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Length-weight and Morphometric Analysis of Mud Lobster, *Thalassina anomala* from Sarawak, Malaysia

Zakaria Nur-Nadiah[1], Masnindah Malahubban[1], Sharida Fakurazi[2], Sie Chuong Wong[3] and Amy Halimah Rajaee[1]*

[1]*Department of Animal Science and Fishery, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008 Bintulu, Sarawak, Malaysia*
[2]*Department of Human Anatomy, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[3]*Department of Basic Science and Engineering, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008 Bintulu, Sarawak, Malaysia*

ABSTRACT

Mud lobsters (*Thalassina* spp.) are nocturnal organisms, belong to Order Decapoda which are lesser known and least studied although their presence were widely distributed across the Indo-West Pacific Region. Mud lobster is considered as an important organism in the mangrove ecosystem for its burrowing activities and the role of its mounds or burrows as home to other animals. All mud lobster samples collected from four distinct regions in Sarawak (Kuala Tatau, Kuala Balingian, Sarikei and Lingga) were identified as *Thalassina anomala* based on the morphological characteristics. Morphometric variations between sexes of *T. anomala* were examined. Sexual dimorphism can be observed where males had significantly longer carapace length, left chelae propodus length and larger left chelae propodus width compared to females ($p<0.05$). Meanwhile, sexual dimorphism can also be seen in the abdominal width, in which it was significantly larger in females, for both absolute values ($p<0.01$) and also the relative values ($p<0.001$). The length-weight relationship of *T. anomala* were analysed between sexes by regression analysis. Results showed that males had isometric growth rate for carapace length-weight (CL/W), total length-weight (TL/W) and abdominal length-weight (ABL/W) relationships. However, females had negative allometric growth in CL/W and ABL/W relationship and isometric growth in TL/W relationship. Data from this study is able to provide baseline information

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E-mail addresses:
nurnadiahzakaria@gmail.com (Zakaria Nur-Nadiah)
masnindah@upm.edu.my (Masnindah Malahubban)
sharida@upm.edu.my (Sharida Fakurazi)
wongsie@upm.edu.my (Sie Chuong Wong)
amyhalimah@upm.edu.my (Amy Halimah Rajaee)
* Corresponding author

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which are useful for future reference on mud lobster resource management in Sarawak, Malaysia.

Keywords: Length-weight, morphology, morphometric, mud lobster, Sarawak, *Thalassina anomala*

INTRODUCTION

Mud lobsters (*Thalassina* spp.) are nocturnal organisms known for their burrowing activities. They are rarely seen and difficult to catch due to their habitats which are far underneath the ground. They are acknowledged as an important organism in mangrove ecosystem due to the role of their volcano-like mounds as home to other animals. The studies of mud lobster are still scarce, however eleven species of *Thalassina* were discovered distributed across Indo-West Pacific region, namely *Thalassina anomala* Herbst, 1804 (as cited in Ngoc-Ho & de Saint Laurent, 2009, p. 121), *T. emerii* Bell, 1844 (as cited in Ngoc-Ho & de Saint Laurent, 2009, p. 121), *T. gracilis* Dana, 1852 (as cited in Ngoc-Ho & de Saint Laurent, 2009, p. 121), *T. squamifera* De Man, 1915 (as cited in Ngoc-Ho & de Saint Laurent, 2009, p. 121), *T. kelanang* (Moh & Chong, 2009), *T. krempfi* (Ngoc-Ho & de Saint Laurent, 2009), *T. spinirostris* (Ngoc-Ho & de Saint Laurent, 2009), *T. spinosa* (Ngoc-Ho & de Saint Laurent, 2009), *T. australiensis* (Sakai & Türkay, 2012), *T. saetichelis* (Sakai & Türkay, 2012) and *T. pratas* (Lin et al., 2016). In Malaysia, four species of *Thalassina* have been reported which are *Thalassina anomala* by De Man (1928), *T. gracilis* by Sasekumar (1974), *T. kelanang* by Moh and Chong (2009) and *T. spinirostris* by Ngoc-Ho and de Saint Laurent (2009). *Thalassina anomala* is the most abundant species, not only in Malaysia but also in the Indo-West Pacific region (Ngoc-Ho & de Saint Laurent, 2009).

Species identification based on morphology has been described extensively in Ngoc-Ho and de Saint Laurent (2009) whilst verification of four species using morphology and molecular approach has been carried out by Moh et al. (2013). Although there are many studies on morphological characteristics of the mud lobster, most of it are focused on species differentiation.

