The morphometric variability of the mangrove horseshoe crab (Carcinoscorpius rotundicauda) from Banyuasin estuarine of South Sumatra, Indonesia

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Article

The morphometric variability of the mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) from Banyuasin estuarine of South Sumatra, Indonesia

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Abstract
The allometric analysis was applied to record the morphometric variability in different sex of the mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) collected from Banyuasin estuarine of South Sumatra, Indonesia during July 2019. The body parameter measurement of body weight (BW), total length (TL), prosoma width (PW), carapace length (CL), and telson length (TL) were recorded then pooled refer to the sex. The differences in each body parameter between the males and females were observed through the Student's t-test. The length/width-weight relationship for both sexes was analyzed using the power equations while the width/length-length relationship was analyzed using the linear equations. The Student's t-test was used to determine significant differences from the isometric value. The females of *C. rotundicauda* were significantly heavier and larger in size than males except for telson length ($p < 0.05$). Both sexes revealed a negative allometric growth for the TL/CL-BW relationships while the males indicated a negative allometric growth but the females indicated an isometric growth for the PW-BW relationships. Both sexes also indicated the isometric growth for the CL-PW relationship. The TL-PW/TEL relationship also revealed a negative allometric growth for both sexes. The study results were expected to be used as baseline data for the horseshoe crab management plan and action.

Key words: Banyuasin estuarine, Body parameters, *Carcinoscorpius rotundicauda,* Morphometric, South Sumatra.

Introduction

Morphometric can be used as an effective tool to study the variation in shape and size of organisms (Webster, 2007) as well as the morphometric studies also useful for comparing various living organisms through the quantitative studies of various body parts (Srijaya et al., 2010). While the relationship between the size and shape of an organism (physical of morphological changes) is described by allometric studies and its results useful for assessing the body shape differences of species inhabiting in various ecosystems (Srijaya et al., 2010; Syuhaida et al., 2019). At the first, the allometric application was used for many organisms especially calculating the population growth characteristics, and furthermore applied to study the population diversity by many biologists extensively (Srijaya et al., 2010).

The mangrove horseshoe crab (*Carcinoscorpius rotundicauda*) is one of the Asian horseshoe crabs (Manca et al., 2017), and was classified in the IUCN red list as data deficient since 1996 (World Conservation Monitoring Centre, 1996). While in Indonesia, the Asian horseshoe crabs are the protected genetic resources based on Minister of Forestry Decree No. 12/Kpts-II/1987 and Government Regulation No. 7/1999. Their distribution includes India, Philippines, Japan, Korea, China, Thailand, Malaysia, Singapore, and Indonesia (Cartwright-Taylor et al., 2011; Chen et al., 2015). In Banyuasin Coastal Waters of South Sumatra (Indonesia), the horseshoe crab was found as a discard catch for the trammel net fishing (Fauziyah et al., 2018) and first investigation record on these horseshoe crabs (*Tachypleus gigas* and *C. rotundicauda*) were successful identified (Fauziyah et al., 2019). However there was no information in detail for the species of *C. rotundicauda* both in the terms of their morphology and population structure.

Generally, there was very limited data found on the horseshoe crab morphology in coastal water of Sumatra Island and this study was a first record on the horseshoe crab morphometric in the coastal waters of South Sumatra, Indonesia. This study's aim was to describe the allometric relationship and the morphometric variability for *C. rotundicauda* from Banyuasin estuarine of South Sumatra, Indonesia. The result could provide baseline information for the growth aspect as well as provide valuable information for future research in detail to create stakeholders awareness in order to save *C. rotundicauda* population.

Material and methods

The live sample was obtained from the Banyuasin estuarine of South Sumatera, Indonesia (Figure 1) during July 2019. The samples were collected using a trammel net fishing and the sampling sites referred to the local fishermen information.

