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Habitat segregations and adaptive morphology of ostracodes in intertidal zones in Indonesia

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ABSTRACT

The intertidal ostracode fauna from Indonesia, all composed of alive specimens on seaweeds, were studied. Seaweeds, composed of about 15 species, were taken from Madura and Bali Islands. The most dominant taxa in the fauna were family Paradoxotomatidae (genera: *Paradoxostoma* s.l., *Brunneostoma* and *Bradystoma*) and genus *Xestoleberis*. The preference of the species to their habitats were clearly recognized; e.g. *Brunneostoma* sp. 1 and *Paradoxostoma* s.s. were dominant on short filamentous algae, *Chondria* and *Bostrychia* respectively while *Brunneostoma* sp. 2 and *Bradystoma* sp. were dominant on tall and smooth-surface algae such as *Prionitis* and *Mastophora*, respectively. This study also gives a good example of morphological adaptation to the habitats by Paradostomatidae. Species living on tall and smooth-surface algae in the wavy rocky shores have specialized large mouth-part which is used as a sucker to stick to the surface of the algae, and this is a reason why Paradoxostomatidae is the only ostracode taxon able to live on such slippery seaweeds. The result indicates that ostracodes will be a good material for the reconstruction of precise intertidal paleoenvironments.

Key words : *Ostracodes, Intertidal zone, Microhabitat, Adaptation, Indonesia*

Introduction

Cytheroidean ostracodes is a small crustacea with a calcified carapace which can be preserved as a fossil/subfossil in marine sediments. The ostracodes has diversified to distribute in various environments with special adaptations (e.g. Kamiya, 1988). Therefore, with the sufficient information on living species, ostracodes will be a good tool to estimate paleoenvironment and an evolutionary process. Although several works on ostracodes in Indonesia were already reported (Dewi, 1993; Mostafawi *et al.*, 2005), our knowledge of living ostracode fauna in this area is still imperfect. This is also true for the works on Southeast Asian ostracodes where reports were limited to the occurrence of the species (alive and dead specimens) from sediments with little attention to their original habitat (e.g. Quanhong and Whatley, 1989; Tanaka *et al.*, 2009). Thus, the studies on the habitat (microhabitat) of ostracodes and their mode of life are very important to be done for both the paleoenvironmental and evolutionary study. This paper aimed to be the first study to understand the main species of living ostracode fauna in various seaweeds in the intertidal zone and their adaptation in Indonesia and Southeastern Asia.

Materials and Methods

Fifteen seaweed samples, composed of about 15 spe-

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cies, were taken from two islands, Madura and Bali Islands (Fig. 1). The two sites in Bali were both open rocky beach coast while the two sites in Madura were relatively embayed sandy and muddy beach where seaweeds were distributed on the coral fragments. Physical parameters of pH and temperature were recorded in situ (Table 1). The morphological features of the algae were temporally classified into two types in this study based on their general shape, branching and surface conditions: one is the "tall and smooth-surface type" algae (e.g. *Prionitis* sp. and *Mastophora* sp.) and another is the "filamentus type" algae, which is short, bushy and encrusting on the rocky shore (e.g. *Chondria* sp. and *Bostrychia* sp.). In Bali, two types of algae were found in terms of their morphological features, but only tall and smooth-surface algae were found from Madura (Table 2). We collected algae and placed them in a bucket, thoroughly washed with seawater, sieved and got the residues between 0.063-1 mm grain-size. The residues were then stored in 70% ethanol. Ostracodes were picked up from the residues under binocular microscope using a small syringe. In order to identify the species and to study their adaptation to microhabitats, the ostracodes were dissected using hand-made thin needle and dissected appendages were enclosed in Neoshigaral (mounting medium) on slide-glass. The soft-parts such as mouthpart, sexual organ, maxilula, mandible, antennae, antennulae, first, second and third thoracic legs