Morphological characteristics such as body length and weight are an essential tool in scientific studies. The length-weight relationships are beneficial to understand biology and ecology of species (Kumar et al., 2018), estimation of growth rate (da Rocha et al., 2015), size at maturity (Waiho et al., 2016) and male-female differentiation (Wang et al., 2011). On the other hand, morphometric analysis has been widely conducted for studies on relative growth (Vasileva et al., 2017). This study reported on length-weight relationships and morphometric analysis of *T. anomala* collected from four locations in Sarawak, Malaysia namely Kuala Tatau (Bintulu), Kuala Balingian (Mukah), Sarikei and Lingga (Sri Aman). Given the difficulty in obtaining substantial number of organisms per sampling location, samples from all locations were pooled in order to determine length-weight relationships and morphometric analyses.

MATERIALS AND METHODS

Sample Collections

A total of 70 samples (37 males and 33 females) were purchased from local people from four distinct locations in Sarawak from March 2016 until May 2017 (Figure 1). Fifty four samples were collected from Kuala Tatau, Bintulu (3°05'42.8"N, 112°51'56.0"E), 8 samples from Kuala Balingian, Mukah (3°00'36.9"N, 112°35'26.0"E), 6 samples from Lingga, Sri Aman (1°14'01.2"N, 111°27'49.5"E) and 2 samples from Sarikei (2°07'55.5"N, 111°30'59.8"E). All samples were weighed with a digital weight and measured with a digital caliper with a precision of 0.01mm. Samples were kept in ice during transport to laboratory prior to further analyses.

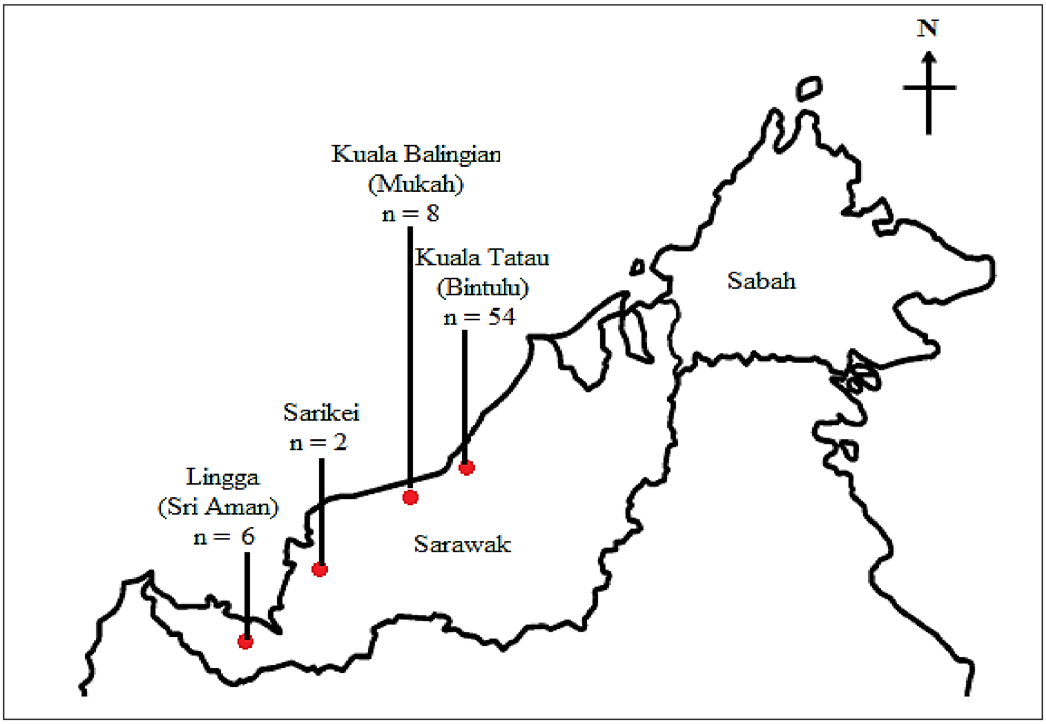

Figure 1. Sampling locations of mud lobster in Sarawak, Malaysia

Species and Sex Identification

Species identification was carried out using morphological characteristics as explain in Moh and Chong (2009) and Moh et al. (2013). Focus were made to certain features to differentiate the species such as carapace, rostrum and abdominal somite (Figure 2). Sex identification was determined according to location of the gonopores. For male, gonopores were located on inner ventral surface of coxa of pereopod 5, meanwhile for females of the pereopod 3. Females also have longer pleopods, with pleopod 2-5 being biramous bearing long setae for carrying eggs during breeding season.

