Burrowing Time of the Three Indonesian Hippoid Crabs After Artificial Dislodgment

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Abstract

Three species of hippoid crabs are the target species of intertidal fishery along coastal line in District Cilacap, south Java; namely Emerita emeritus, Hippa adactyla and Albunea symmista. In Adipala sandy beach, Cilacap an experiment was conducted to reveal the burrowing time and velocity of the crabs. The experiment was performed by removing the crabs from their burrows, measuring their carapace length, and releasing them immediately on the substrate. Burrowing time was measured from the start of burrowing to the disappearance of the entire carapace under the sediment surface. Among the three species, E. emeritus had the fastest burrowing time. As a consequence in terms of velocity, the burrowing velocity of Albunea symmista was higher than that of Hippa adactyla and Emerita emeritus; meaning that with the same size A. symmista needs longer time to burrow. By evaluating with other previous studies, the burrowing time and burrowing velocity of the three sand crabs were comparable. The ability of fast burrowing in the three species seems likely to be the advantage for their survival in large wave disturbed coarse sandy habitat and for their ability to widely exist along the sandy coast of south Java.

Keywords: behavior; Indian ocean; intertidal; sand crab; south Java; swash zone

Introduction

In Indonesia sand crabs of superfamily Hippoidea are common species inhabiting the swash zone of intertidal sandy areas (Sarong and Wardiatno, 2013; Wardiatno *et al*., 2014). In terms of diversity, seven species of the superfamily were found in Indonesia, i.e. *Emerita emeritus*, *Hippa adactyla, H. admirabilis*, *H. marmorata, H. ovalis, H. celaeno* and *Albunea symmista* (Mashar *et al*., 2014; Ardika *et al*., 2015; Mashar *et al*., 2015; Wardiatno *et al*. 2015). Ecologically, the hippoid crabs play significant roles, such as one level position in the trophic structure of sandy beach ecosystems (Rodgers, 1987; Lercari and Defeo, 1999; Hubbard and Dugan, 2003; Hidalgo *et al*., 2010), giving a major contribution to secondary benthic production (Subramoniam and Gunamalai, 2003), or as bioindicator of polycyclic aromatic hydrocarbons pollution (Dugan *et al*. 2005).

In southern coast of Java Island – Indonesia three species of sand crabs co-exist intertidally, namely *E. emeritus, H. adactyla* and *A. symmista* (Mashar *et al*., 2014; Mashar *et al*., 2015; Wardiatno *et al*. 2015). The three species are species target in coastal fishery, and they have economic value because as fishery resources these crabs are popular as special snack in tourism destination beaches of south Java. They are also sometimes sold for bait in leisure fishing activities.

Generally, the shore as habitat of the three crab species is positioned at an intersecting point of the salinity gradient and the other, at least three major environmental gradients, *i.e.* (1) intertidal gradient or vertical gradient, from sea to land, (2) horizontal gradient of exposure to large wave action, and (3) particle size gradient of the substrate (Raffaelli & Hawkins, 1996). As they live in a very harsh environment due to large wave disturbance in a coarse sandy beach (Wardiatno *et al*., 2014), the sand crabs face a possibility to be dislodged when they burrow themselves within the substrate. The dislodgement could make them more vulnerable to the predator. Escape and hiding under the substrate is the way to defend from and avoid predator (Wirsing et al., 2010). Although to some extent the large wave occurence could be a good timing for larva release in *Emerita talpoida*, so the settling juveniles could survive better from benthic and surf zone predators (Amend and Shanks, 1999).

Burrowing behavior as adaptation is a standard of living and very important for benthic fauna living in exposed sandy beaches (Brown and McLachlan, 1990). Related to the burrowing behavior of benthic macrofauna living in the exposed beaches, swash exclusion hypothesis was

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introduced to anticipate critical consequences of the relationship between the burrowing times of benthic macrofauna and the swash period (McLachlan, 1990; McLachlan *et al.,* 1993; Lastra *et al*. 2002). It means the longer burrowing time in compared to swash period the higher possibility of the benthic macrofauna to face high turbulence. As a result, the possibility of benthic macrofauna for being splashed away from their burrows is increasing (McLachlan *et al.,* 1995).