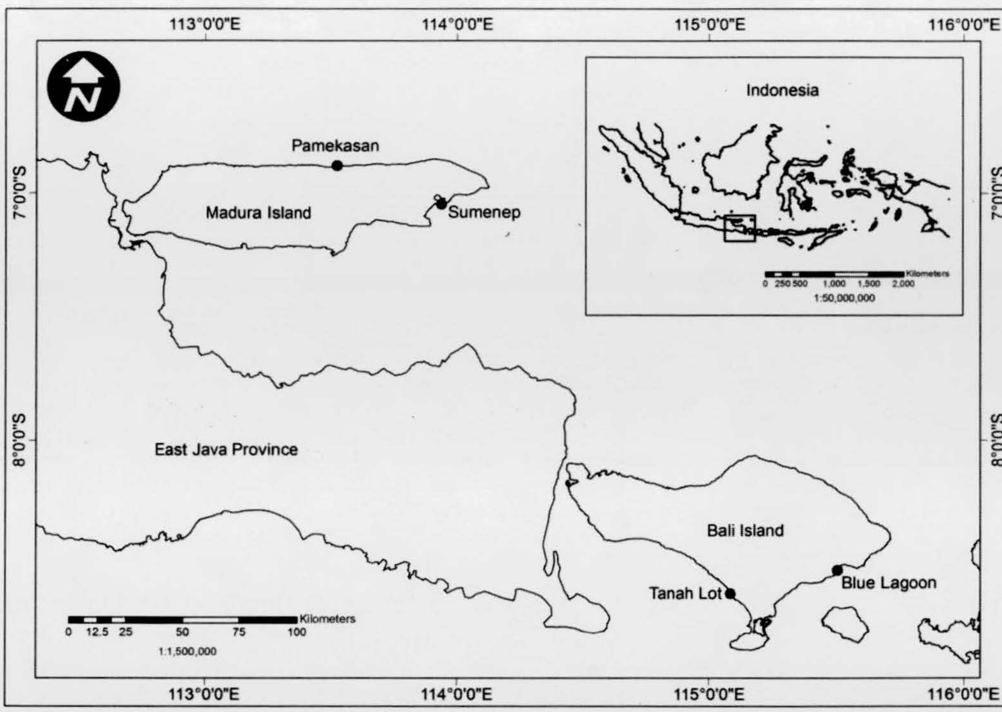

Fig. 1. Map of Madura and Bali Islands Indonesia, showing four sampling sites, two in Madura and two in Bali Islands.

Table 1. Type of beach, pH, and water temperature recorded in the sampling sites.

Islands	Bali		Madura	
Sites	Tanah Lot	Blue Lagoon	Pamekasan	Sumenep
Type of beach	Rocky beach	Rocky beach partly sandy with coral fragments	Sandy muddy beach with coral fragments	Sandy muddy beach with coral fragments
No. of samples	10	3	1	1
pH	8.1	7.9	8.3	8.4
Temperature (°C)	30.5	27.8	30.5	30

were observed and illustrated. SEM were used to observe the detail of mouthpart and carapace.

Results

Species composition in open and embayed coasts

As the results, 21 ostracode species were found. The details of the fauna is to be described in the separated paper. Two families, Paradoxostomatidae and Xestoleberididae, were found to be dominant in terms of number of species and abundance in the phytal faunas. Paradoxostomatidae has 10 species and Xestoleberididae has 4 species, and other families such as Loxoconchidae, Hemicytheridae and Bairdidae were subordinate. Out of the 21 species there are species were proved to be dominant (50% in more than one sample) in Bali and Madura. They were *Brunneostoma* sp. 1, *B.* sp. 2, *Paradoxostoma* (s.l.) sp., *Bradystoma* sp., *Xestoleberis* spp. (Fig. 2).

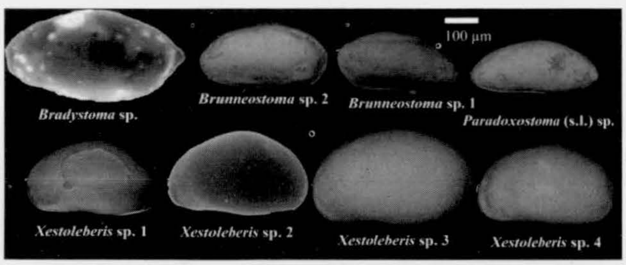

Fig. 2. Lateral left view of carapace of six dominant ostracode species in Bali and Madura Islands (1: *Bradystoma* sp., 2: *Brunneostoma* sp. 2, 3: *Brunneostoma* sp. 1, 4: *Paradoxostoma* (s.s.) sp., 5: *Xestoleberis* sp. 1, 6: *Xestoleberis* sp. 2), the scale is 50 µm.

