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Allometry relationship of mangrove horseshoe crab, *Carcinoscorpius rotundicauda* from the West Coast of Peninsular Malaysia

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Abstract
Carcinoscorpius rotundicauda is mangrove horseshoe crab that inhabit in mudflats ecosystem. The values information on morphometric variability of *C. rotundicauda* is still limited especially along west coast of Peninsular Malaysia. A total of 148 samples *of C. rotundicauda* were collected randomly from Merlimau, Melaka and Pendas, Johor characterized by different environmental conditions in order to study the intraspecific variations using allometry relationship. Body weight for male *C. rotundicauda* was 80.02±21.71 g and female was 141.17±54.56 g in Merlimau while in Pendas, the mean for body weight in male was 110.78±39.27 g and female was 177.05±70.98 g. All morphometric parameter were converted into logarithmic value as allometric growth analysis. An isometric allometry growth (b=3) was recorded in the relationship between length-weight for female in Pendas and width-weight for female in Merlimau population. The length/width-length relationships were recorded as an isometric growth (b=1) except for width-length and length-length relationships of male in both population. Overall performance showed that increment in all body parts of female *C. rotundicauda* showed better growth than males. Follow up study on the relationship of horseshoe crab population growth are needed in developing strategies on monitoring, conservation and breeding of horseshoe crab.

Keywords: Morphometric, allometric, *Carcinoscorpius rotundicauda*, peninsular Malaysia

Introduction
Horseshoe crab locally known as 'belangkas' in Malay are one of old marine metazoan belong to family Limulidae that live for more than 400 million years. Studies have proven its closest gelated relatedness with scorpion, tics and mites than to common crabs [13].There are four species of horseshoe crab in the world but only three species that discovered live in Malaysia which are *Tachypleus tridentatus*, *Tachypleus gigas*, and *Carcinoscorpius rotundicauda* [16]. *Carcinoscorpius rotundicauda* is the only horseshoe crab that inhabits in muddy areas and brackish waters [3]. The horseshoe crab is an important in food chain and highly valued in biomedical science. Interestingly, *C. rotundicauda* also contain high biomaterial compounds that have great potential in medical aspect [12]. Unfortunately, the population of *C. rotundicauda* is dwindling dramatically due to habitat degradation and changes in nesting grounds and human activities [1]. Therefore, this study introduced allometry as the method in statistical shape analysis for growth rate in order to protect and monitoring of living of this species.

Allometry is the study of physical or morphological changes with size that may be changes by factors such as age, environment and population density within the same species. The allometry has been demonstrated into biological scaling relationships in terms of log transforming by linear regression. An understanding of the allometry relationships between the size of a body part and the size of the body as a whole is important in define the growth of a species. The increment of body size of a species influenced by increase in age [15]. This concept have been widely used on research marine organisms including the horseshoe crab *T. tridentatus* in Sabah and *T. gigas* [4, 9, 15] but a few studies on *Carcinoscorpius rotundicauda* [14] in Malaysian Peninsular.

Present research attempted to provide baseline information for the growth of *C. rotundicauda* on the basis of the allometry relationships studies. The estimated length/width-weight and length/width-length relationships of *C. rotundicauda* in this study could provide valuable

information for future research in order to make comparison between years and locations.

Materials and Methods

The live sample was collected from different population which are situated along west coast of Peninsular Malaysia, Merlimau, Melaka (N 2º14'73.7'', E102º45'92.62'') and Pendas, (N 1°45′15.1″, E103º 59.701'') in Johor (Figure 1) during June 2017 to July 2017. Male and female crabs were identified and morphometric measurements include body weight, carapace length, prosoma width, telson length and total length were recorded. The samples were weighted to the nearest 0.01 g by using an electronic scale.

The allometric relationship were analyzed as log y = log a + b log x [5] where 'x' is the independent variable, (TL) and body weight (BW) refer to a basis for all other measurements while 'y' is dependent variable determined as prosoma width (PW), carapace length (CL) and telson length (TEL) then log a is the intercept of the line on the y-axis and b is the slope of the line also known as the regression coefficient. The growth pattern for weight relations can be interpret by b value; b = 3 represent isometric allometry growth, b > 3 represent as positive allometry and b < 3 as negative allometry but different interpret for length variables; b=1 as isometric, b>1 as positive allometry and b<1 as negative allometry [5,14]. The comparison between slopes of all logarithm value body parameter was carried out by means of ANOVA ($p < 0.05$) considered as significant differences. All tests were carried out using SPSS Statistics software version 20.0.