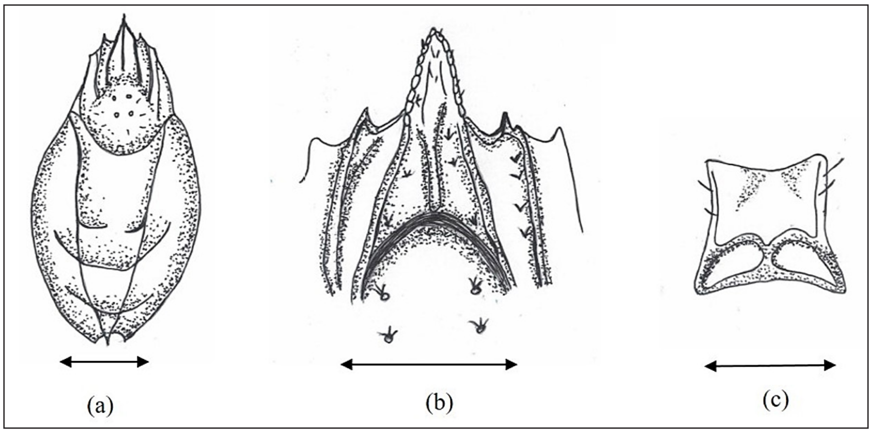

Figure 2. *Thalassina anomala*, female (TL/CL, 252.09/82.70mm). (a) = Dorsal view of carapace, (b) = Dorsal view of cephalothorax, (c) = Dorsal view of first abdominal somite. Scale bars, (a) = 30mm, (b) = 10mm, (c) = 10mm

Morphometric Analysis

Each individual sample was measured for 9 morphological characteristics; total length (TL), carapace length (CL), carapace width (CW), abdomen length (ABL), abdomen width (ABW), chelae propodus length (CPL), chelae propodus height (CPH), chelae propodus width (CPW) and wet weight (WW). Specimens with damaged or missing cheliped were not used for any propodus measurements. Figure 3a showed measurements of TL, CL, CW, ABL and ABW, while Figure 3b showed measurements of CPL, CPH and CPW.

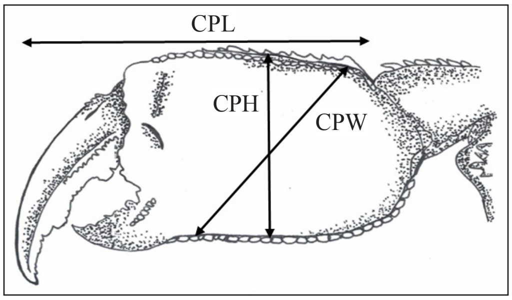

Figure 3b. Morphometric measurements of cheliped mud lobster. CPL = chelae propodus length, CPH = chelae propodus height, CPW = chelae propodus width

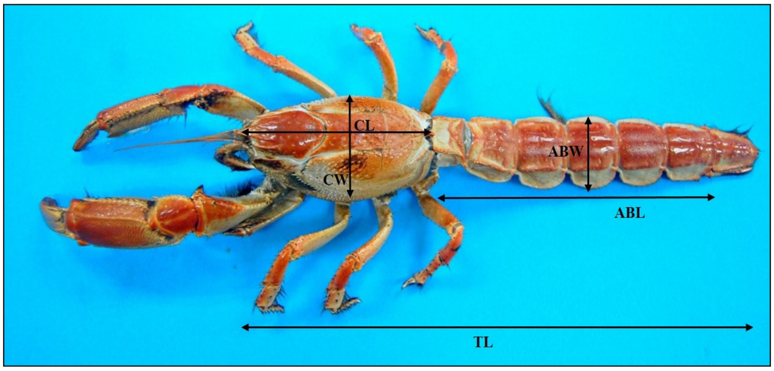

Figure 3a. Morphometric measurements of mud lobster. TL = total length, CL = carapace length, CW = carapace width, ABL = abdomen length, ABW = abdomen width

Data Analysis

The relative values of variables CL, CW, ABL, ABW, WW, CPL, CPW and CPH were calculated on the basis of their absolute values versus total length. Comparisons between sexes were analysed by means of a Student's t-test where the degree of probability was $p<0.05^*$, $p<0.01^{**}$ or $p<0.001^{***}$.