In the open and wavy rocky shores (Tanah Lot and Blue Lagoon in Table 1), the living phytal fauna was mainly composed of the genera such as *Brunneostoma, Paradoxostoma* (s.l.), *Bradystoma* (all Paradoxostomatidae) and *Xestoleberis* (Table 2). On the other hand, on the seaweeds in the relatively embayed sandy shores (Pamekasan and Sumenep in Table 2), the fauna was dominantly consisted with *Xestoleberis*, accompanied by subordinate species such as Paradoxostomatidae and Loxoconchidae (Table 2).

Preference for specific seaweed by ostracode species

Table 2 shows the result of the relationship between

Table 2. The composition of ostracode species found in particular algae species in Bali and Madura Islands, Indonesia. The notation represents the percentage of ostracodes, x=31-40%, xx=41-60%, xxx=61-80%, xxxx=more than 81%, while notation with parenthesis means the total number of ostracode less than 40 individuals in sample.

Type of Algae	Location	Algae Species	*Brunneostoma* sp. 1	*Brunneostoma* sp. 2	*Paradoxostoma* (s.l.) sp.	*Bradystoma* sp.	*Xestoleberis* sp.1+sp.2+ sp.3+sp.4
Tall and smooth-surface algae	Tanah Lot	Ulva sp.	(xxx)				
		Sargassum sp. 1			(xxx)		
		Grateloupia sp.		(x)			
		Galaxaura sp.			(xxx)		
		Padina sp.			(xxxx)		
		Nemalion sp.				(xxxx)	
		Mastophora sp.				(xxxx)	
		Chondrus sp.				(xxxx)	
	Blue lagoon	Prionitis sp.		xxx			
		Chlorodesmis sp.			(xx)		
	Pamekasan	Gigartina sp.					xx
	Sumenep	Sargassum sp.2					xxxx
Fillamentus algae	Tanah Lot	Chondria sp.	xxx				
		Bostrychia sp.			xxxx		
	Blue Lagoon	gen. et. sp. indet.					xxxx

6 main ostracode species, algae species of their habitats, and the morphological features of the algae. It is interesting that one species of algae generally attached by single dominant species of ostracode. For example, *Ulva* sp. dominated by *Brunneostoma* sp. 1, *Sargasum* sp. 1 dominated by *Paradoxostoma* s.l., *Prionitis* sp. dominated by *Brunneostoma* sp. 2, *Mastophora* sp. dominated by *Bradystoma* sp., and *Sargassum* sp. 2 dominated by *Xestoleberis* spp. *Paradoxostoma* (s.l.) sp. is the most flexible to the habitats selection and found from five species of algae, followed by *Bradystoma* sp. and *Xestoleberis* spp. from three algal species. Meanwhile, *Brunneostoma* sp.1 was only found from two species of algae, *Ulva* sp. and *Chondria* sp. The same is true for *Brunneostoma* sp. 2 (*Prionitis* sp. and *Grateloupia* sp.). However, those estimates include the data with low total individual number (less than 40) of the fauna (e.g. *Ulva* sp. *Sargassum* sp.1 and *Grateloupia* sp.)

Adaptation of Paradoxostomatidae and Xestoleberididae to microhabitats

The relationships between the main ostracode species, type of the main habitat of algae, diameter of the ostracode fused mouthpart (suctorial disk for Paradoxostomatidae) and the shape of the claw at the tip of walking legs are shown in Table 3. Figure 3 shows the species attach to "tall and smooth-surface" algae have larger mouth diameter (61 µm for *Brunneostoma* sp. 2 and 72 µm for *Bradystoma* sp.) than that the species live between/on the "filamentus" algae (17 µm for *Paradoxostoma* (s.l.) sp. 50 µm for *Brunneostoma* sp.1). The morphology of the mouthparts of *Paradoxostoma* and *Xestoleberis* is illustrated in Fig. 4. In the lateral position (Figure 4: a, c, e, g, h) the mouthpart of Paradoxostoma is seen to protrude outside from carapace. The mouthpart of Xestoleberis, on the other hand, is accommodated in the carapace. The ventral position (Fig. 4: b, d, f) clearly shows the mouthpart of *Paradoxostoma* to be a suction-cup-like structure as compared to the usual mouthpart (upper and lower lip) of *Xestoleberis* (Fig. 4: i, k).

