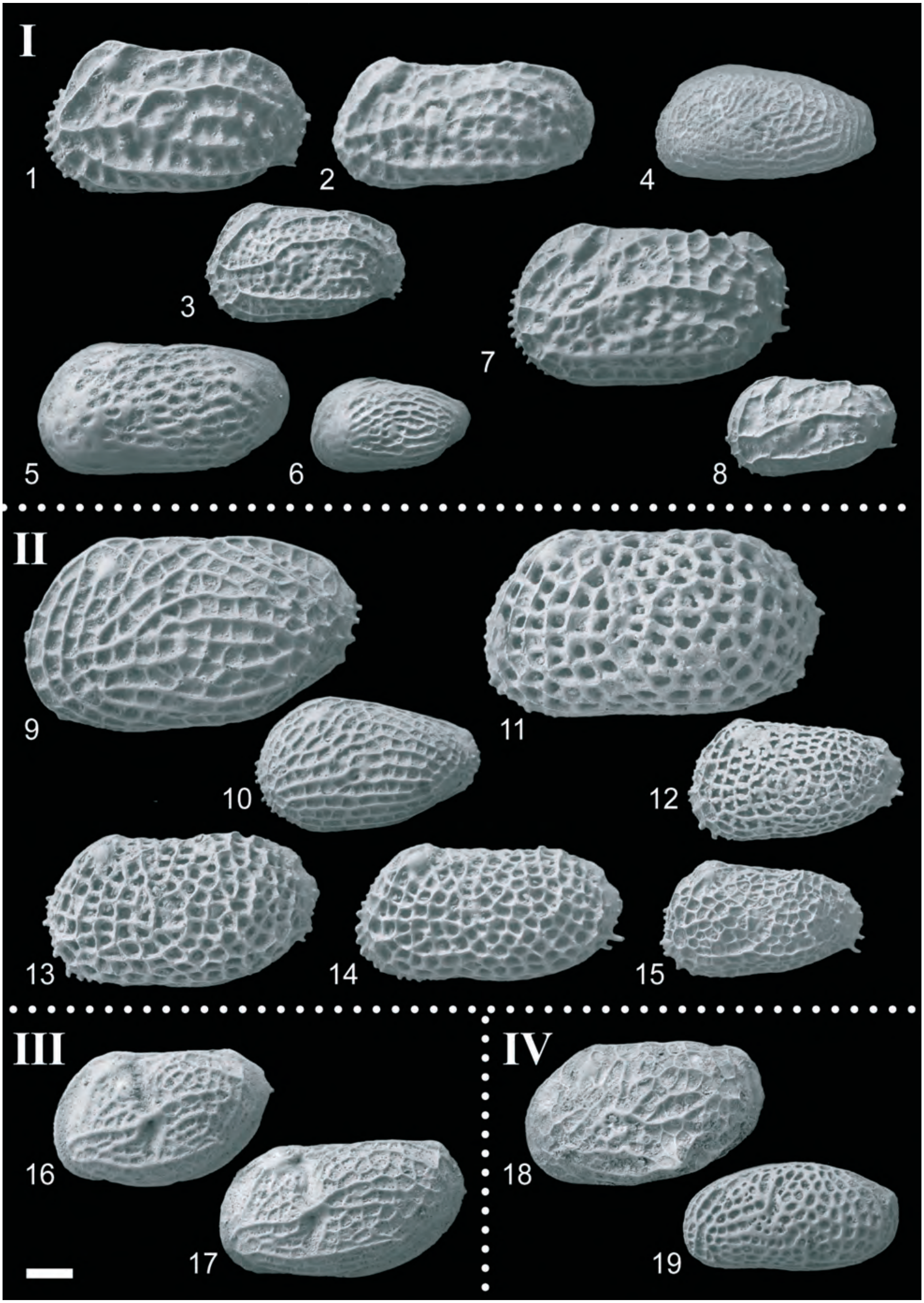
11,12, *Pistocythereis* aff. *bradyi* (Ishizaki). 11, female, sample TR-3; 12, juvenile, sample TR-9.

