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Variation in Morphometric Characters in Four Sand Crab (*Albunea symmysta*) Populations Collected from Sumatra and Java Island, Indonesia

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Abstract: Variation in morphometric characters in four sand crab (*Albunea symmysta*) populations from four intertidal areas in Sumatra (Aceh and Bengkulu) and Java (Cilacap and Yogyakarta) were studied. Crabs collected from the four sites were measured to obtain 10 morphometric characters, i.e., carapace length (CL), carapace width (CW), ocular peduncle length and width (LOP and WOP), telson length and width (LT and WT), merus length (ML), carpus length (CaL), propodus length (PL), and dactylus length (DL). Allometric relationships were established among three morphometric characters (CW, PL, and DL) for each site, in which CL was fixed on the abscissa as a reference variable. The analysis of covariance showed that population from Yogyakarta had a greater carapace width and the Aceh population had a longer dactylus length. In terms of propodus length, the Aceh population had a longer dactylus length than the Bengkulu population. Two group populations were detected by cluster analysis with 10 morphometric characters, i.e., the Sumatra population and the Java population.

Keywords: Allometric Relationships, Anomura, Cluster Analysis, Decapoda, Hippoidea

INTRODUCTION

The superfamily Hippoidea is one of the crab-like groups within the infraorder Anomura and is commonly referred to as mole or sand crabs. These hippoids are specialized to live buried in sandy substrates or fine sediment from the intertidal to offshore zones (Boyko, 2002; Osawa *et al.* 2010; Wardiatno & Mashar 2013). Wardiatno *et al*. (2015a) reported seven genera of superfamily Hippoidea distributed in Indonesian waters, including *Albunea symmysta.* This superfamily can be found along the west coast of Sumatra (Aceh, Bengkulu) and the south coast Java (Cilacap, Yogyakarta). Ecologically, sand crabs have an important role as components of the macrofaunal community in tropic and subtropic sandy beaches (Lastra *et al.* 2002). They also contribute to benthic secondary productivity (Subramoniam & Gunamalai 2003).

Most of the morphometric characters of crustaceans have been used in taxonomical studies to illustrate and describe morphometric usable characters

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displayed by adult, juvenile or larvae stages of genera or species of various organisms found in certain areas [e.g., for thalassinidean shrimps: Manning and Tamaki (1998), Wardiatno and Tamaki (2001), Dworschak (2003), Marin (2013); for copepods: Suárez-Morales and Fuentes-Reiné (2015a, 2015b); for crabs: Guerao *et al*. (1998), Komatsu and Takeda (2007); etc.]. For taxonomists, morphometric characters can be useful features to establish phylogenetic relationships among species placed in monotypic genera with clear familial or ordinal placement. In addition, morphometric analysis provides a powerful complement to genetic and environmental stock identification approaches (Cadrin 2000). Wardiatno and Tamaki (2001) studied the morphological characters of two Japanese ghost shrimps, *Nihonotrypaea japonica* and *N. harmandi*, to separate the two species by identification. Some researchers have used morphological characters to show sexual dimorphism in decapod crustaceans using their chelipeds (e.g., Shimoda *et al.* 2005; Claverie & Smith 2010; Trevisan *et al*. 2012), which was believed to be a consequence of the common male habits of combat, contest, and courtship (e.g., Hartnoll 1974).

Studies of the crustacean biology in Indonesia have been increasing recently, e.g., the occurrence of lobsters as a first record (Wardiatno *et al*. 2016), the biology of mantis shrimp (Wardiatno & Mashar 2010, 2011; Wardiatno *et al.* 2012; Wardiatno & Mashar 2013), the biology of blue swimming crabs (Hamid 2011; Hamid & Wardiatno 2015; Hamid *et al.* 2015a,b; Zairion *et al*. 2014; Wiyono & Ihsan 2015; Zairion *et al*. 2015a, b), as well as the biology of mole/sand crabs (Mashar & Wardiatno 2013a,b; Sarong & Wardiatno 2013; Wardiatno *et al.* 2014; Mashar *et al*. 2014, 2015; Santoso *et al*. 2015; Wardiatno *et al*. 2015a,b; Muzammil *et al*. 2015). Of the numerous studies on Indonesian mole/sand crabs, there has been no published work as yet on the morphometric variations of albuneid crab populations in Indonesia.