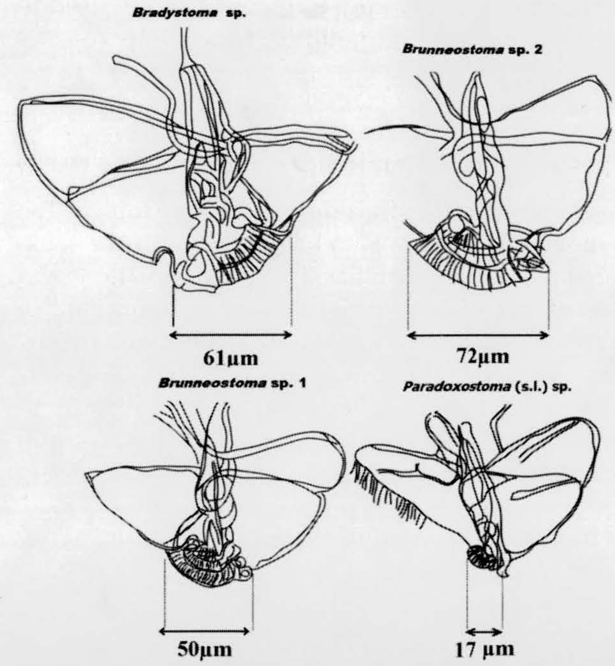

Fig. 3. The lateral view of mouthpart (scale bar on µm) of Paradoxostomatidae species.

Discussion

There seems to be a tendency that particular ostracode species were mostly found from particular algae species. Based on the reliable data (notation without parenthesis in Table 2) Paradostomatidae species were classified in to two groups. One is the species mainly live in bushy "filamentus" algae. They are *Brunneostoma* sp. 1 in *Chondria* sp. and *Paradoxostoma* s.l. in *Bostrychia* sp. Meanwhile, another is the species that are found from tall and smooth-surface algae. They are

Table 3. The relationship between species of ostracodes, type of the habitat, mouthpart size (major axis), and morphology of claw.

Species	Tall and smooth-surface algae	Filamentus algae	Size of mouthpart (µm)	Claw
Brunneostoma sp. 1	(V)	V	50	Very thin
Brunneostoma sp. 2	V		61	Thin
Paradoxostoma (s.l.) sp.	(V)	V	17	Thin
Bradystoma sp.	V		72	Thin-thick
Xestoleberis spp.	V	V	-	Robust