13-15 *Pistocythereis* aff. *bradyformis* (Ishizaki). 13, female, sample TR-10; 14, male, sample TR-10; 15, juvenile, sample TR-37.

16,17 *Neomonoceratina iniqua* (Brady). 16, female, sample TR-17; 17, male, sample TR-24.

18 *Loxoconcha* aff. *tekkaliensis* Varma et al., adult, sample TR-30.

19 *Tanella gracilis* Kingama, adult, sample TR-4.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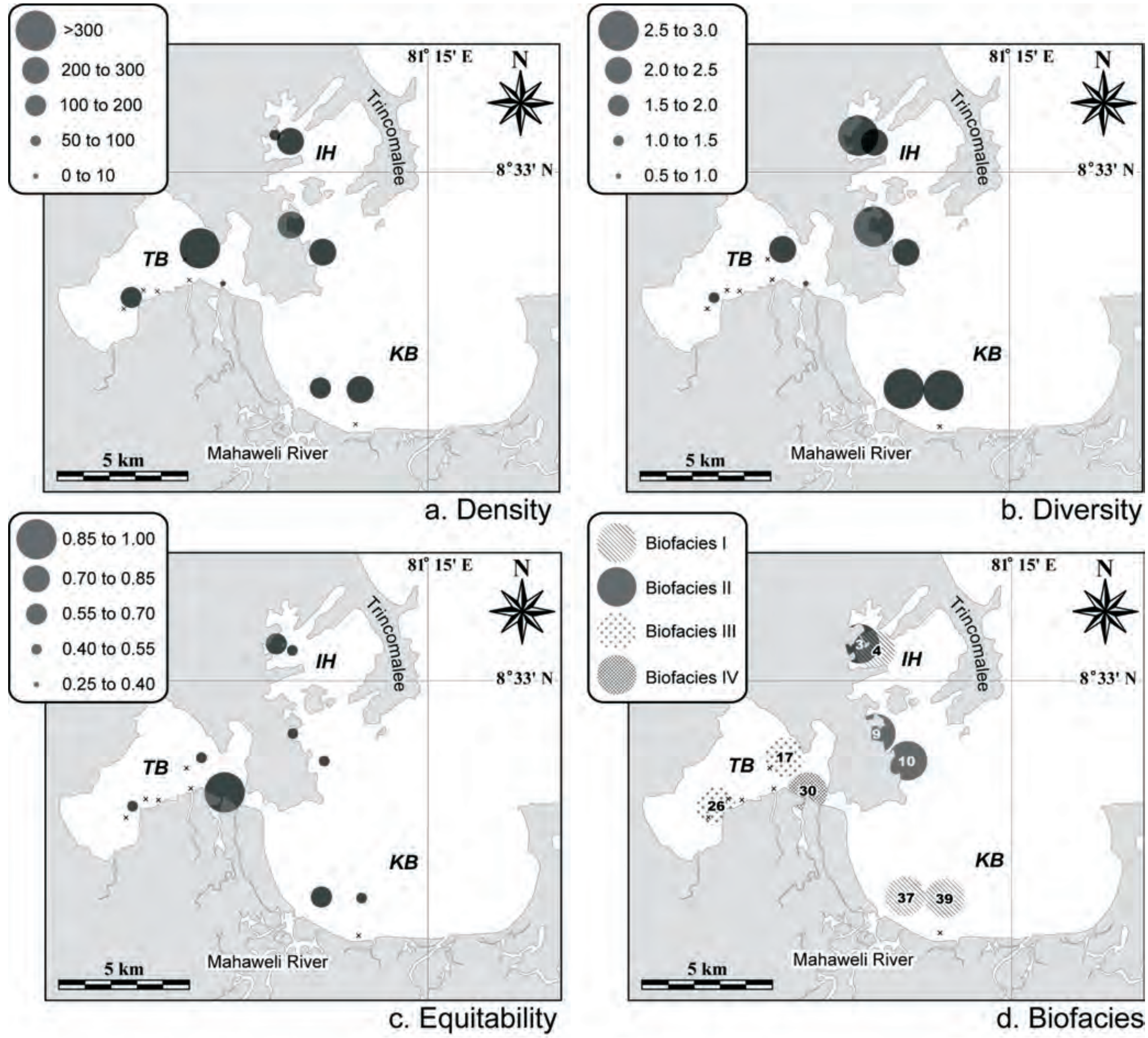


TEXT-FIGURE 5
Distribution of ostracode density (a), diversity (b), equitability (c), and biofacies (d) in Trincomalee Bay. TB: Tambalagam Bay, IH: Inner Harbor, KB: Koddiyar Bay.