A comparison of the variation in morphometric characters of the same genera or species among several localities would be of interest to aquatic biologists (e.g., Wardiatno & Tamaki 2001; Spivak & Schubart 2003; Samaradivakara *et al*. 2012; Qonita *et al*. 2015). Therefore, this study was aimed at assessing the morphological variation in *A. symmysta* populations from two locations in Sumatra (Aceh and Bengkulu) and from two locations in Java (Cilacap and Yogyakarta).

MATERIALS AND METHODS

Sample Collection

A total of 174 *Albunea symmysta* individuals (Fig. 1) were collected from four sandy beaches in Sumatra (Aceh and Bengkulu) and Java (Cilacap and Yogyakarta), as shown in Fig. 2. All crabs were immediately fixed in 10% buffered seawater-formalin. The collected crabs were measured for the following 10 morphometric characters: carapace length (CL), carapace width (CW), ocular peduncle length and width (LOP, WOP), telson length and width (LT, WT), merus length (ML), carpus length (CaL), propodus length (PL), and dactylus length (DL).

The last four characters were measured on both the left and right sides. Measurements were made to the nearest 0.1 mm using a calliper. Detailed information on the crabs used in this study is presented in Table 1.

Figure 1: *Albunea symmysta* specimens were collected from an intertidal sandy beach in Cilacap, Java Island, Indonesia.

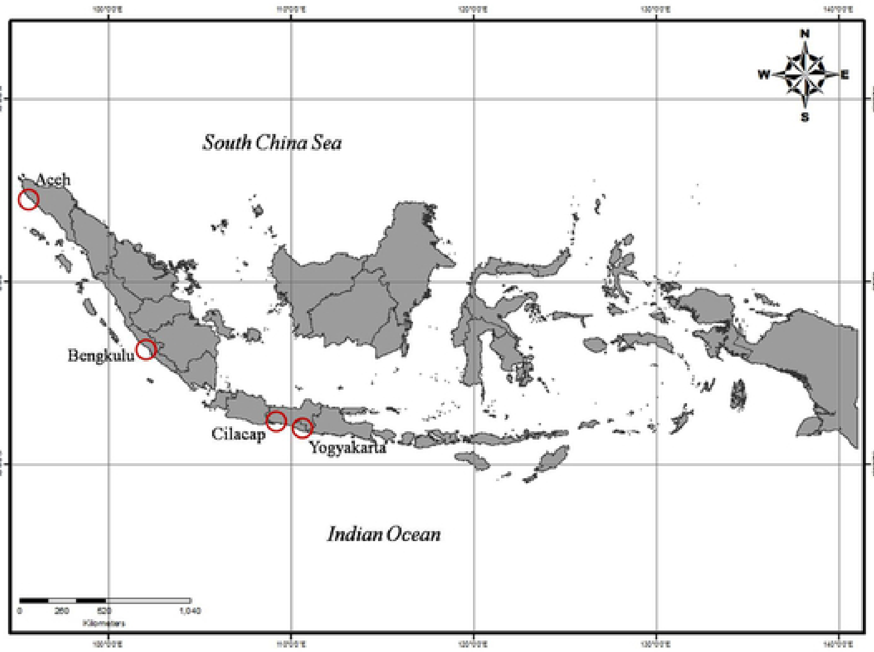

Figure 2: Sampling locations of *Albunea symmysta* in Sumatra and Java Island. Red circles indicate the sandy beaches where the sand crabs were collected. (Source: Indonesia topographical map in http://www.bakosurtanal.go.id)

Table 1: Information on the size and sex of specimens measured from each site in this study.