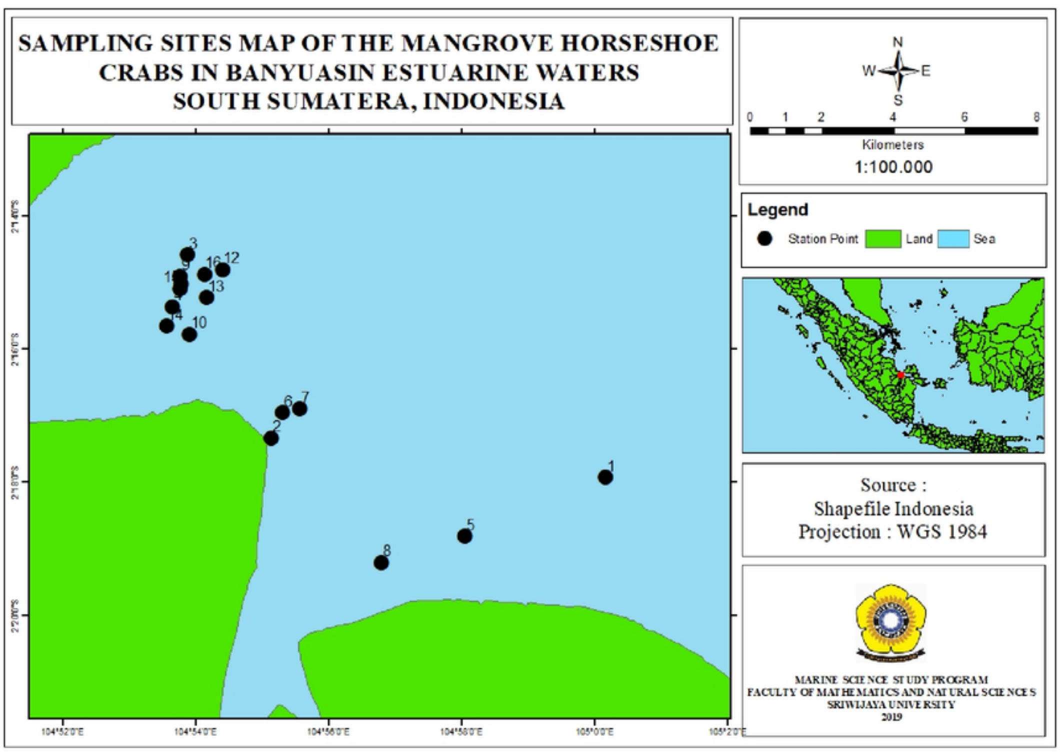

Figure 1. The sampling sites map in Banyuasin Estuarine of South Sumatra, Indonesia (Fauziyah et al. 2019).

The cross-section morphology of the telson was used to distinguish between *C. rotundicauda*, *Tachypleus gigas*, and *Tachypleus tridentatus* (Yang and Ko, 2015). Their telson is triangular for both *Tachypleus* species whereas circular for *C. rotundicauda* (Cartwright-Taylor et al., 2009; Dolejš and Vaňousová, 2015; Tanacredi et al., 2009). Female has a chelate clasper like scissors while the male has a hemichelate clasper like hooks on the first and second walking legs. For this study, female and male were identified as well as morphometric measurements were recorded (Figure 2). The carapace length (CL), prosoma width (PW), telson length (TEL), and total length (TL) were recorded to 1 mm accuracy while body weight (BW) was recorded to 1gram accuracy. All measurements data obtained were pooled refer to the species and sex. The difference in morphometric parameters between the males and females were observed through Student's t-test (Two-Sample Assuming Unequal Variances) using Excel program.