A linear regression analysis was used to analyse length-weight relationship of the specimens between sexes. The analysis was based on the allometric equation:

$$W = aL^b \quad (1)$$

(Hartnoll, 1978). The log transformed data was calculated using the formula:

$$\text{Log } W = b \log L + \log a \quad (2)$$

where a = intercept, b = slope of regression line, W = wet weight of the specimens (g) and L = total length (mm). The b values obtained from all the samples were compared using t-test to investigate allometric growth pattern of the specimens using statistic:

$$t_s = (b-3) / S_b \quad (3)$$

where t_s = t statistic value, b = slope of regression line and S_b = standard error of the slope, according to Sokal and Rohlf (1987). Isometric growth pattern can be identified when b equals to 3. Values of b greater than 3 have positive allometric growth while smaller than 3 shows negative allometric growth.

Positive allometry means weight is gaining faster than length. All statistical tests were carried out using Microsoft Excel 2013 and IBM SPSS version 20 software (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Species Identification

Based on the morphological characteristics, all 70 samples were identified as *Thalassina anomala*. Rostrum for all samples were triangular in shape, with a shallow median sulcus (groove) that did not extend beyond the adostrals, identical to *T. anomala* and *T. squamifera*. In *T. kelanang*, the rostrum is waisted with an acute tip and a deep median sulcus (groove) that reaches behind the adostrals. In addition, tergite of first abdominal somite of all samples has two petaloid depressions in the form of an inverted V which is also in agreement with morphology of *T. anomala*. Other species such as *T. kelanang* and *T. squamifera* have an inverted Y groove instead (Moh & Chong, 2009). These morphological findings strongly suggested that mud lobster collected from all four locations are *T. anomala*.

Sexual Dimorphism

A total of 70 samples were analysed and morphometric variations between males and females were shown in Table 1. From these 70 samples, only 28 samples were analysed for cheliped measurement analysis. Relative values of carapace length of males were significantly higher than females ($p<0.05$).

Relative values for the left chelae propodus in males in terms of length and width were also significantly higher than females ($p<0.05$). Meanwhile, sexual dimorphism could also be seen in the abdominal width, in which it was significantly larger in females, for both absolute values ($p<0.01$) and also the relative values ($p<0.001$). All other parameters showed no significant difference between males and females.

Table 1
Absolute values and relative values for morphological parameters in mud lobster

Parameters	Absolute values ± SD		Relative values ± SD	
	Males (n=37)	Females (n=33)	Males (n=37)	Females (n=33)
Total Length (mm)	197.90±31.42	204.63±45.91	-	-
Carapace Length (mm)	66.02±10.66	66.06±16.16	33.36±1.30*	32.06±2.98
Carapace Width (mm)	34.92±7.14	35.88±9.68	17.54±1.50	17.34±1.93
Abdominal Length (mm)	109.68±18.25	113.43±27.40	55.38±1.62	55.14±2.89
Abdominal Width (mm)	23.09±4.06	28.63±8.96**	11.66±0.76	13.66±2.40***
Wet Weight (g)	126.67±62.03	139.46±77.27	60.86±21.29	62.78±26.34
Chelae Propodus Length (L)(mm)	60.21±14.39	55.29±17.34	29.63±4.30*	27.12±4.31
Chelae Propodus Length (R)(mm)	60.46±16.20	56.24±16.07	29.62±4.96	27.83±4.35
Chelae Propodus Width (L)(mm)	29.59±8.64	25.77±12.06	14.54±3.62*	12.15±3.99
Chelae Propodus Width (R) (mm)	28.07±10.67	24.32±9.64	13.56±4.07	11.65±3.44
Chelae Propodus Height (L)(mm)	22.44±5.83	20.00±8.30	11.19±2.72	9.75±2.89
Chelae Propodus Height (R)(mm)	21.51±8.10	19.10±6.04	10.46±3.06	9.49±2.24

For all propodus parameters, n= 28 for males and n = 28 for females. L = left, R = right. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

The results of this study are in agreement with many morphometric studies of crustaceans. It is common for males to have longer carapace length and bigger chelae (Vasileva et al., 2017; Zaikov et al., 2011). Body size and chelae are among the important morphological characteristics for better opportunities for competition, predation and reproduction (McLain & Pratt, 2007; Miyajima et al., 2012).

According to Rufino et al. (2004), males crab (*Liocarcinus depurator*) had broader carapace than females. Larger carapace is crucial for the insertion of muscles of poreiopods and chelipeds which may contribute to stronger muscles for defence against predators. Besides, larger carapace in males is useful during agonistic interactions in the competition for females (Moore, 2007; Reid et al., 1994).