Site	Number of females	Number of males	Total Number	Size range (mm-CL) of both sexes
Sumatra Island				
Aceh	37	13	50	10.30–21.60
Bengkulu	14	16	30	12.70–21.80
Jawa Island				
Cilacap	27	35	62	10.30–21.60
Yogyakarta	22	10	32	12.70–21.80

Data Analysis

Allometric relationships were established among three morphometric characters (CW, PL, and DL) for each site, in which CL was fixed on the abscissa as a reference variable. The significance of the differences between the two sites (concerning slopes and intercepts) was tested by analysis of covariance (ANCOVA). To determine the similarity of *Albunea symmysta* populations among these sites, cluster analysis was performed based on 10 morphometric characters. Data from both sexes are combined in all analyses.

RESULTS

Allometric Relationships

The relationships among carapace length and carapace width, propodus length, and dactylus length are presented in Table 2. A simple regression analysis of CL-CW showed significant differences in intercept values between *A. symmysta* from Yogyakarta with individuals from Bengkulu, Cilacap, and Yogyakarta. *A. symmysta* from Yogyakarta had a greater carapace width than the others (p<0.05).

Table 2 shows that population from Yogyakarta had a greater carapace width than other sites. Regression analysis between CL and PL for Cilacap vs. Yogyakarta showed a significant difference slope (p<0.05). In contrast, the comparisons of *A. symmysta* from Aceh vs. Cilacap, Aceh vs. Bengkulu, Bengkulu vs. Cilacap, and Bengkulu vs. Yogyakarta showed no differences in either slope and intercept, indicating that propodus length does not significantly differ between individuals of the same length (p<0.05). However, a comparison between Aceh and Bengkulu showed significant differences in intercept values; the Aceh population showed a greater propodus length than the Bengkulu population at the same carapace length (p<0.05).

A comparison between CL and DL showed significant differences in slope values for population from Aceh vs. other sites, indicating that *A. symmysta* from Aceh had greater dactylus length than the others (p<0.05). In contrast, a comparison of Bengkulu vs. Cilacap, Bengkulu vs. Yogyakarta, and Cilacap vs. Yogyakarta showed no differences in both slope and intercept values, indicating that individuals with the same carapace length had the same dactylus length.

Table 2: Linear regression equations for four morphometric variables (CL is the reference variable) in *Albunea symmista* collected from Sumatra (Aceh and Bengkulu) and Java (Cilacap and Yogyakarta), with the ANCOVA results to determine the difference between two respective sites.