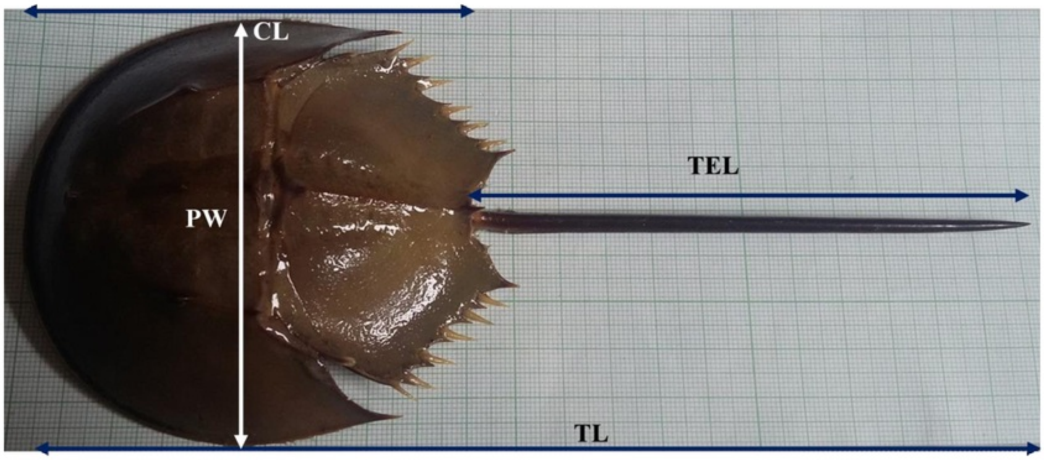

Figure 2. The morphometric measurement of the horseshoe crab; total length (TL), telson length (TEL), prosoma width (PW), and carapace length (CL). The measurement was recorded to 1 mm accuracy.

The length-weight relationship for males and females were analyzed using the power equations $W = aL^b$ (Le Cren, 1951; Froese, 2006; Graham et al., 2009; Jawahir et al., 2017) while the carapace width-length relationship for males and females were analyzed using the linear equations $L_y = a + bL_x$ (Amaral et al., 2014). Regarding the PW-CL, PW-TL and TEL-TL relationships (Amaral et al., 2014), the growth pattern could be isometric ($b = 1$), negative allometric ($b < 1$) or positive allometric ($b > 1$) whereas for the PW-BW, TL-BW, and CL-BW relationships, the growth pattern could be isometric ($b = 3$), negative allometric ($b < 3$), or positive allometric ($b > 3$). The b value is describing growth pattern (Syuhaida et al., 2019) and the Student's t-test (Hegele-drywa et al., 2014) was needed to determine significant differences from the isometric value ($b = 3$ or $b = 1$) with the significant level at 5% ($P < 0.05$). The Student's t-test or known as Bailey's t-test was expressed as follows (Nair et al., 2015; Thomas, 2013):

$$t_s = \left|\frac{3-b}{Sb}\right| \quad \text{or} \quad t_s = \left|\frac{1-b}{Sb}\right|$$

where: t_s = the Student's t-test or Bailey's t-test
Sb = standard error of the b coefficients
b = slope or coefficients regression
3 = isometric value for the PW-BW, TL-BW, and CL-BW relationship
1 = isometric value for the PW-CL, PW-TL and TEL-TL relationship

Results

A total of 45 adults *C. rotundicauda* were found during the survey (♂ = 18, ♀ = 27) and no juvenile individuals were obtained. The specimen sizes were shown as the normal distribution histograms (Figure 3).

In the measurement results of this study (Table 1), the BW means of males and females were 119.61±22.88 gram (ranged from 85 gram to 163 gram) and 202.26±53.80 grams (ranged from 72 gram to 285 gram). The PW means of males and females were 114.17±8.62 mm (ranged between 100-130 mm) and 130±12.48 mm (ranged between 100-150 mm). The CL means of males and females were 110.83±10.04 mm (ranged between 100-130 mm) and 131.48±11.59 mm (ranged between 100-150 mm). The TEL means of males and females were 138.53±18.53 mm (ranged between 80-160 mm) and 145.56±19.87 mm (ranged between 105-180 mm). The TL means of males and females were 250±22.01 mm (ranged between 190-280 mm) and 277.04±26.94 mm (ranged between 215-325 mm).

