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Distribution of Recent Ostracoda in Offshore Sediment of the South China Sea

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ABSTRACT

A study on the distribution of Recent Ostracoda in offshore sediment was carried out around the South China Sea. A total of 30 sediment samples were taken from the sampling stations between latitude 1°48' and 7°25'N and longitude 102°09' and 105°16'E. From this study, 79 species of ostracods belonging to 16 families and 44 genera were identified. The dominant species was *Foveoleberis cypraeoides* with 937 individuals obtained. There were 13 to 43 species in total. Diversity Index, H(s), was in the range of 2.1 to 3.3, whereas the dominance values were between 4.4 and 14.7%. Several environmental parameters were measured including depth, temperature and salinity. The range values for each of these parameters are 13-72 m, 25.24-30.06^{o}C and 27.74-34.91 ppt, respectively. The sediment texture in this study area can be categorized as sand, sandy mud, clayey mud, silty mud, silty clay, clayey sand, clayey silt and silty sand. The observations revealed that abundance and diversity of ostracod appeared to be principally controlled by depth. Two faunal assemblages were identified in terms of faunal composition, namely, shallow water (*Hemikrithe orientalis, Neomonoceratina iniqua, Stigmatocythere indica, Cytherelloidea leroyi* and *Neocytheretta snellii*) and deep water (*Paracypris* sp., *Alataconcha pterogona, Bythocytheropteron alatum, Keijella paucipunctata* and *Actinocythereis scutigera*). A comparative analysis showed a high degree resemblance between the study area and south-eastern Malay Peninsula (the South China Sea).

Keywords: Abundance, diversity, Recent Ostracoda, depth, assemblages

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INTRODUCTION

Among crustaceans, ostracods are the most diverse groups of living crustaceans, whereas these are abundantly represented by fossil arthropods with about 33,000 species (Cohen *et al*., 1998). All of them are essentially aquatic, inhabiting both marine and non-marine environments, although some taxa are

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adapted to semi-terrestrial life. The majority of ostacods are free living (benthonic or pelagic) but some are commensal on other crustaceans, echinoderms and even on sharks. The class of ostracoda is subdivided into two, namely, Myodocopa and Podocopa. The vast majority of ostracods encountered in Quaternary sediments are likely to be Podocopids (Horne *et al*., 2002). Ostracods are widely used in biostratigraphy, in determining palaeoenvironments and palaeoclimates and are indispensable as indicators of ancient shorelines and plate distributions. Recent ostracods from the South China Sea have been the subject of numerous investigations in the last decades (e.g., Gou *et al*., 1983; Zhao *et al.*, 1985; Gou, 1990; Whatley & Zhao, 1993; Zhao, 2005). However, information on ostracods from Malaysian waters, particularly in the South China Sea, is comparatively inadequate. An important work on the recent ostracoda of the south eastern Malay Peninsula has been contributed by Zhao and Whatley (1989), wherein ostracods from shallow waters (< 20 m) from the Sedili River and Jason Bay regions were described. Another study on the recent ostracoda of the Malacca Straits was done by Whatley and Zhao (1987 & 1988) who reported a total of 129 species, among which 22 species and 2 genera (*Bythocytheropteron* and *Alataconcha*) are described as new from 18 bottom samples taken from depths ranging from 20 to 100 m. The abundance and diversity of ostracods were found to be influenced by the types of substrate. Thus, this study will provide a more complete list of species and patterns of ostracods distribution in relation to different environmental parameters. The present paper is an attempt to study the distribution of ostracods in this area and to provide a comparative analysis of this group in this region.