Research on the three species sand crabs (*E. emeritus, H. adactyla* and *A. symmista*) has been theme of the first author and his colleagues recently, e.g. their presence in Indonesian coastal waters (Ardika *et al*., 2015; Mashar *et al*., 2015; Wardiatno *et al*., 2015), allometric growth (Mashar and Wardiatno 2013a,b; Muzammil *et al*., 2015), habitat characteristics (Sarong and Wardiatno, 2015; Wardiatno *et al*., 2014), abundance dynamics (Mashar *et al*., 2014), and biochemical composition (Santoso *et al*., 2015). To understand the burrowing time of the crabs after being dislodged to the surface of the substrate, we conducted an artificial dislodgment experiment. This article reports and compares the burrowing time of the three sand crab species after being dislodged from their burrow.

Materials and Methods

For the experiment a total of 114 individuals of the three species (50 individuals *E. emeritus*, 33 individuals *H. adactyla*, and 31 individuals *A. symmista*) were collected at Adipala beach, Cilacap during July 2015 (Figure 1). The crabs were captured by digging the substrate in the swash zone of the beach. Except *H. adactyla*, the other two species was categorized as two groups in the experiments, i.e. small size (< 2-cm CL) and big size (≥ 2-cm CL). Carapace length (CL) was measured to the nearest 0.1 mm.

Experimental procedure

The experiment of burrowing time of the crabs after artificial dislodgment was conducted directly in the swash zone of Adipala beach in District Cilacap. The crabs were removed one by one from their burrows, mesured for their carapace length, and immediately released on the surface of the swash zone. Following Lastra et al. (2002), burrowing time was measured from the start of burrowing to the disappearance of the entire carapace under the sediment surface and burrowing velocity was calculated by dividing the carapace length by the burrowing time.

Data analyses

Spearman Rank Correlation were performed to show the relationship between carapace length and burrowing time of sand crabs. Statistical differences of burrowing time and burrowing velocity between two species or two sizes were analyzed using Mann-Whitney U test (Fowler and Cohen, 1992).

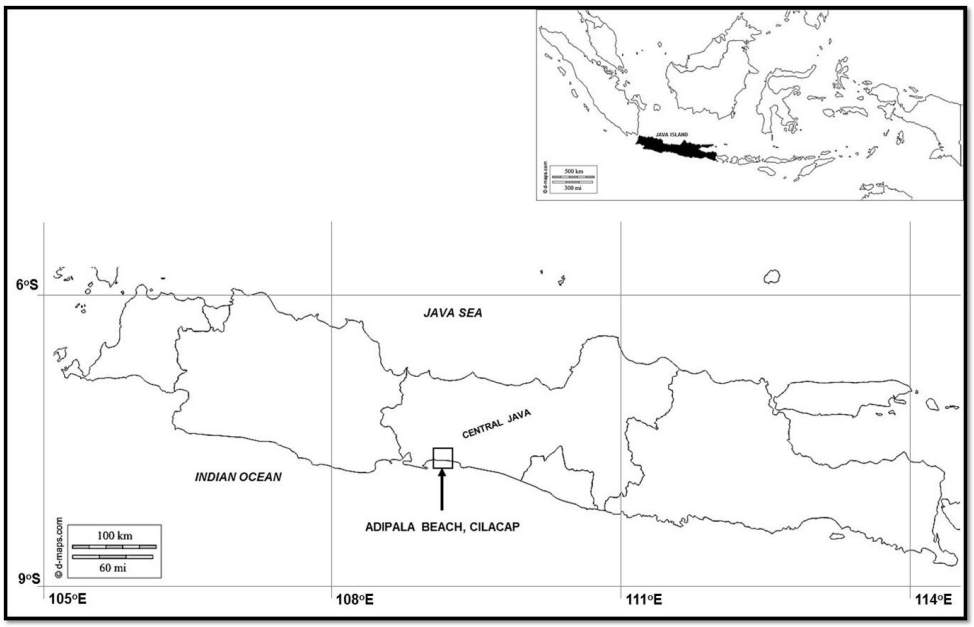

Figure 1. Map of Java Island showing the location of experiment as indicated by a small open square and pointed by the arrow.