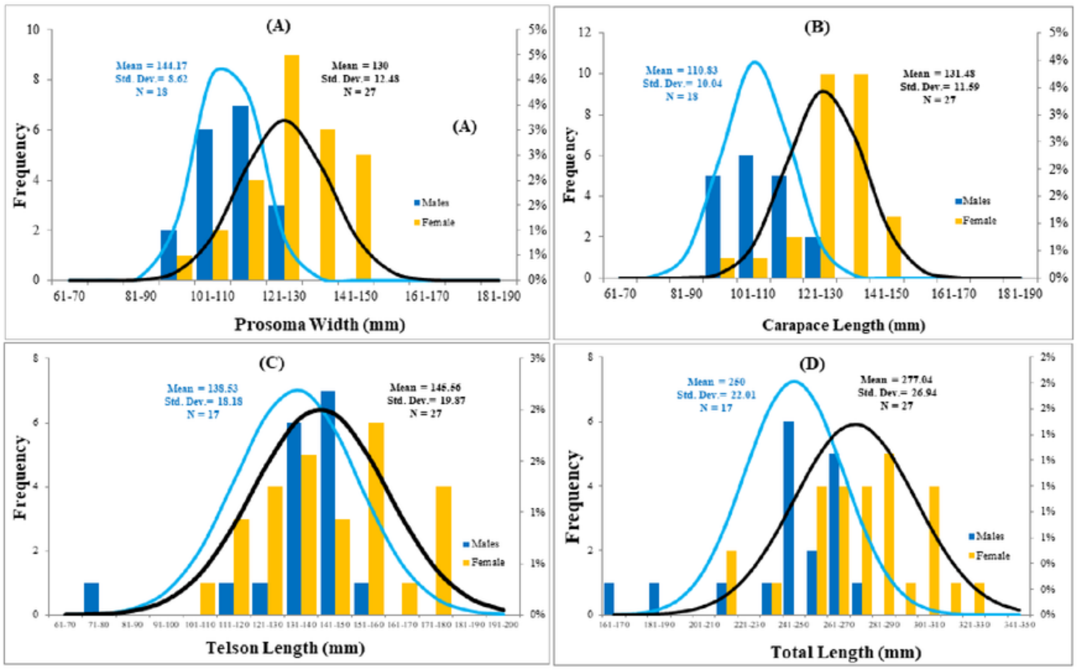

Figure 3. The size distribution of *Carcinoscorpius rotundicauda*. Females were greater in size than males for each measurement of prosoma width (A), carapace length (B), telson length (C) and total length (D).

Table 1. Morphometric measurement records of *Carcinoscorpius rotundicauda* male and female collected from Banyuasin estuarine of South Sumatra, Indonesia. There was a significant difference between sex for the parameters of BW, CL, TL, and PW unless the TEL parameter.

Parameters	Males (N = 18)		Females (N = 27)	
	Mean	Std. Dev.	Mean	Std. Dev.
BW (gram)	119.61[a]	22.88	202.26[b]	53.80
CL (mm)	110.83[a]	10.04	131.48[b]	11.59
TEL (mm)	138.53[a]	18.53	145.56[a]	19.87
TL (mm)	250[a]	22.01	277.04[b]	26.94
PW (mm)	114.17[a]	8.62	130[b]	12.48

BW = body weight, CL = carapace length, TEL = telson length, TL = total length, PW = prosoma width, Std. Dev. = standard deviations, and the same superscripts of each parameters indicated not significant difference between sex at $\alpha = 0.05$.

The most males were found in the PW class 111-120 mm whereas most females were found in the PW class 121-130 mm (Figure 3). The most males were found in the CL-class 101-110 mm while most females were found in the two CL-class namely 121-130 mm and 131-140 mm. The most males were found in the TEL class 141-150 mm while most females were found in the TEL class 151-160 mm. The most males were found in the TL class 241-250 mm while most females were found in the TL class 281-290 mm. The body parameters measurement indicated that the females were greater in size than males for each measurement of prosoma width, carapace length, telson length, and total length. However statistically (Table 1), the females of *C. rotundicauda* were significantly heavier (BW parameter) and larger (CL, PW, and TL parameters) than males while the females were not significantly larger than males for the TEL size.

Table 2. Different relationships between body part parameters for *Carcinoscorpius rotundicauda* male and female. Samples were collected from Banyuasin estuarine of South Sumatra, Indonesia using trammel net fishing. All regressions are significant (α = 0.05).