In this study, females appeared to have larger abdominal width than males. The sexual dimorphism in the abdomen size between sexes of *T. anomala* might be due to the differences in the role of the male gonopods and female pleopods. In females, the increase in abdomen size with long setae is necessary as an incubation chamber for egg development. Daniels (2001) reported that in freshwater crab (*Potamonautes* *warren*), females have marked increase in abdomen size as well for the purpose of carrying eggs during breeding season. According to Goldstein et al. (2014), female lobsters (*Homarus americanus*) have larger abdominal areas to allow attachment of eggs to ovigeorus setae of pleopods on the ventral side of their abdomen.

In decapod crustaceans, cheliped also known as the first pereiopod with a chela (claw) formed by a modification of the dactylus and propodus (Claverie & Smith, 2010). The chelipeds in decapods have important role in feeding, territory defense, for facilitate predation and for communication during courtship and mating (Mariappan et al., 2000). According to Pillai (1990) and Voris and Murphy (2002), the chelipeds of mud lobster are mainly used for burrowing, combat or defence against predators and for feeding. The chelipeds are variable in sizes and no specific handedness was observed in *T. anomala*. Males are more prominent, having larger cheliped than females and sexual dimorphism in terms of cheliped size is common in decapod crustacean (Hartnoll, 1978). Previous study done by Claverie and Smith (2009) revealed sexual dimorphism in cheliped length of the squat lobster (*Munida rugose*). In addition, sexual dimorphism in cheliped size can also be observed in the temperate crayfish, (*Orconectes rusticus*) (Snedden, 1990). In the present study, *T. anomala* exhibits sexual dimorphism where males had significantly longer left chelae propodus length and larger left chelae propodus width than females. Greater cheliped size in males is expected since cheliped plays an important role during agonistic interactions and used as a weapon against predators (Claverie & Smith, 2007) or for sexual competition (Mariappan et al., 2000). Both males and females *T. anomala* in this study have monomorphic and dimorphic chelipeds, with no significant preferences between sexes.

Length-weight Relationship

The total length-weight relationships showed an isometric growth pattern for both sexes and combined sexes as recorded in Table 2. For males ($b = 3.292$, $p > 0.05$) while females ($b = 2.928$, $p > 0.05$) and combined sexes ($b = 3.023$, $p > 0.05$). The regression equation for TL/W relationship for males, females and combined sexes were as follows:

$$\text{Log W} = 3.292\text{Log TL} - 5.495 \quad (R^2 = 0.962) \tag{4a}$$

$$\text{Log W} = 2.928\text{LogTL} - 4.680 \quad (R^2 = 0.965) \tag{4b}$$

$$\text{Log W} = 3.023\text{Log TL} - 4.890 \quad (R^2 = 0.960) \tag{4c}$$

The scatterplots of the TL/W relationship for males and females were plotted in Figures 4a and 4b.

The regression analysis of carapace length-weight relationship of *T. anomala* is shown in Table 3. Males had isometric growth ($b = 3.138$, $p > 0.05$) while females had negative allometric growth ($b = 2.740$, $p < 0.05$). For combined sexes, negative allometric growth was observed ($b = 2.822$,

Table 2
Descriptive statistics and estimated parameters of total length-weight relationship of Thalassina anomala *for both sexes in Sarawak, Malaysia*

Sex	N	Total length (mm)		Wet weight (g)		Regression parameters					Allo-metric growth
		Min	Max	Min	Max	Log a	b	SE	CL	R^2	
M	37	144.27	252.55	47.00	241.00	- 5.495	3.292	0.116	3.055- 3.528	0.962	I
F	33	98.50	265.27	15.00	287.00	- 4.680	2.928	0.099	2.724- 3.131	0.965	I
C	70	98.50	265.27	15.00	287.00	- 4.890	3.023	0.077	2.870- 3.177	0.960	I

M = male, F = female, C = combine sexes, N = number of specimens, Min = minimum, Max = maximum, a = intercept, b = slope, SE = standard error of b, CL = confidence limits of b, R^2 = coefficient of determination, I = Isometric growth