Sites	Equation	R^2	ANCOVA Result/ Crossing Point	
	$y = ax + b$		a	b
Relationship between CL and CW				
Aceh	CW = 0.890CL – 0.267 (*p*<0.001)	0.96	parallel	$b_1 = b_2$
Bengkulu	CW = 0.899CL – 0.330 (*p*<0.001)	0.95		
Aceh	CW = 0.890CL – 0.267 (*p*<0.001)	0.96		$b_1 = b_2$
Cilacap	CW = 0.817CL + 1.285 (*p*<0.001)	0.81		
Aceh	CW = 0.890CL – 0.267 (*p*<0.001)	0.96		$b_1 \neq b_2$
Yogyakarta	CW = 0.804CL + 1.395 (*p*<0.001)	0.77		
Bengkulu	CW = 0.899CL – 0.330 (*p*<0.001)	0.95		$b_1 = b_2$
Cilacap	CW = 0.817CL + 1.285 (*p*<0.001)	0.81		
Bengkulu	CW = 0.899CL – 0.330 (*p*<0.001)	0.95		$b_1 \neq b_2$
Yogyakarta	CW = 0.804CL + 1.395 (*p*<0.001)	0.77		
Cilacap	CW = 0.817CL + 1.285 (*p*<0.001)	0.81		$b_1 \neq b_2$
Yogyakarta	CW = 0.804CL + 1.395 (*p*<0.001)	0.77		
Relationship between CL and PL				
Aceh	PL = 0.469CL - 0.226 (*p*<0.001)	0.88	parallel	$b_1 \neq b_2$
Bengkulu	PL = 0.454CL + 0.327 (*p*<0.001)	0.88		
Aceh	PL = 0.469CL - 0.226 (*p*<0.001)	0.88		$b_1 = b_2$
Cilacap	PL = 0.449CL + 0.199 (*p*<0.001)	0.87		
Aceh	PL = 0.469CL - 0.226 (*p*<0.001)	0.88	non-parallel	at 12.909 mm-CL
Yogyakarta	PL = 0.381CL + 1.362 (*p*<0.001)	0.76		
Bengkulu	PL = 0.454CL + 0.327 (*p*<0.001)	0.88	parallel	$b_1 = b_2$
Cilacap	PL = 0.449CL + 0.199 (*p*<0.001)	0.87		
Bengkulu	PL = 0.454CL + 0.327 (*p*<0.001)	0.88	non-parallel	at 14.178 mm-CL
Yogyakarta	PL = 0.381CL + 1.362 (*p*<0.001)	0.76		
Cilacap	PL = 0.449CL + 0.199 (*p*<0.001)	0.87		at 17.103 mm-CL
Yogyakarta	PL = 0.381CL + 1.362 (*p*<0.001)	0.76		
Relationship between CL and DL				
Aceh	DL = 0.409CL - 0.957 (*p*<0.001)	0.879	non-parallel	at 14.959 mm-CL
Bengkulu	DL = 0.336CL + 0.135 (*p*<0.001)	0.865		
Aceh	DL = 0.409CL - 0.957 (*p*<0.001)	0.879		at 12.851 mm-CL
Cilacap	DL = 0.335CL - 0.006 (*p*<0.001)	0.856		
Aceh	DL = 0.409CL - 0.957 (*p*<0.001)	0.879		at 14.495 mm-CL
Yogyakarta	DL = 0.318CL + 0.362 (*p*<0.001)	0.681		

(*continued on next page*)

Table 2: (*continued*)

Sites	Equation	R^2	ANCOVA Result/ Crossing Point	
	$y = ax + b$		a	b
Bengkulu	DL = 0.336CL + 0.135 (p<0.001)	0.865		$b_1 \neq b_2$
Cilacap	DL = 0.335CL - 0.006 (p<0.001)	0.856		
Bengkulu	DL = 0.336CL + 0.135 (p<0.001)	0.865	parallel	$b_1 = b_2$
Yogyakarta	DL = 0.318CL + 0.362 (p<0.001)	0.681		
Cilacap	DL = 0.335CL - 0.006 (p<0.001)	0.856		$b_1 = b_2$
Yogyakarta	DL = 0.318CL + 0.362 (p<0.001)	0.681		

Cluster Analysis

A dendrogram constructed using 10 morphometric characters showed that *A. symmysta* from the four sites could be classified into two groups, i.e., the Sumatra (Aceh and Bengkulu) and the Java (Cilacap and Yogyakarta) populations. The similarity values were 82.74% and 72.86% for each group, respectively (Fig. 3).