Body Parameter	Parameters of the relationship					Bailey's t-test			Growth pattern
	b	Sb	Sig. F	R^2	t_b	β	t_{tab}	t_s	
TL-BW (Males)	1.847	0.308	0.000	0.800	5.995 ^{S}	3	2.262	3.741^S	allometric (-)
TL-BW (Females)	2.191	0.174	0.000	0.909	12.621 ^{S}	3	2.120	4.662 ^{S}	allometric (-)
PW-BW (Males)	2.244	0.261	0.000	0.822	8.605 ^{S}	3	2.120	2.901 ^{S}	allometric (-)
PW-BW (Females)	3.012	0.217	0.000	0.885	13.892 ^{S}	3	2.060	0.054 ^{NS}	Isometric
CL-BW (Males)	1.347	0.275	0.000	0.649	4.907 ^{S}	3	2.160	6.021 ^{S}	allometric (-)
CL-BW (Females)	2.077	0.295	0.000	0.712	7.033 ^{S}	3	2.086	3.128 ^{S}	allometric (-)
CL-PW (Males)	0.745	0.123	0.000	0.722	6.034 ^{S}	1	2.145	2.064 ^{NS}	Isometric
CL-PW (Females)	0.884	0.099	0.000	0.815	8.918 ^{S}	1	2.101	1.171 ^{NS}	Isometric
TL-PW (Males)	0.508	0.062	0.000	0.828	8.203 ^{S}	1	2.145	7.946 ^{S}	allometric (-)
TL-PW (Females)	0.336	0.037	0.000	0.806	9.128 ^{S}	1	2.086	18.061 ^{S}	allometric (-)
TL-TEL (Males)	0.739	0.095	0.000	0.800	7.739 ^{S}	1	2.131	2.737 ^{S}	allometric (-)
TL-TEL (Females)	0.680	0.057	0.000	0.849	11.837 ^{S}	1	2.060	5.580 ^{S}	allometric (-)

BW = body weight, CL = carapace length, TEL = telson length, TL = total length, PW = prosoma width, Sb = standard error of the b coefficients, Sig. F = significance F-test, R^2 = the coefficient of determination, t_b = the t-test statistic for H_0 of b = 0, β = allometric value, t_{tab} = critical values of the t distribution, t_s = Bailey's t-test for allometric values, S = Significant, and NS = Not significant.

The TL-BW, PW-BW, CL-BW, CL-PW, TL-PW and TL-TEL relationships for both sexes were shown in Figures 4-6 and Table 2. All relationships between body parameters of *C. rotundicauda* showed a significant difference ($p < 0.05$). The TL/CL-BW relationship for both sexes presented a negative allometric growth ($b < 3$). It's indicated that the BW grew slowly with respect to the TL/CL after molting. The different growth patterns were shown by the PW-BW relationship where the males indicated a negative allometric growth whereas the females indicated an isometric growth (the PW and BW grew at the same rate). The isometric growth was occurrence on the CL-PW relationship (b = 1) for both sex (the PW and CL grew at the same rate). The TL-PW/TEL relationship for both sex ($b < 1$) indicated a negative allometric growth (the PW/TEL grew slowly with respect to the TL). The highest R^2 value in the regression model was shown in females for the TL-BW relationship (R^2 = 0.909) whereas the lowest was male for the CL-BW relationship (R^2 = 0.649). In terms of the R^2 value (R^2 > 0.5), all relations between the major body parameters of *C. rotundicauda* indicated a strong correlation with each other.