MATERIALS AND METHODS

Thirty sediment samples were collected from thirty sampling stations around the South China Sea during June, 2008 (Fig.1). A Smith McIntyre grab sampler was used to collect the sediments over a surface of about 400 cm^2. Several environmental parameters such as temperature, salinity, depth, and sediment type were measured in the study area. The types of sediment were determined in the laboratory, as follows: grain coarser than 2 mm was considered as gravel, from 2 mm to 0.063 mm as sand, from 0.002 to 0.063 mm as silt and finer than 0.002 mm as clay. Using the information of grain distribution, all the samples were classified using a triangular diagram of Folk (1980) on the basis of percentages of sand, silt and clay. For ostracods, the samples were washed over three different size sieves, namely, 0.50 mm, 0.15 mm and 0.063 mm, and dried at 60°C in an oven. The specimens were picked, identified and counted. The data obtained were used to compute the species diversity (number of species in each sample), abundance (specimen number in each sample) and dominance (percentage of the most abundance species in each sample). The Shannon-Wiener's diversity indices, H(s), and correlation analysis were calculated using PAST (Palaeontological Statistics) software to elucidate the nature of the various ostracod communities and their relationships with environmental factors and types of sediment. The species were identified using Scanning Electron Microscopy (SEM) and Light Microscopy (LM). For identification purposes, a comparison was carried out on the morphology features between the collected specimens with the ostracods species that had been recorded by earlier researchers (Zhao *et al.,* 1985; Whatley & Zhao, 1987; 1988; Zhao & Whatley, 1989; Gou, 1990; Mostafawi, 1992; Dewi, 2000).