Results and Discussion

The burrowing behaviour has been attracting theme in biological research of hippoid crabs since last four decades (Trueman, 1970; Faulkes and Paul, 1997, 1998; Dugan *et al*., 2000; Lastra *et al*., 2002; Boere *et al*., 2011; Joseph and Faulkes, 2014). The mechanisms of burrowing in *Emerita* were recorded longtime ago by Trueman (1970) using the analysis of cine film and electronic recordings. He concluded that burrowing was started by tactile spur of the base of the telson and was conducted by the fourth thoracic legs and uropods constantly mining a hole in the sediment.

The carapace length range of the three species used in this experiment was as follow: *Emerita emeritus* from 1.3 to 3.0 cm, *Hippa adactyla* from 2.0 to 3.3 cm, and *Albunea symmista* from 0.9 to 3.3 cm. The fastest burrowing time was observed in *Emerita emeritus* with 0.71 s of burrowing time and 1.9 cm of carapace length. Table 1 showed the range of carapace length and burrowing time by species.

Mean burrowing times of all size of the three species showed that *E. emeritus* could burrow faster than *H. adactyla* and *A. symmysta.* The burrowing time within the same species (*E. emeritus* and *A. symmista*) was different between the two group size (small size vs big size). In addition, it is the fact that burrowing time increased with the increasing of carapace length in the three species. Spearman Rank Correlation coefficient between carapace length and burrowing time show positive values indicating the bigger size of carapace length the longer burrowing time (Table 2).

The comparison of small size individuals (<2cm) between *E. emeritus* and *A. symmista* showed a significant difference ($p<0.05$). It showed that small *E. emeritus* had a faster burrowing time than *A. symmista.* However, there was no difference of burrowing time between the two species for the big size individuals (>2 cm) ($p>0.05$) (Table 3).

There were variation in burrowing velocity among species. Burrowing velocity of *E. emeritus*, *H. adactyla*, and *A. symmista* ranged from 0.26 to 1.96 cm/s, from 0.44 to 1.44 cm/s, and from 0.48 to 3.31 cm/s, respectively. While the mean of burrowing velocity were were 0.90±0.39 cm/s, 0.91±0.26 cm/s, and 1.31±0.76 cm/s, respectively. The comparison of burrowing velocity among species showed that there was a significant difference of burrowing velocity among species (Kruskal Wallis test; $p<0.05$). The burrowing velocity of *E. emeritus* and *H. adactyla* were faster than *A. symmista* (Mann Whitney test; $p<0.05$), but no difference burrowing velocity found between *E. emeritus* and *H. adactyla* (Mann Whitney test; $p>0.05$) (Figure 2).

The three species of sand crabs found in Cilacap coastal were belong to two different families, *i.e*. Hippidae (*E. emeritus* and *H. adactyla*) and Albunidae (*A. symmista*) of superfamily Hippoidea. Former studies showed that members of those families were fast burrowers in swash zone (Dugan *et al*., 2000; Lastra *et al*., 2002). By considering the group size, small size of *E. emeritus* burrowed faster than *A. symmista* (no small size individual found for *H. adactyla*). The result of burrowing velocity comparison of the three species also showed that *A. symmista* was the slowest one. Fast burrowing time and burrowing velocity are important for those who live in the intertidal swash zone, because the faster burrowing time, the faster it can escape from predators and wave dislodgement at the same time.

Table 1. Range of carapace length and burrowing time of sand crabs (*Emerita emeritus, Hippa adactyla, Albunea symmista*) during experiment.