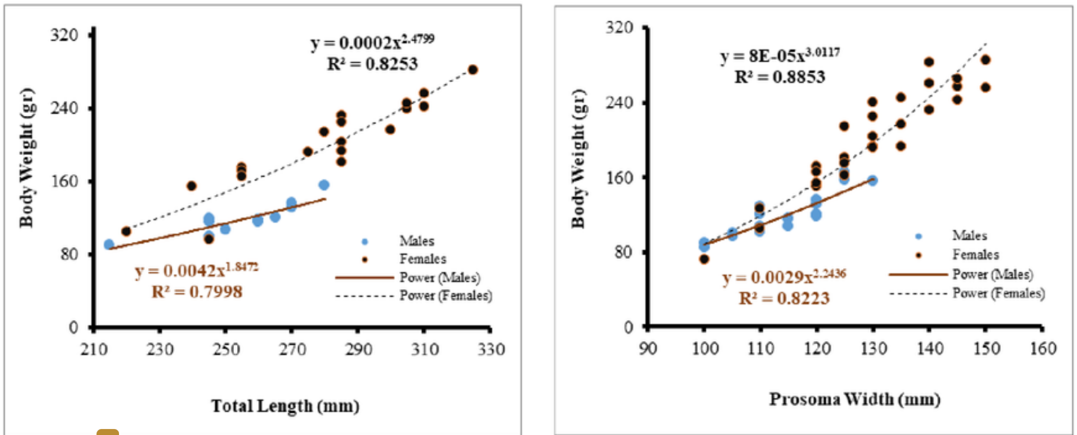

Figure 4. Total length-body weight (left) and prosoma width-body weight (right) relationship of males and females *Carcinoscorpius rotundicauda* from Banyuasin estuarine of South Sumatra, Indonesia. Both sex indicated the body weight grown slowly with respect to the total length (negative allometric, $b < 3$, $p < 0.05$) while the body weight of females also grown slowly with respect to the prosoma width (negative allometric, $b < 3$, $p < 0.05$) but the prosoma width and body weight for males grown at the same rate (isometric, $b = 3$, $p < 0.05$).

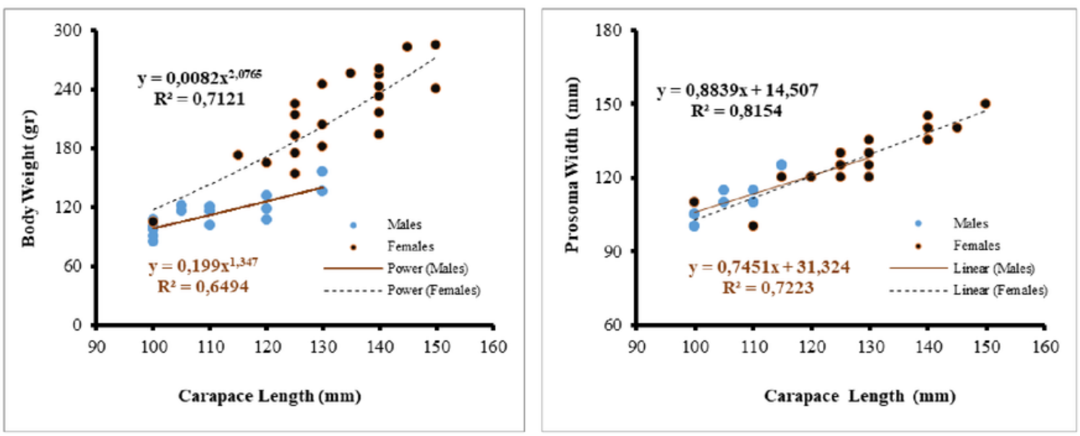

Figure 5. Carapace length-body weight (left) and prosoma width-carapace length (right) relationship of males and females *Carcinoscorpius rotundicauda* from Banyuasin estuarine of South Sumatra, Indonesia. The body weight grew slowly with respect to the carapace length (negative allometric, $b < 3$, $p < 0.05$) for both sexes while the carapace length and prosoma width grown at the same rate (isometric, $b = 1$, $p < 0.05$).

Discussion

This study results provided important data that related to the difference of various body parameters for *C. rotundicauda* males and females from Banyuasin Estuarine since no information and publication before thus became the first record on morphometrical and allometric of horseshoe crabs in South Sumatra, Indonesia. An understanding of the relationship between one body parameter and the other of horseshoe crab was essential to know their growth (Panda and Naik, 2017). The morphometric variation in weight, width, and length for *C. rotundicauda* indicated the populations structure from immature to mature (Syuhaida et al., 2019) and the *C. rotundicauda* populations in this study indicated a mature specimen for both sexes due to their prosomal width were 8 cm and above (Cartwright-Taylor et al., 2009).

The measurement of major body parameters (PW, CL, TL) indicated that the females statistically significant larger in size than male, but statistically there was no a significant difference in size of the TEL between females and males. Similarly, the females larger in size than males were found in another study such as Gelang Patah (Johor) and Setiu of Peninsular Malaysia (Srijaya et al., 2010), Bhitarkanika National Park of Odisha (Panda and Naik, 2017), and Singapore (Cartwright-Taylor et al., 2009). The molting activities and numerous egg in a prosomal cavity for females affecting the females larger in size than males (Graham et al., 2009; Tan et al., 2012) and the reproductive activities of the *C. rotundicauda* also affecting variation in maturity level among their populations (Syuhaida et al., 2019).