REFERENCES

BODERGAT, A. M. and IKEYA N., 1988. Distribution of recent Ostracoda in Ise and Mikawa bays, Pacific coast of central Japan. In: Hanai, T., Ikeya, N., Ishizaki, K. and Kodansha, Eds., *Evolutionary Biology of Ostracoda: Its fundamentals and applications*, 413–428. Amsterdam: Elsevier Scientific Publishing Co., and Tokyo: Kodansha. Developments in Palaeontology and Stratigraphy, no. 11.

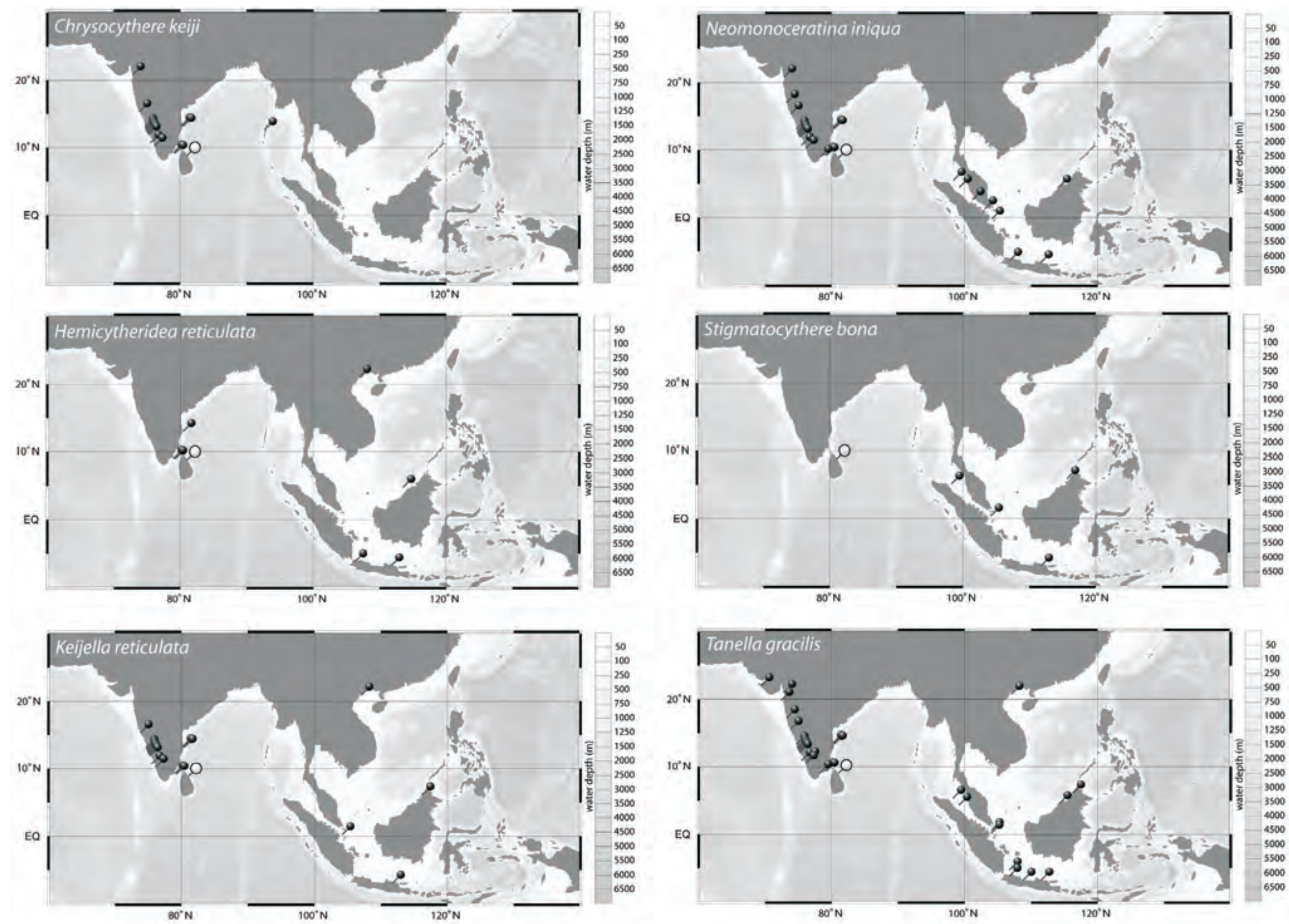
BRADY, G. S., 1886. Notes on Entomostraca collected by Mr. A. Haly in Ceylon. *The Journal of the Linnean Society of London*, 19: 293–317.