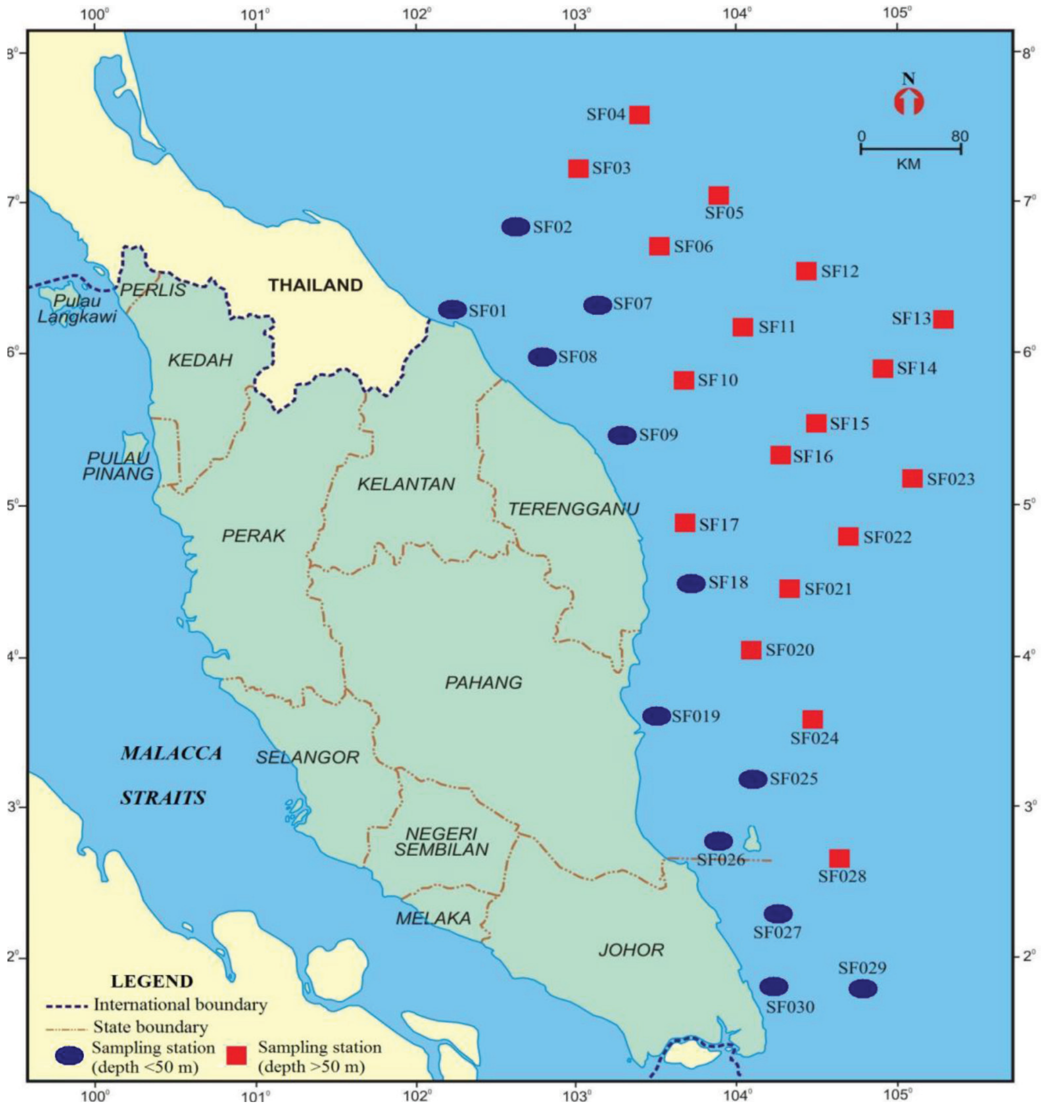

Fig.1: Location of the sampling stations in the South China Sea

RESULTS AND DISCUSSION

Environmental Factors

In marine environments, salinity, substrate types, temperature and depth mostly govern the distribution and diversity of ostracodas (Armstrong & Brasier, 2005). The environmental data and faunal composition are given in Table 1. Station SF11 showed the deepest depth (72 m) and station SF01 had the lowest depth (13 m) from all 30 sampling stations (Table 1). As for water temperature, the maximum value was 30.06°C at station SF01, and the minimum value was 25.24°C at station SF24 (Table 1). For salinity, station SF13 showed the maximum value, i.e. 34.91 ppt. The minimum value for salinity was 27.74 ppt at station SF24 (Table 1). The

TABLE 1
Environmental data and faunal composition of ostracoda at sampling stations

Station	Location		Sampling area	Depth (m)	Temperature (°C)	Salinity (ppt)	Type of sediment	No. of Species	Index of diversity
	Longitude (E)	Latitude (N)							
SF01	102°19’00.3”	06°13’59.0”	Kelantan	13	30.06	33.64	Clayey mud	25	2.6
SF02	102°47’03.2”	06°50’02.5”	Kelantan	47	27.06	34.80	Silty clay	29	2.7
SF03	103°05’03.6”	07°05’01.6”	Kelantan	50	27.00	34.78	Clayey mud	27	2.9
SF04	103°26’01.8”	07°25’59.4”	Kelantan	62	26.93	34.18	Clayey silt	38	3.2