Species	Carapace length (cm)		Burrowing time (s)	
	Range	Mean±SD	Range	Mean±SD
Emerita emeritus				
Small size	1.3-1.9	1.77±0.16	0.71-3.72	1.36±0.77
Big size	2.0-3.0	2.53±0.36	0.74-5.30	2.46±1.11
All size	1.3-3.0	2.30±0.47	0.71-5.30	2.20±1.14
Hippa adactyla	2.0-3.3	2.50±0.32	1.11-4.00	2.30±0.74
Albunea symmista				
Small size	0.9-1.9	1.70±0.31	1.08-5.96	2.34±1.39
Big size	2.0-2.9	2.20±0.25	1.24-5.89	2.63±1.51
All size	0.9-2.9	1.90±0.40	1.08-5.96	2.50±1.40

As mentioned above, the sand crabs were categorized as a fast burrower due to their shorter burrowing time, especially in compared to other aquatic invertebrates, such as bivalves (Stanley, 1970; Ansell and Trueman, 1973; McLachlan *et al*., 1995). Yet, the burrowing time of sand crabs from Cilacap coastal were still slower compared to another Hippidae species, such as *H. pacifica* in Makalawena beach, Hawaii (Lastra *et al*., 2002), though it was still comparable with other previous studies on sand crabs. Comparisons of burrowing time for some aquatic invertebrates (Table 4).

Factors affecting the burrowing behavior of benthic crustaceans have been studied by many researchers, such as parasites infection (Oliva *et al*., 2008; Kolluru *et al*., 2011), carapace length differences (Dugan *et al*., 2000; Lastra *et al*., 2002; Kolluru *et al*., 2011), sediment size (Nel *et al*., 1999; Dugan *et al*., 2000; Lastra *et al*., 2002), and morphological character differences (Paul, 1981; Dugan *et al*., 2000). Significant change of the host phenotipe and morphology, host behaviour, and host physiology due to parasite infection was detected (Hindsbo, 1972; Holmes and Bethel, 1972; Oetinger and Nickol, 1981; Hurd, 1990; Bakker *et al*., 1997; Kristan and Hammond, 2000; Moore, 2002; Schwanz, 2006). It was also proved that parasite infection could influence host burrowing time because the parasite could alter the energy need for

Table 2. Spearman Rank Correlation between carrapace length and burrowing time of sand crabs in Cilacap sandy beach, south Java, Indonesia.

Species	Carrapace length-Burrowing Time Correlation		
	N	Spearman Correlation	P value
Emerita emeritus	50	0. 62	<0.05
Hippa adactyla	33	0.45	<0.05
Albunea symmista	31	0.16	0.19