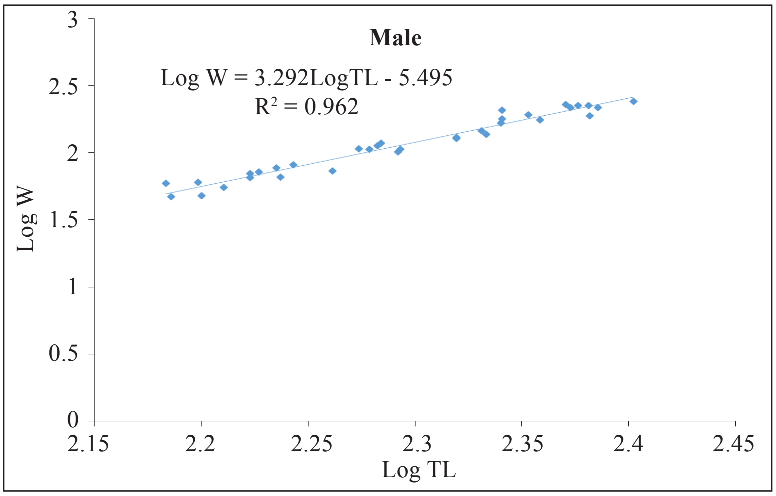

Figure 4a. Total length-weight relationship of male *Thalassina anomala* in Sarawak, Malaysia. W = wet weight, TL = total length

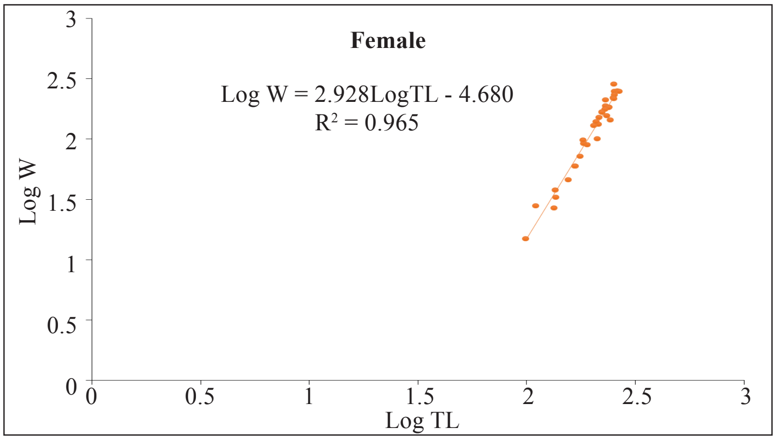

Figure 4b. Total length-weight relationship of female *Thalassina anomala* in Sarawak, Malaysia. W = wet weight, TL = total length

$p < 0.05$). The regression equation for CL/W relationship for males, females and combined sexes were as follows:

$$\text{Log W} = 3.138\text{LogCL} - 3.650 \quad (R^2 = 0.964) \tag{5a}$$

$$\text{Log W} = 2.740\text{LogCL} - 2.894 \quad (R^2 = 0.950) \tag{5b}$$

$$\text{Log W} = 2.822\text{Log CL} - 3.057 \quad (R^2 = 0.950) \tag{5c}$$

The scatterplots of the CL/W relationship for males and females were plotted in Figures 5a and 5b.

Table 3
Descriptive statistics and estimated parameters of carapace length-weight relationship of Thalassina anomala *for both sexes in Sarawak, Malaysia*

Sex	N	Carapace length (mm)		Wet weight (g)		Regression parameters					Allo-metric growth
		Min	Max	Min	Max	Log a	b	SE	CL	R^2	
M	37	42.53	85.13	47.00	241.00	-3.650	3.138	0.121	2.887-3.388	0.964	I
F	33	19.10	83.54	15.00	287.00	- 2.894	2.740	0.127	2.478- 3.002	0.950	-A
C	70	19.10	85.13	15.00	287.00	- 3.057	2.822	0.093	2.635- 3.009	0.950	-A

M = male, F = female, C = combine sexes, N = number of specimens, Min = minimum, Max = maximum, a = intercept, b = slope, SE = standard error of b, CL = confidence limits of b, R^2 = coefficient of determination, I = Isometric growth, -A = negative allometric growth

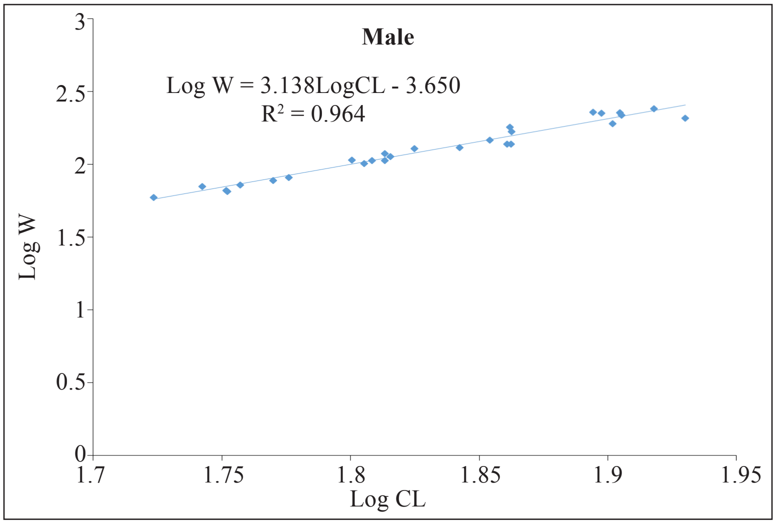

Figure 5a. Carapace length-weight relationship of male *Thalassina anomala* in Sarawak, Malaysia. W = wet weight, CL= carapace length