SF05	103°56’03.2”	06°56’07.7”	Kelantan	54	26.58	28.90	Silty sand	33	3.0
SF06	103°35’03.7”	06°42’08.5”	Kelantan	52	26.55	34.75	Silty sand	36	3.0
SF07	103°01’00.1”	06°10’06.1”	Kelantan	45	26.79	34.77	Sandy mud	30	2.9
SF08	102°51’56.7”	05°52’06.6”	Kelantan	34	26.64	34.70	Clayey sand	30	2.7
SF09	103°21’58.6”	05°22’04.6”	Terengganu	47	26.19	34.60	Sandy mud	38	3.0
SF10	103°48’10.0”	05°48’59.9”	Terengganu	55	27.10	34.72	Clayey sand	31	2.8
SF11	104°09’07.8”	06°06’09.4”	Terengganu	72	26.98	34.71	Silty clay	42	3.3
SF12	104°22’06.9”	06°32’01.3”	Terengganu	56	27.34	34.71	Silty clay	29	2.8
SF13	105°16’54.9”	06°16’54.8”	Terengganu	55	29.54	34.91	Sand	27	2.9
SF14	104°58’08.5”	05°57’09.4”	Terengganu	56	29.37	34.64	Sand	29	2.9
SF15	104°29’00.5”	05°29’06.3”	Terengganu	60	28.87	34.86	Sand	29	2.9
SF16	104°12’37.1”	05 18’23.3”	Terengganu	60	29.02	34.89	Sand	21	2.6
SF17	103°42’59.5”	04°54’07.0”	Terengganu	55	27.57	34.68	Sand	37	3.0
SF18	103°49’51.7”	04 29’02.7”	Terengganu	45	28.51	34.47	Sand	31	3.0
SF19	103°41’04.5”	03°37’06.0”	Pahang	24	29.13	34.41	Sand	13	2.1
SF20	104°00’02.6”	03°55’05.1”	Pahang	51	26.29	34.67	Clayey sand	37	3.2
SF21	104°22’04.1”	04°22’05.8”	Pahang	66	25.32	34.76	Clayey silt	38	3.2
SF22	104°38’30.7”	04°44’30.3”	Pahang	63	25.34	34.81	Clayey silt	37	3.2
SF23	105°12’54.1”	05°08’04.1”	Pahang	67	26.41	31.24	Clayey mud	36	3.2