BUZAS, M. A. and GIBSON, T. G., 1969. Species diversity: Benthonic foraminifera in western North Atlantic. *Science*, 163: 72–75.

CRONIN, T. M. and VANN, C. D., 2003. The sedimentary record of climatic and anthropogenic influence on the Patuxent Estuary and Chesapeake Bay ecosystems. *Estuaries*, 26: 196–209.

DASSANAYAKE, H., 1984. Shri Lanka. In: Holmgren, S., Ed., *An environmental assessment of the Bay of Bengal region*, 209–218. Madras: Nagaraj & Co.

DEPARTMENT OF CENSUS AND STATISTICS, SRI LANKA, 2012. A2: Population by ethnic group according to districts. http://www.statistics.gov.lk/PopHouSat/CPH2011/index.php?fileNam=pop42&gp=Activities&tpl=3. Accessed 12 May 2013.



TEXT-FIGURE 6
The geographical distribution of dominant species (modified after Marine biodiversity database of India by Bioinformatics Centre, National Institute of Oceanography). White and black head pins indicate the study area and adjacent area's records, respectively.

DEWI, K. T.,1997. *Ostracoda from the Java Sea, West of Bawean Island, Indonesia*. Bandung: Marine Geological Institute. Special Publication, no. 4, 86 pp.

FOLK, R. L. and WARD, W. C., 1957. Brazos River bar: a study in the significance of grain size parameters. *Journal of Sedimentary Petrology*, 27: 3–26.

GOPALAKRISHNA, K., SHABI, B. and MAHESH, B. L., 2008. Distribution of ostracode assemblages along the nearshore and offshore areas of Malabar Coast, Kerala (west coast of India). *Indian Journal of Marine Sciences*, 37: 298–306.

HANAI, T., IKEYA, N., ISHIZAKI, K., SEKIGUCHI, Y. and YAJIMA, M., 1977. *Checklist of Ostracoda from Japan and its adjacent seas*. 119 pp. Tokyo: The University of Tokyo Press.

HORN, H. S., 1966. Measurement of "overlap" in comparative ecological studies. *The American Naturalist*, 100: 419–424.

HUSSAIN, S. M., 1998. Recent benthic ostracoda from the Gulf of Mannar, off Tuticorin, southeast coast of India. *Journal of the Palaeontological Society of India*, 43: 1–22.

HUSSAIN, S. M. and MOHAN, S. P., 2000. Recent Ostracode from Adyar River Estuary, Chennai, Tamil Nadu. *Journal of the Palaeontological Society of India*, 45: 25–31.

———, 2001. Distribution of recent benthic Ostracoda in Adyar river estuary, east coast of India. *Indian Journal of Marine Sciences*, 30: 53–56.

HUSSAIN, S. M., GANESAN, P., RAVI, G., MOHAN, S. P. and SRIDHAR, S. G. H., 2007. 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. *Indian Journal of Marine Sciences*, 36: 369–377.