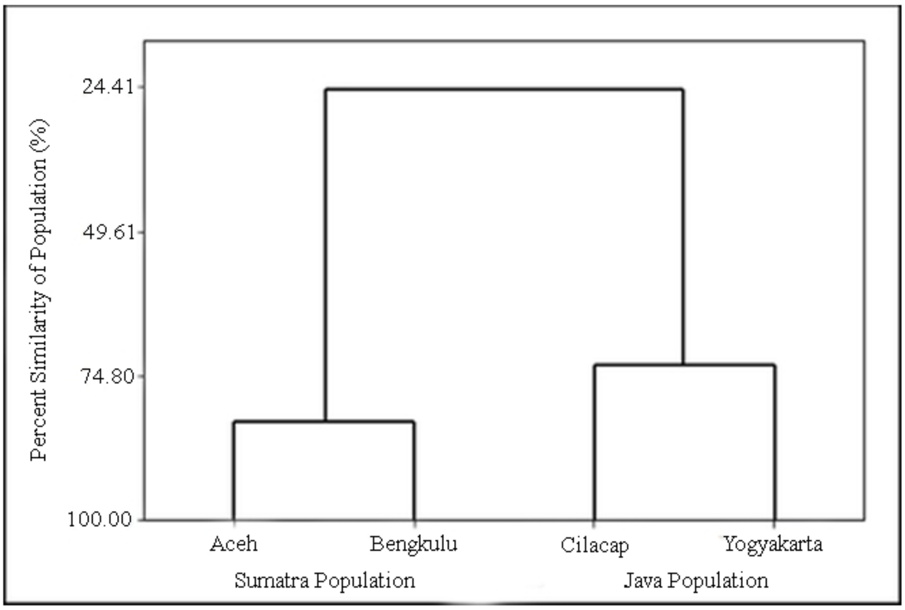

Figure 3: Dendrogram of *Albunea symmysta* population groupings by means of 10 morphometric characters, showing two groups, i.e., a Sumatra population (Aceh and Bengkulu) and a Java population (Cilacap and Yogyakarta).

DISCUSSION

Many morphometric studies of decapod crustaceans have shown significant relationships among some morphometric characters to carapace or total length (e.g., Oh & Hartnoll 1999; Sampedro *et al.* 1999; Conan *et al*. 2001; Wardiatno & Tamaki 2001; Mashar & Wardiatno 2013a,b; Wardiatno & Mashar 2013; Muzammil *et al.* 2015). Widely used allometric relationships have been used mostly to quantify the relative growth of body parts expressing secondary sexual characters in crustaceans (Hartnoll 1978, 1982). White and Gould (1965) found that at molt before maturity, the slope of the allometric relationship undertakes an impulsive transformation.

Variations of some morphometric characters within the same species from different sites or different species from the same family at the same site would be interesting and useful from a biological or taxonomical perspective. Wardiatno and Tamaki (2001) revealed that variations in the size of the cornea and rostrum angle of *Nihonotrypaea japonica* and *N. harmandi* were effective characters to separate the two species. Wardiatno and Mashar (2013) speculated that variations in claw size between two mantis shrimp species (*Harpiosquilla raphidea* and *Oratosquillina gravieri*) may be a factor behind their competitive abilities.

In this study, the analyses of covariance were able to detect size variations in the carapace widths and dactylus lengths at the same size of carapace lengths among populations of *Albunea symmista* collected from two sites in Sumatra and two sites in Java (see Table 2). Some researchers have indicated that the variation in morphometric characters of any species may be caused by various factors, such as geographic region (Hepp *et al*. 2012) including elevation and latitude, environmental conditions (Waldman *et al*. 1988; Hausch *et al*. 2013, Wahidah *et al*. 2015), as well as genetic factors (Waldman *et al*. 1988; Bissaro *et al*. 2012). Qonita *et al*. (2015) showed that variations in morphology were due to environment conditions in the pile ark cockle (*Anadara pilula*), and this finding strengthened the argument of Barria *et al*. (2011) who hypothesized that morphological variations were brought about by adaptive responses to environmental conditions.

Using ten morphometric characters, our cluster analysis generated two group populations of the sand crab, i.e., a Sumatra population and a Java population (see Fig. 3). The separation that formed between the two population groups from Sumatra and Java may also be due to their adaptation to differences in environmental conditions of the two islands. Visually, the substrate in Sumatra is coarser and whiter than in Java. Ingole (1998) stated that populations of burrowing crustacean species are affected by the sediment structure of their habitat. Rosenberg (2002) found different claw forms among *Uca* living in sandy and muddy habitats, which indicates a significant correlation between claw shape and habitat.

CONCLUSION

Morphometric variations in four populations of *A. symmysta* collected from Aceh, Bengkulu, Cilacap and Yogyakarta were detected, and these variations were used to cluster these populations into the following two groups: the Sumatra population and the Java population. The cluster pattern was likely determined by the local environmental conditions and the geographical distances between sampling sites. Further biological evidence (biomolecular approach) is necessary to strengthen the argument for subdividing these two *A. symmysta* populations.

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