TABLE (Continue)

SF24	104º36’00.0”	03º31’59.6”	Pahang	62	25.24	27.74	Silty sand	37	3.1
SF25	104º09’01.5”	03º09’09.1”	Pahang	41	25.95	34.76	Sand	43	3.2
SF26	103º49’59.5”	02º56’08.8”	Pahang	20	27.72	34.48	Sand	36	3.0
SF27	104º16’59.1”	02º16’57.6”	Johor	30	28.82	34.28	Clayey sand	28	2.7
SF28	104º38’55.9”	02º39’08.5”	Johor	58	25.28	34.78	Silty sand	32	3.1
SF29	104º41’58.7”	02º00’30.1”	Johor	46	27.55	34.44	Sandy mud	30	3.0
SF30	104º15’01.2”	01º48’02.9”	Johor	14	29.20	34.10	Silty mud	24	2.5

nature of the substrate has a pronounced effect on the composition of ostracoda communities. The sediment-inhabiting species live either at the surface of the sediment or within the sediment. The sediment texture in this study area can be categorized as sand, sandy mud, clayey mud, silty mud, silty clay, clayey sand, clayey silt and silty sand (Table 1). Correlation analysis showed that only depth was positively and significantly correlated ($P<0.05$) with the abundance of ostracods, while other parameters (temperature, salinity and type of sediment) did not show any significant correlation.

Abundance and Diversity

A total of 79 species belonging to 44 genera were identified from about 11,148 specimens that had been picked from the sediment samples. Out of these, 77.3% of species belong to Cytheracea, 6.3% to the Cypridacea, 3.8% to Bairdiacea, 10.1% to Cytherellidae, and 2.5% to Polycopidae. All of the ostracods were podocopid and only one species was from the order of myodocopida. Most of the cytheraceans belong to Trachyleberididae (30 species, 38.0%), followed by Cytherellidae (8 species, 10.1%) and Hemicytheridae (6 species, 7.6%). Representatives of these families are typical of infralittoral marine environments around the world. The number of species ranged from 13 to 43 species. The highest species diversity was recorded at station SF25. The H(s) values were from 2.1 to 3.3, with the highest value at station SF11 and the lowest at station SF19 (Table 1). The dominance was from 4.4 to 14.7%. These illustrated the ostracod diversity in the study area. The dominant species was *Foveoleberis cypraeoides* (1137 specimens or 10.20%), followed by *Loxoconcha paiki* (1119 specimens or 10.03%). The selected species from the SEM micrograph are shown in Plate 1.

The abundance and diversity are most related to the depth factor. A correlation analysis showed that depth was positively and significantly correlated ($r=0.650$, $P<0.05$) with Index of Diversity, H(s). The highest value of H(s) lies at the deepest station (Table 1). Meanwhile, the values of H(s) seemed to increase slightly with water depth (Fig.2). A correlation analysis showed that depth was negatively and significantly correlated ($r=-0.726$, $P<0.05$) with dominance, D. The value of dominance decreased with increasing water depth (Fig.3).

Some published reports (Zhao & Whatley, 1989) suggested that depth was also a controlling factor in the abundance and diversity of recent podocopid ostracoda in the south-eastern of Malay Peninsula. More specifically, they found that the Index of Diversity, H(s), slightly increased with depth and the dominance decreased with water depth. The shelf or neritic assemblages occurred between 0 to 200 m depth, and they included many of the marginal marine forms whereas the densest populations were found in the marginal areas, with the highest diversities tended to occur in a shallow-shelf sea. The Ostracod species in marginal marine environments is markedly lower than in non-marine and fully marine ecosystems (Boomer & Eisenhauer, 2002). In high energy shallow waters, both diversity and density of the ostracods were lower than in deeper and more stable environments. The absence or the lowest number of species in shallower samples, closer to the coast, could be mainly due to the instability of the bottom sediment due to the wave action (Whatley *et al.*, 1995; Ramos *et al.*, 1999; Machado *et al.*, 2005).