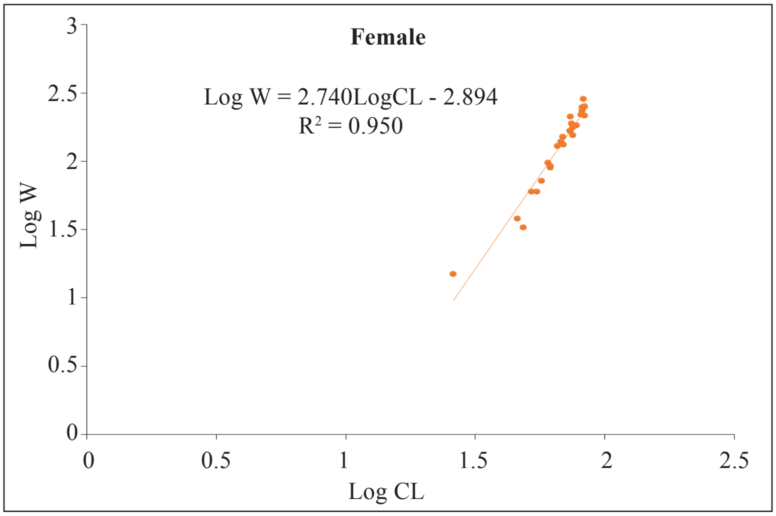

Figure 5b. Carapace length-weight relationship of female *Thalassina anomala* in Sarawak, Malaysia. W = wet weight, CL = carapace length

As shown in Table 4, the abdominal length-weight relationship showed an isometric growth in males ($b = 2.981$, $p > 0.05$) and negative allometric growth in females ($b = 2.743$, $p < 0.05$) and combined sexes ($b = 2.821$, $p < 0.05$). The regression equation for ABL/W relationship for males, females and combined sexes were as follows:

Log W = 2.981Log ABL - 4.016 (R^2 = 0.956) (6a)

Log W = 2.743Log ABL - 3.547 (R^2 = 0.959) (6b)

Log W = 2.821Log ABL - 3.699 (R^2 = 0.955) (6c)

The scatterplots of the ABL/W relationship for males and females were plotted in Figures 6a and 6b. All regression models were statistically significant ($p < 0.05$).

Table 4
Descriptive statistics and estimated parameters of abdominal length-weight relationship of Thalassina anomala *for both sexes in Sarawak, Malaysia*

Sex	N	Abdominal length (mm)		Wet weight (g)		Regression parameters					Allometric growth
		Min	Max	Min	Max	Log a	b	SE	CL	R^2	
M	37	75.65	140.46	47.00	241.00	- 4.016	2.981	0.108	2.762- 3.201	0.956	I
F	33	40.64	151.21	15.00	287.00	- 3.547	2.743	0.106	2.526- 2.959	0.959	-A
C	70	40.64	151.21	15.00	287.00	- 3.699	2.821	0.076	2.670- 2.972	0.955	-A

M = male, F = female, C = combine sexes, N = number of specimens, Min = minimum, Max = maximum, a = intercept, b = slope, SE = standard error of b, CL = confidence limits of b, R^2 = coefficient of determination, I = Isometric growth, -A = negative allometric growth

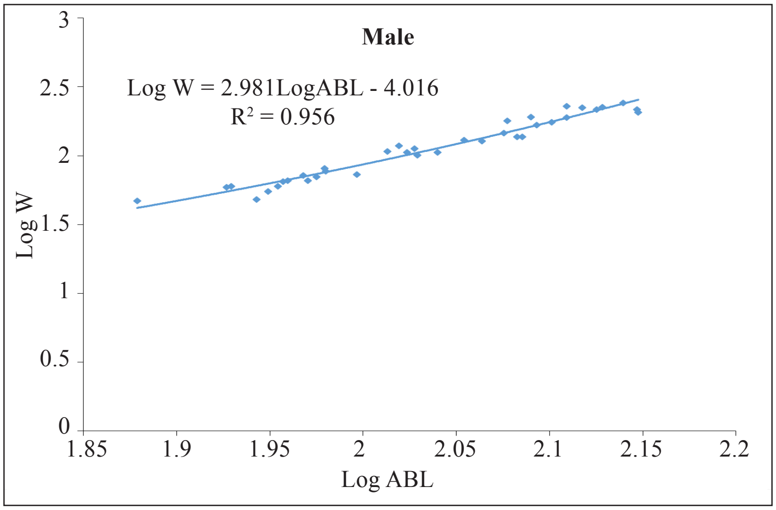

Figure 6a. Abdominal length-weight relationship of male *Thalassina anomala* in Sarawak, Malaysia. W = wet weight, ABL = abdominal length