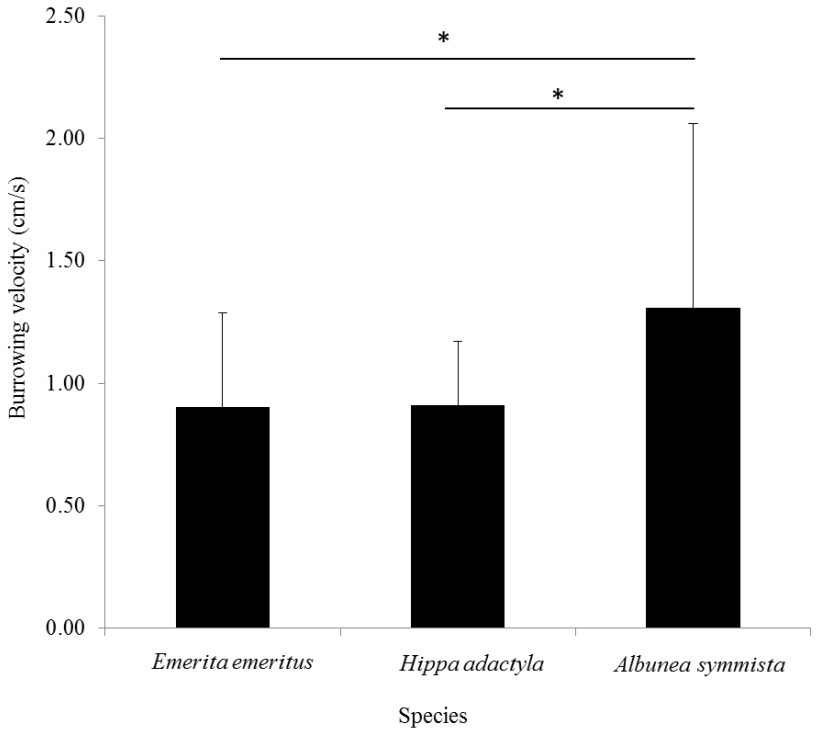

Figure 2. Comparison of burrowing velocity among sand crabs species (*Emerita emeritus, Hippa adactyla, Albunea symmista*) in Cilacap sandy beach, south Java - Indonesia. The asterisks indicate significant difference at p=0.05 (Mann-Whitney U test).

Table 3. Comparison of burrowing time among sand crabs species (*Emerita emeritus, Hippa adactyla, Albunea symmista*) in Cilacap coastal based on individual size.

Size	*Emerita emeritus*	*Hippa adactyla*	*Albunea symmista*
Small	1.77 ± 0.77[a]		2.34 ± 1.39[b]
Big	2.53 ± 1.11[a]	2.31 ± 0.74[a]	2.63 ± 1.51[a]

[a,b] within the same row, values with different superscript are significantly different (Mann-Whitney U test; $p<0.05$). Small size: <2cm-CL; Big size: ≥ 2cm-CL

Table 4. Burrowing time comparison of some aquatic invertebrates.

Species	Burrowing time (s)	Source
Emerita analoga	0.7-8.2	Dugan et al. (2000)
Lepidopa californica	1.0-20.9	Dugan et al. (2000)
Blepharipoda occidentalis	1.0-9.9	Dugan et al. (2000)
Hippa pacifica	0.4-1.5	Lastra et al. (2002)
Gastrosaccus psammodytes	1.2-2.2	Nel et al. (1999)
Bivalve	3.0-120	McLachlan et al. (1995)
Emerita emeritus	0.7-5.3	This study
Hippa adactyla	1.1-4.0	This study
Albunea symmista	1.1-5.9	This study

burrowing or distort the burrowing process due to morphology and behaviour modification in the host (Thomas *et al*., 2005; Poulin, 2007).

The difference of burrowing time and burrowing velocity among sand crabs species in Cilacap coastal could be caused by their morphological traits. One of the results shows that carapace length affected the burrowing time of the three species. The correlation between carapace length and burrowing time indicated that the larger carapace length the longer burrowing time, consistent with other previous studies (see Dugan *et al*., 2000; Lastra *et al*., 2002).

The other thing is that morphology and anatomy different among sand crabs species highly influenced the burrowing abilility as found by Paul (1981) and Dugan *et al*. (2000). The members of family Hippidae tend to have larger telson and tailfan than those of the Albunidae. As shown by Trueman (1970) and Faulkes and Paul (1997; 1998) morphological traits had significant affect in burrowing ability of the sand crabs. It is clear that Hippidae has stronger tail than that of Albuneida. The tail is used to physically shovel substrate during burrowing processes. Therefore, burrowing ability of Hippidae (*E. emeritus* and *H. adactyla*) are better than that of Albunidae (*A. symmista*) because *A. symmista* has smaller and weaker tailfan.

Conclusion

The burrowing ability of *E. Emeritus, H. Adactyla* and *A. symmista* was categorized fast as found in several hippoid crabs of the previous studies. However, there was discrepancy in terms of burrowing time period among the species due to probably their morphological differences, especially in telson and tailfan. The ability of fast burrowing in the three species seems likely to be the factor behind their success to withstand reflective conditions (large wave disturbance in coarse sandy habitat). It also likely contributes to a large extent to the wide existence of the hippoid crabs along sandy coasts of District Cilacap, and even along sandy coasts of south Java.

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