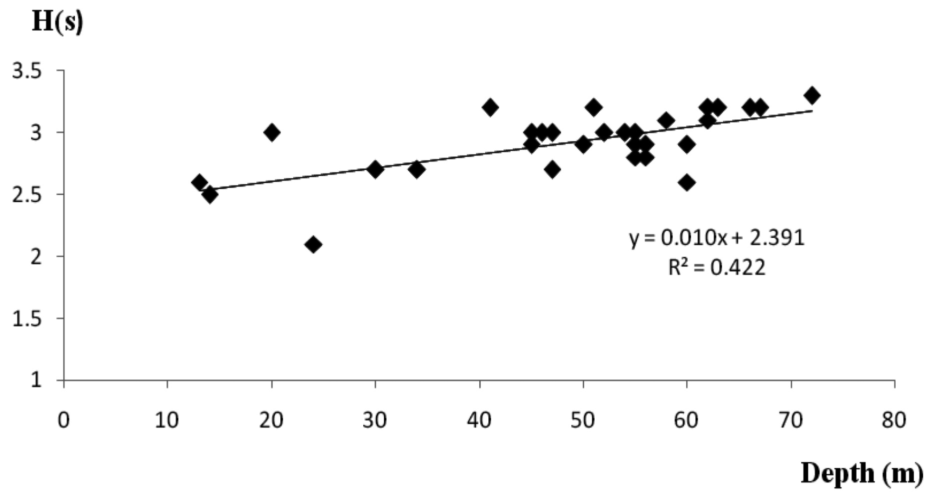

Fig.2: Variations in H(s) with water depth (m)

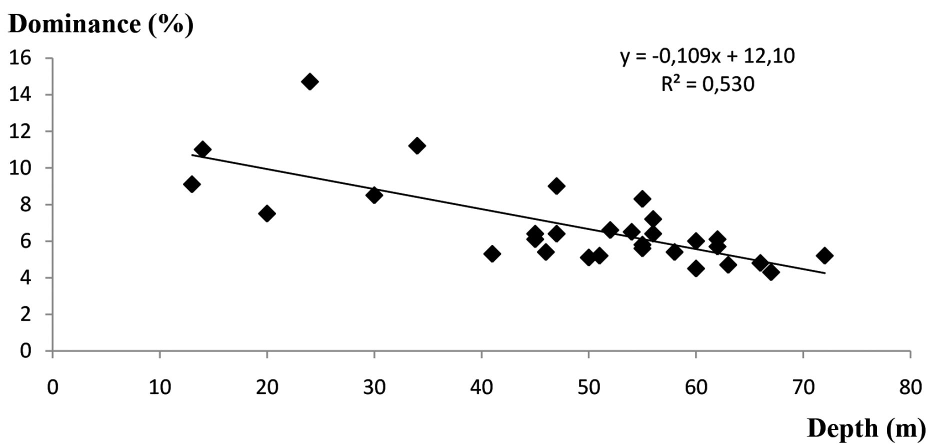

Fig.3: Variations in dominance (%) with water depth (m)

The presence of thick valves with eye spots, strong sculpture, amphidont hinges and conspicuously branched pore canals are the features common in extant shallow-water ostracods from coarse grained substrates such as *Neomonoceratina iniqua* and *Stigmatocythere indica* (Table 2). Deeper water neritic substrates, which also tend to be finer grained, support forms with smooth, thin, often translucent carapaces with relatively weak hinges and no eyes or eye spots (Armstrong & Brasier, 2005). The results also showed that the species *Paracypris* sp. and *Bythocytheropteron alatum* were found in deeper water (Table 2). The Platycopina such as *Cytherella semitalis, Cytherelloidea cingulata, Cytherelloidea leroyi and Cytherelloidea malaccaensis* become an important element of the fauna in the deeper parts of the Jason Bay (Zhao & Whatley, 1989).