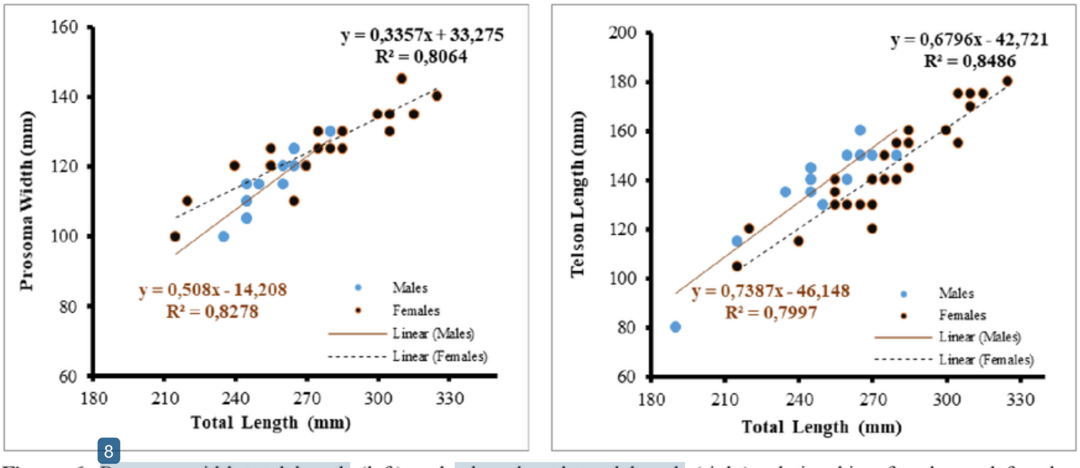

Figure 6. Prosoma width-total length (left) and telson length-total length (right) relationship of males and females *Carcinoscorpius rotundicauda* from Banyuasin estuarine of South Sumatra, Indonesia. The telson length or prosoma width grew slowly with respect to the total length (negative allometric, $b < 1$, $p < 0.05$) for both sexes.

The TL/CL-BW relationships indicated the same growth patterns (negative allometric) for both sexes whereas the PW-BW relationships presented the differences in growth patterns (isometric for females and negative allometric for males). The PW and BW parameters of females grew at the same rate (isometric growth) and the same pattern also occurs in the PW and CL parameters for both sexes. Similar to *C. rotundicauda* from Merlimau Merlimau of Melaka (West Coast of Peninsular Malaysia), the isometric growth in The PW-CL relationship for both sexes was also recorded (Syuhaida et al., 2019). The TL parameter grew rapidly than the PW/TL for both sexes. Nonetheless, females grew slightly greater than males that exhibiting by the value of b females were greater than males.

The negative allometric growth in the TL-BW relationships also recorded in the West Coast of Peninsular Malaysia (Merlimau and Pendas) except female *C. rotundicauda* in Pendas expressed an isometric growth (Syuhaida et al., 2019). The negative allometric growth in the PW-BW relationships also recorded in the West Coast of Peninsular Malaysia except for females in Merlimau expressed an isometric growth (Syuhaida et al., 2019). The female *C. rotundicauda* from Bintan Bay of Riau Islands Province indicated negative allometric growth in the CL-BW relationships but positive allometric growth for males (Anggraini et al., 2017). The differences in the relationship between body parameters for *C. rotundicauda* population could indirectly be affected by food availability, local environmental conditions, feeding efficiency, population density, and genetic effect (Le Cren, 1951; Jawahir et al., 2017; Panda and Naik, 2017; Srijaya et al., 2010; Vijayakumar et al., 2000). Further detailed studies using appropriate molecular tools are needed to find out the growth in the body parameters from the different populations of *C. rotundicauda* (Srijaya et al., 2010). In order to conserve these horseshoe crabs, monitoring the balance of sex ratio and juveniles is essential as an indicator of this population's health (Cartwright-Taylor et al., 2009). In addition, these study results can be used as the baseline data for the conservation management plan to prevent declining the horseshoe crabs population in the future.

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