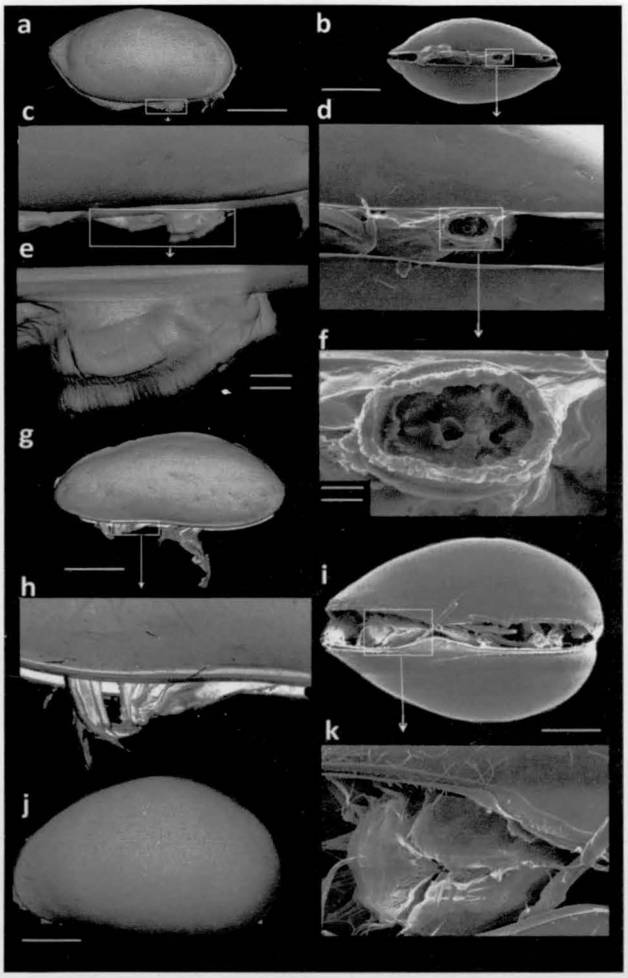

Fig. 4. The SEM of suctorial disk of Paradoxostoma and the mouth part of *Xestoleberis* sp. a, c, e: Lateral view of *Bradystoma* sp. with the suction-cup-like mouthpart. b, d, f: Ventral view of the *Bradystoma* sp. illustrating suction-cup-like mouthpart. g, h: Lateral view of the *Paradoxostoma* (s.l.) sp. j: : Lateral view of the *Xestoleberis* sp. with normal mouthpart (no prominent suction-cup-like feature). i, k : Ventral view of the *Xestoleberis* sp. (Scalebar: Single - 100µm, e, f: Doble - 5µm).

Brunneostoma sp. 2 on *Prionitis* sp. and *Bradystoma* sp. on *Mastophora* sp, *Chondrus* sp. and *Prionitis* sp. *Xestoleberis* sp. whose habitat was not so under wavy, was found from both "tall and smooth-surface algae (*Gigartina* sp. and *Sargassum* sp.).

Paradoxostomatidae is the only ostracode taxon whose upper lip and lower lip are fused to be a suctorial disk and its function is are supposed to be piercing and/or sucking (Athersuch *et al.*, 1989). Our observation in the laboratory confirmed that Japanese living Paradoxotomatidae species used their mouthpart as a sucker to stick to the bottom of petri-dish as if they try to avoid being detached from the bottom when we tried to suck them by syringe. The ability of mouthpart as a sucker will depend on size of the area of mouthpart. Therefore the difference of diameter between 17µm, 50µm, 61µm and 72 µm turned to be ca. 227 μm^2, 1963μm^2, 2921 μm^2 and 4069μm^2 as the difference of areas, if we calculated them as simple circles. This will provide the large difference of ability to stick to the surface of seaweeds. It seems apparent that Paradoxostomatidae species that live on tall and slippery smooth-surface algae developed the special large mouth as suckers to hold themselves on the algae. This adaptive strategy is further well shown by the fact that *Brunneostoma* sp. 2, living on the tall and smooth-surface algae, has developed a large mouth part (4069 μm^2) while congeneric *B.* sp. 1 living on/in the filamentous algae has smaller mouthpart (1963 μm^2). Meanwhile, *Xestoleberis* spp. whose mouthpart are not fused to be a sucker, seem to develop the robust claw at the tip of the three pairs of walking legs to hook themselves on the seaweeds (Fig. 5). The fact that the *Xestoleberis* species mainly live in not the typical wavy coast but the relatively embayed environments will make the modification of the claw enough device to stick themselves to habitats.

Kamiya (1988) reported that ostracode *Loxoconcha japonica* that lives on seagrass *Zoostera marina* has robust hooked claw at the tip of the walking legs in order to attach to the tall seaweed whereas the congeneric *L. uranouchiensis,* living on the sandy bottom, have thin claw. The present study newly showed that various strategies exist even within the phylal mode of life; to live on/between algae under wavy physical conditions, ostracodes require special adaptations. Basically only Paradoxostomatidae have been successful to live on such tough habitat after fusing the upper and lower lip into a suctorial disk, a sucker. Out of the Paradoxostomatidae species, only the species with extraordinarily large sucker are able to live on the "tall and smooth-surface" algae, physically the toughest habitat.