Assemblages

In this paper, we use the following terms, 'abundant', 'common' and 'rare' to describe the incidence of one species in its sample. 'Abundant' indicates that one species has a percentage of more than 10% of the total specimens of the samples; 'common' indicates 5 to 10%, and 'rare' indicates less than 5%. Most of the species obtained in the study area are rare. Only two species are abundant (*Foveoleberis cypraeoides* and *Loxoconcha paiki*), while 14 other species are common in the study area (Table 2). Some of these species were found to be widespread throughout the entire study area (*Pistocythereis bradyi, Foveoleberis cypraeoides, Hemicytheridea reticulata, Phlyctenophora orientalis, Loxoconcha paiki* and *Keijella multisulcus*). It was observed that other species displayed a restricted distribution and dominated only in certain areas.

The observations made in the present study revealed two broad assemblages; shallow water fauna (< 50 m depth) comprising *Hemikrithe orientalis, Neomonoceratina iniqua, Stigmatocythere indica, Cytherelloidea leroyi* and *Neocytheretta snellii* (Table 2) and the deep water (> 50m depth) assemblage was distinguished by *Paracypris* sp*., Alataconcha pterogona, Bythocytheropteron alatum, Keijella paucipunctata,* and *Actinocythereis scutigera* (Table 2). Earlier reports (Zhao & Whatley, 1989) on recent podocopid ostracoda from south-eastern Malay Peninsula found that the dominant species (*Hemicytheridea reticulata, Neomonoceratina delicata, Neomonoceratina iniqua* and *Lankacythere coralloides*) were ubiquitous and most abundant in all the open sea samples. The common species (*Actinocythereis scutigera, Phlyctenophora orientalis* and *Stigmatocythere roesmani*) occurred more frequently in deeper water (10 to 20 m) compared to *Keijella jankeiji* which was confined to shallow water (0 to 7 m).

TABLE 2
Distribution of the species in the South China Sea

SPECIES	STATION (SF)																													
	< 50 m												> 50 m																	
	1	2	7	8	9	18	19	25	26	27	29	30	3	4	5	6	10	11	12	13	14	15	16	17	20	21	22	23	24	28
Loxoconcha paiki	C	C	C	R	R	R	R	C	R	R	C	R	R	C	A	A	C	A	R	R	C	C	R	C	C	C	C	R	A	C
Foveoleberis cypraeoides	R	C	C	C	R	C	R	C	C	R	A	R	C	R	A	A	A	A	R	C	R	C	C	A	C	R	R	C	C	R
Pistocythereis bradyi	C	C	C	-	R	R	-	C	R	R	C	C	R	C	R	R	C	C	-	C	A	R	A	A	R	R	R	C	C	R
Phlyctenophora orientalis	R	C	R	-	R	C	-	C	R	C	C	R	C	R	-	C	C	A	R	C	A	C	C	C	R	R	C	R	C	R
Hemicytheridea reticulata	C	R	C	R	R	C	R	R	-	R	A	R	R	C	R	R	C	A	-	C	C	C	A	C	R	R	C	R	R	R
Keijella multisulcus	R	C	R	-	-	A	C	C	R	C	R	C	R	C	R	C	R	C	-	R	R	C	A	R	R	R	R	C	A	R
Hemikrithe orientalis	C	A	C	C	R	A	C	A	C	C	C	R	R	R	-	R	R	-	-	R	R	R	R	R	-	-	R	R	R	-
Neomonoceratina iniqua	R	C	C	R	C	A	C	A	C	-	C	C	-	R	R	R	R	R	R	R	R	-	-	R	R	R	R	-	R	R
Stigmatocythere indica	C	C	R	C	C	C	A	R	C	C	R	C	R	-	R	-	R	-	-	R	R	R	R	R	R	R	R	-	-	R
Cytherelloidea leroyi	C	A	R	R	C	A	C	C	C	R	C	C	R	R	R	R	-	-	-	R	R	-	R	R	-	-	R	R	R	-
Neocytheretta snellii	C	C	C	C	R	C	C	C	A	A	A	R	R	R	-	-	R	R	-	-	-	R	R	-	R	R	-	-	-	C
Actinocythereis scutigera	R	R	R	R	-	C	-	R	R	-	C	R	C	C	R	C	R	R	R	C	C	C	A	C	R	R	R	-	R	-
Keijella paucipunctata	C	C	C	R	R	-	-	R	R	-	-	-	R	C	C	C	R	C	R	C	C	C	A	R	-	-	R	C	C	-
Bythocytheropteron alatum	R	R	R	-	R	R	R	R	R	-	R	-	C	R	C	C	R	C	C	C	A	C	A	C	R	R	C	C	C	-
Alataconcha pterogon	-	-	R	-	-	-	-	R	-	-	-	-	R	C	C	R	R	R	R	C	C	R	R	C	-	R	C	C	C	-
Paracypris sp.	R	-	-	-	-	R	-	-	-	-	-	-	C	C	R	R	-	R	C	C	C	C	R	R	-	-	-	R	C	-