HUSSAIN, S. M., KRISHNAMURTHY, R., SURESH, G. M., ITAYARAJA, K., GANESAN, P. and MOHAN, S. P., 2006. Micropalaeontological investigations on tsunamigenic sediments of Andaman Islands. *Current Science*, 91: 1655–1667.

HUSSAIN, S. M., MOHAN, S. P. and JONATHAN, M. P., 2010. Ostracoda as an aid in identifying 2004 tsunami sediments: a report from SE coast of India. *Natural Hazards*, 55: 513–522.

IKEYA, N. and SHINOZAKI, M., 1993. Characteristics of the inner bay ostracodes around the Japanese islands –The use of ostracodes to reconstruct paleoenvironments. *Memoirs of the Geological Society of Japan*, 39: 15–32.

IRIZUKI, T., SETO, K. and NOMURA, R., 2008. The impact of fish farming and bank construction on Ostracoda in Uranouchi Bay on the Pacific coast of southwest Japan – Faunal changes between 1954 and 2002/2005. *Paleontological Research*, 12: 283–302.

IRIZUKI, T, TAKATA, H. and ISHIDA, K., 2006. Recent Ostracoda from Uranouchi Bay, Kamikoshiki-jima Island, Kagoshima Prefecture, Southwestern Japan. *Laguna*, 13: 13–28.

IRIZUKI, T., TAKIMOTO, A., SAKO, M., NOMURA, R., KAKUNO, K., WANISHI, A. and KAWANO, S., 2011. The influences of various anthropogenic sources of deterioration on meiobenthos (Ostracoda) over the last 100 years in Suo-Nada in the Seto Inland Sea, southwest Japan. *Marine Pollution Bulletin*, 62: 2030–2041.

ISHIZAKI, K., 1968. Ostracodes from Uranouchi Bay, Kochi Prefecture, Japan. *Science Reports of the Tohoku University, Second Series, Geology*, 40: 1–45.

———, 1969. Ostracodes from Shinjiko and Nakanoumi, Shimane Prefecture, western Honshu, Japan. *Science Reports of the Tohoku University, Second Series, Geology*, 41: 197–224.

———, 1971. Ostracodes from Aomori Bay, Aomori Prefecture, northeast Honshu, Japan. *Science Reports of the Tohoku University, Second Series, Geology*, 43: 59–97.

JAIN, S. P., 1978. Recent ostracoda from Mandvi Beach, west coast of India. *Bulletin of the Indian Geologists Association*, 11: 89–139.

———, 1981. Checklist of Ostracoda from India-1. Cenozoic Ostracoda (Marine). *Journal of the Palaeontological Society of India*, 25: 85–105.

KINGMA, J. T., 1948. “Contributions to the knowledge of the Young-Caenozoic Ostracoda from the Malayan region”. Unpublished doctoral dissertation, Utrecht University, 119 pp.

LILI, FAUZIELLY, IRIZUKI, T. and SAMPEI, Y., 2013. Spatial distribution of recent ostracode assemblages and depositional environments in Jakarta Bay, Indonesia, with relation to environmental factors. *Paleontological Research*, 16: 267–281.

MALMGREN, B. J., HULUGALLA, R., HAYASHI, Y. and MIKAMI, T., 2003 .Precipitation trends in Sri Lanka since the 1870s and relationships to El Niño-Southern Oscillation. *International Journal of Climatology*, 23: 1235–1252.

BIOINFORMATICS CENTRE, NATIONAL INSTITUTE OF OCEANOGRAPHY. *Marine biodiversity database of India*, http://www.biosearch.in. Accessed 7 October 2013.

MINISTRY OF ENVIRONMENT, SRI LANKA, 2011. *Sri Lanka's second national communication on climate change*. Colombo: Climate Change Secretariat, 160 pp.

MOHAN, S. P., RAVI, G. and HUSSAIN, S. M., 2002. Distribution of Recent benthic Ostracoda off Karikkattukuppam (near Chennai), southeast coast of India. *Indian Journal of Marine Sciences*, 31, 315–320.