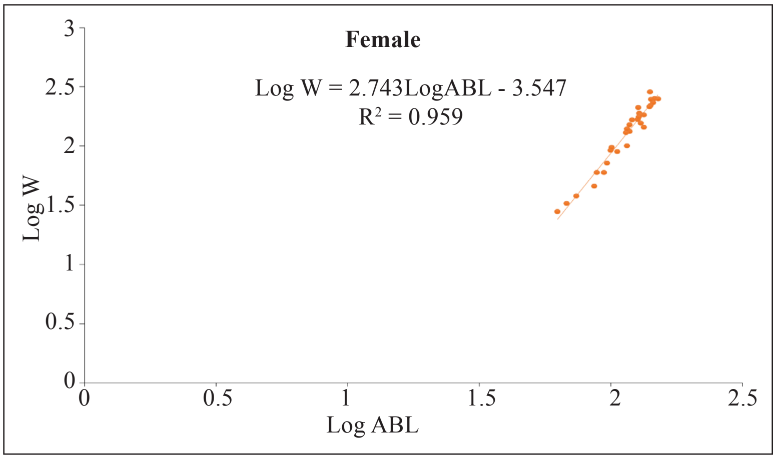

Figure 6b. Abdominal length-weight relationship of female *Thalassina anomala* in Sarawak, Malaysia. W = wet weight, ABL = abdominal length

The present study showed the differences of growth pattern between sexes of *T. anomala*. There are several factors that could contribute to the variations in allometry of decapod crustaceans such as age, sex, differences in diet, foraging behaviour, availability and quality of food, environmental changes regulated by abiotic factors which include season, temperature, salinity and rainfall (Moutopoulos & Stergiou, 2002; Robertson & Butler, 2003; Taddei et al., 2017). In morphometric relationship of length and weight of crustaceans, analysis of total length, carapace length and abdominal length in length-weight relationship are prevalent as these parameters are less variables and more easily measured in the field. As such, the use of these measurements in aquaculture are highly recommended because there are the most precise and simple alternative of analysing growth pattern of organism (Lalrinsanga et al., 2012).

In this study, *T. anomala* males had isometric growth in TL/W, CL/W and ABL/W relationships, indicating that total length, carapace length, abdominal length and body weight of males were growing at the same rate.

Growing at slower rate may be advantageous in terms of energy efficiency as larger individuals require more energy and food intake, which lead to more foraging, thus increase risk of predation. Food limitation and availability may also influence growth rate. According to Claverie and Smith (2009) and Silva et al. (2014), crustacean males are more likely to experience change in energy allocation, in which males may investing more energy in cheliped growth compare to other parts of their body, since cheliped mostly used for agonistic interaction and as an anti-predator adaptation. Meanwhile, *T. anomala* females had negative allometric growth in CL/W and ABL/W relationship, indicating that carapace length and abdominal length increased at a faster rate than body weight. In addition, females had isometric growth in TL/W relationship, where total length increased at a rate proportional to body weight. This growth pattern are presumably a result of devoting and investing more energy in reproduction over growth by females (Robertson & Butler, 2003; Silva et al., 2014). The abdomen part used as an incubation chamber for developing eggs, hence the abdomen growth rate are faster to effectively carry all the eggs produced by the females.

Similar growth patterns can be observed in previous study done by Senevirathna et al. (2014) which showed that in spiny lobster (*Panulirus Homarus*), isometric growth was observed for males in TL/W relationship and negative allometric growth for females in CL/W relationship.

CONCLUSION

This study reported that all mud lobster samples collected from Kuala Tatau (Bintulu), Kuala Balingian (Mukah), Sarikei and Lingga (Sri Aman) are from the same species which is *T. anomala*. Morphometric analyses showed that sexual dimorphism occurred in the carapace length, abdominal width, chelae propodus length and chelae propodus width. The present study also provides basic information of length-weight relationships of *T. anomala* which is useful as references of their biomass and specific management units for their conservation in the future.

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