LEGEND
A – abundant (more than 10%) C – common (5 to 10%) R – rare (less than 5%)

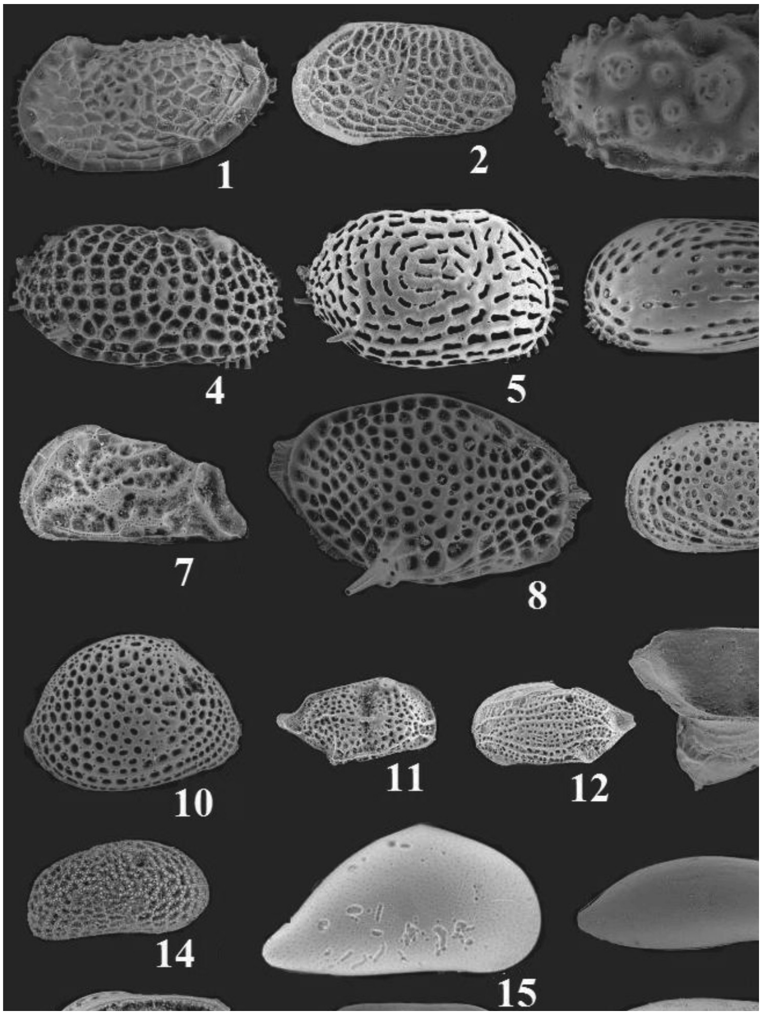

Fig.4: 1.) *Neocytheretta murilineata* (Zhao & Whatley, 1989); left valve, x400, sample station SF01; 2.) *Hemikrithe orientalis* (Van den Bold, 1950); left valve, x400, sample station SF03; 3.) *Actinocythereis scutigera* (Brady, 1868); right valve, x200, sample station SF04; 4.) *Pistocythreis bradyi* (Ishizaki, 1968); right valve, x300, sample station SF03; 5.) *Lankacythere euplectella* (Brady, 1869); right valve, x300, sample station SF03; 6.) *Keijella multisulcus* (Whatley & Zhao, 1988); left valve, x400, sample station SF04; 7.) *Caudites scopulicolus* (Hartmann 1981); left valve, x400, sample station SF01; 8.) *Alataconcha pterogona* (Zhao, 1985); right valve, x200, sample station SF03; 9.) *Loxoconcha paiki* (Whatley & Zhao, 1987); left valve, x400, sample station SF10;10.) *Foveoleberis cypraoeides* (Brady, 1868); right valve, x300, sample station SF10;11.) *Neomonoceratina macropora* (Kingma, 1948); right valve, x500, sample station SF01;12.) *Semicytherura contraria* (Zhao & Whatley, 1989); left valve, x500, sample station SF01;13.) *Bythocytheropteron alatum* (Whatley & Zhao, 1987); right valve, x400, sample station SF04;14.) *Corallicythere* sp., right valve, x400, sample station SF01; 15.) *Propontocypris* sp., right valve, x400, sample station SF10; 16.) *Paradoxostoma* sp., right valve, x300, sample station SF04; 17.) *Cytherelloidea cingulata* (Brady, 1869), left valve; x300, sample station SF10; 18.) *Cytherella semitalis* (Brady, 1868); right valve, x400, sample station SF07; Fig.19.) *Cytherella* sp., right valve, x500, sample station SF04.

Comparison

A comparative analysis of the data collected in the present study with the adjacent area showed a high degree of resemblance with south-eastern Malay Peninsula fauna, South China Sea (Zhao & Whatley, 1989). Out of the 79 species obtained, 51 were found to be common to both areas. Among these, a few species were found to be widespread (*Pistocythereis bradyi, Hemicytheridea reticulata* and *Phlyctenophora orientalis*). The above species were also found to be reported earlier from the Straits of Malacca (Whatley & Zhao, 1987; 1988), Sunda Shelf (Mostafawi, 1992), and Java Sea (Dewi, 2000).

The observations made revealed that a large number of species were common between the study area and south-eastern Malay Peninsula. However, the dominant species was different and this could probably be due to the difference in water depth in the study area. The dominant species in the south-eastern Malay Peninsula were *Hemicytheridea reticulata, Neomonoceratina bataviana, Neomonoceratina delicata* and *Lankacythere coralloides*. The abundant species included *Actinocythereis scutigera, Alocopocythere kendengensis, Keijella jankeiji, Keijella papuensis, Parakrithella pseudadonta, Phlyctenophora orientalis, Pistocythereis bradyi, Stigmatocythere roesmani* and *Tanella gracilis* (Zhao & Whatley, 1989). The present study reported six species (*Pterygocythereis* sp., *Hemicytherura* sp., *Cytherella* sp., *Caudites* sp., *Polycope orbulinaeformis* and *Trachyleberis* sp.) as new records in Malaysian waters.

CONCLUSION

The recognised ostracod fauna constituted by a total of 79 species belonging to 44 genera were identified from the study area. A shallower water (< 50 m) fauna is characterized by *Hemikrithe orientalis, Neomonoceratina iniqua, Stigmatocythere indica, Cytherelloidea leroyi* and *Neocytheretta snellii,* while a deeper water (>50 m) fauna is distinguished by *Paracypris* sp*., Alataconcha pterogona, Bythocytheropteron alatum, Keijella paucipunctata* and *Actinocythereis scutigera*. However, some of these fauna (*Pistocythereis bradyi, Feveoleberis cypraeoides, Hemicytheridea reticulata, Phlyctenophora orientalis, Loxoconcha paiki* and *Keijella multisulcus*) were widespread throughout the entire study area. The analysis and comparison showed that a high degree of faunal replication between the study area and south-eastern Malay Peninsula (South China Sea). A total of 51 species are common to the two areas, with relative abundance and distribution (*Pistocythereis bradyi, Hemicytheridea reticulata* and *Phlyctenophora orientalis*).

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