Conclusion

The faunal composition of phytal ostracodes in Indonesian intertidal will gives us a clue for the detailed coastal paleoenvironment reconstructions.

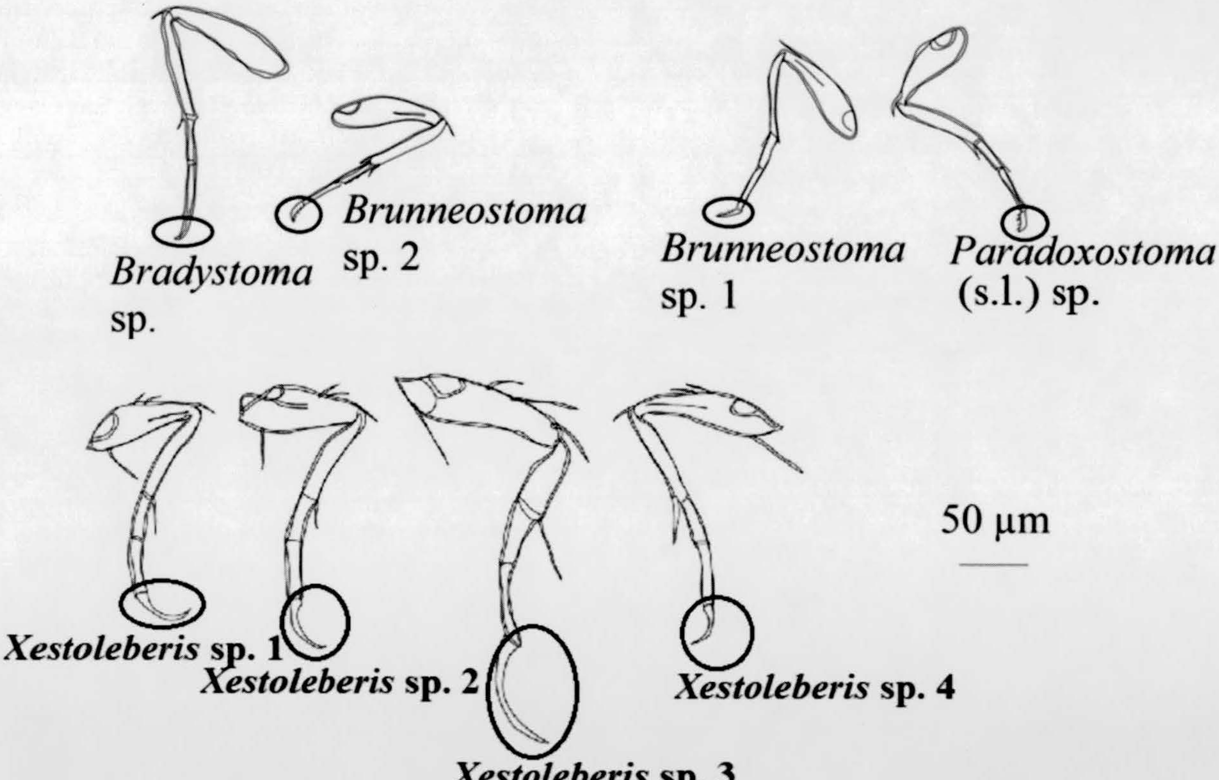

Fig. 5. The thoracic legs of the 6 abundant species of ostracodes in Indonesian intertidal (the scale bar is 50 μm).

Species combinations we get from fossil ostracode assemblage will tell that what types of the shores (wavy, rocky/embayed) and algae (bushy, filamentus/tall, smooth-surface) had developed in past environments.

It required a special device for ostracodes to live on seaweeds on the open wavy coast not to be pulled apart from the habitat. The family Paradoxostomatidae has succeeded in living on the busy, filamentus algae on the open coast by modifying the mouthpart to be a sucker. Some species of the family further succeeded in living on the tall and smooth-surface algae, the toughest habitats for ostracodes, for the first time to enlarge the mouthpart to be a strong sucker. The result of the present study gives one of the great example of evolution and adaptation of intertidal ostracodes to microhabitats.

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