RAJASURIYA, A., PERERA, N. and FERNANDO, M., 2005. Status of Coral Reefs in Trincomalee, Sri Lanka. In: Souter, D. and Lindén, O., Eds., *Coral reef degradation in the Indian Ocean status,* 97–192. Stockholm: CORDIO Report 2005.

RUIZ, F., ABAD, M., BODERGAT, A. M., CORONEL, P., RODRÍGUEZ-LÁZARO, J. and YASUHARA, M., 2005. Marine and brackish-water ostracods as sentinels of anthropogenic impacts. *Earth-Science Reviews,* 72: 89–111.

RUIZ, F., ABAD, M., OLÍAS, M., GALÁN, E., GONZÁLEZ, I., AGUILÁ, E., HAMOUMI, N., PULIDO, I. and CANTANO, M., 2006. The present environmental scenario of the Nador Lagoon (Morocco). *Environmental Research*, 102: 215–229.

RUIZ, F., BORREGO, J., GONZÁLEZ-RAGALADO, M. L., LÓPEZ GONZÁLEZ, N., CARRO, B. and ABAD, M., 2008. Impact of millennial mining activities on sediments and microfauna of the Tinto River estuary (SW Spain). *Marine Pollution Bulletin*, 56: 1258–1264.

SAMPEI, Y. and MATSUMOTO, E., 2001. C/N ratios in a sediment core from Nakaumi Lagoon, Southwest Japan - usefulness as an organic source indicator. *Geochemical Journal*, 35: 189–205.

SCOTT, A., 1905. Report on the Ostracoda collected by Herdmann at Ceylon in 1902. *Supplementary Report of Ceylon Pearl Oyster Fisheries*, 22: 365–384.

SRIDHAR, S. G. D., HUSSAIN, S. M., KUMAR, V. and PERIAKALI, P., 2002. Recent benthic ostracoda from Palk Bay, off Rameswaram, southeast coast of India. *Journal of the Palaeontological Society of India*, 47: 17–39.

TITTERTON, R. and WHATLEY, R. C., 1988. The provincial distribution of shallow water Indo-Pacific marine Ostracoda: origin, antiquity, dispersal routes and mechanisms. In: Hanai, T., Ikeya, N. and Ishizaki, K., Eds., *Evolutionary biology of Ostracoda: its fundamentals and applications*, 759–786. Tokyo: Kodansha.

WHATLEY, R. and ZHAO, Q., 1988. Recent Ostracoda of the Malacca Straits, Part 2. *Revista Española de Micropaleontología*, 20: 5–37.

WIJAYANANDA, N. P., 1985. Geological setting around the heads of the Trincomalee canyon, Sri Lanka. *Journal of the National Science Council of Sri Lanka, 13: 213–226.*

YAMANE, K., 1998. Recent ostracode assemblages from Hiuchi-nada Bay, Seto Inland Sea of Japan. *Bulletin of Ehime Prefectural Science Museum*, 3: 19–59 (in Japanese with English abstract).

YASUHARA, M. and YAMAZAKI, H., 2005. The impact of 150 years of anthropogenic pollution on the shallow marine ostracode fauna, Osaka Bay, Japan. *Marine Micropaleontology*, 55: 63–74.

YASUHARA, M., YAMAZAKI, H., IRIZUKI, T., YOSHIKAWA, S., 2003. Temporal changes of ostracode assemblages and anthropogenic pollution during the last 100 years, in sediment cores from Hiroshima Bay, Japan. *The Holocene*, 13: 527–536.

YASUHARA, M., YAMAZAKI, H., TSUJIMOTO, A. and HIROSE, K., 2007. The effect of long-term spatiotemporal variations in urbanization-induced eutrophication on a benthic ecosystem, Osaka Bay, Japan. *Limnology and Oceanography*, 52: 1633–1644.

ZHAO, Q. and WHATLEY, R, 1988. The genus Neomonoceratina (Crustacea: Ostracoda) from the Cainozoic of the West Pacific margins. *Acta Oceanologica Sinica*, 7: 562–577.