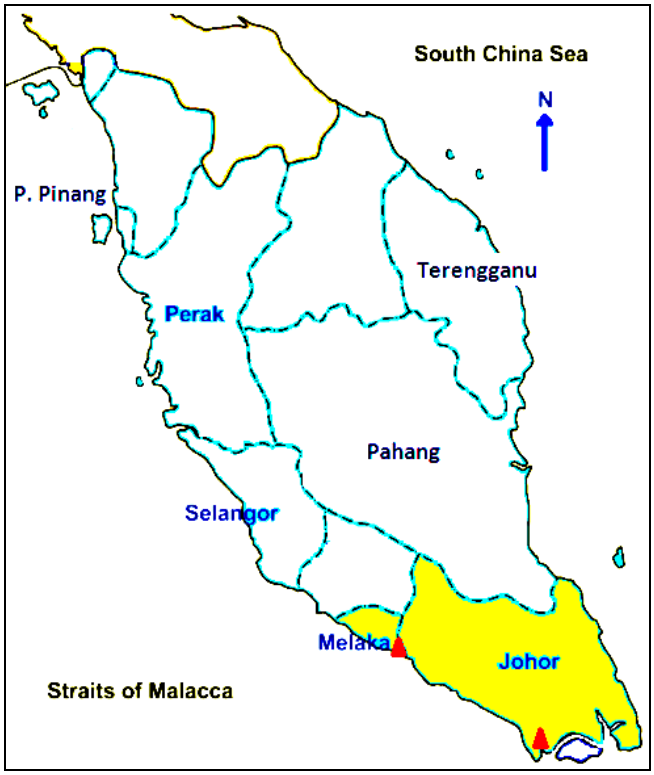

Fig 1: The location of sampling area at Peninsular Malaysia

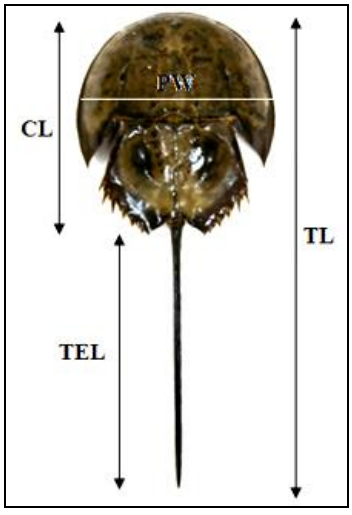

Fig 2: The measurement of morphometric characteristic

Results

Total number of individuals for this study was 88 (59.46%) for males and 60(40.54%) for females respectively. Both males and females had been different size of body. The mean of total width for males and females in Pendas population was 13.59±2.42 cm and 15.72±3.02 while Merlimau was 10.43±1.09 for male and 13.28±2.12 cm for female (Table 1). The mean of males and females body weight in Pendas was 110.78±39.27g and 177.05±70.98g respectively larger than the mean of males and female's body weight in Merlimau was 80.02±21.71g and 141.17±54.56 respectively. Size distribution of total individual *C. rotundicauda* was recorded in Melaka and Johor with 12.00 cm to 13.99 cm prosoma width presented the highest density. While the horseshoe crab ranged from 20.00 cm to 21.99 cm prosoma width had the lowest density (Figure 3).

Table 1: The mean± SD of morphometric parameters of *C. rotundicauda* measured from different populations

	Merlimau, Melaka		Pendas, Johor	
Parameter	**Male**	**Female**	**Male**	**Female**
Total length(cm)	21.70±2.56	28.27±4.33	25.40±3.19	28.94±4.41
Carapace length(cm)	11.13±1.64	14.31±2.28	12.89±2.32	14.75±3.17
Prosoma width(cm)	10.43±1.09	13.28±2.12	13.59±2.42	15.72±3.02
Telson length(cm)	11.56±1.89	14.76±2.54	12.96±2.12	15.38±2.45
Body Weight (g)	80.02±21.71	141.17±54.56	110.78±39.27	177.05±70.98

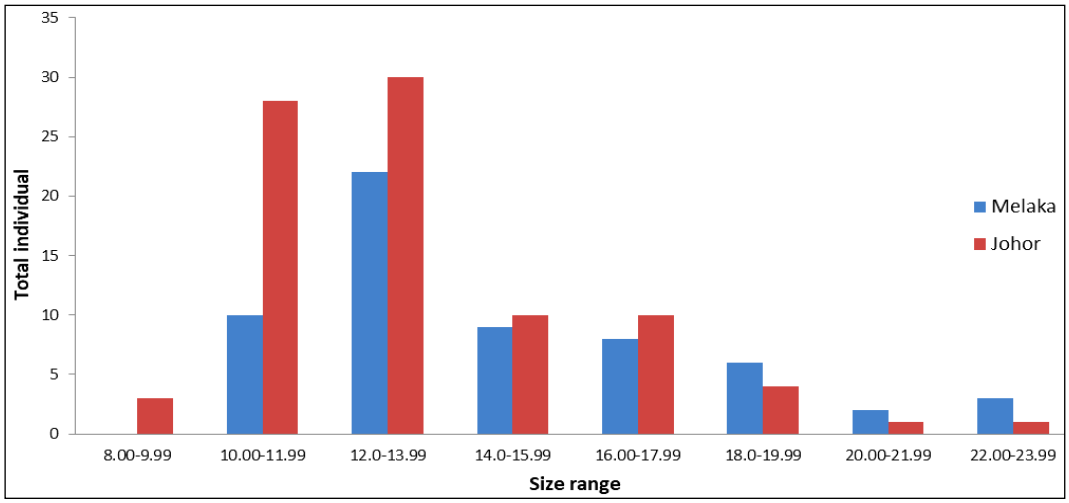

Fig 3: Distribution of length frequency of total individual was recorded in Melaka and Johor

Table 2: Different parameters of length-weight, width-weight, width-length and length-length relationships of male and female of *C. rotundicauda* of two populations

Parameters	**Merlimau, Melaka**							
	Male				Female			
	a	b	r^2	S	a	b	r^2	S
TL:BW	0.428	1.736	0.609	S	1.344	2.391	0.729	S
PW:BW	0.051	1.835	0.454	S	0.882	2.605	0.824	S
PW:CL	0.042	0.941	0.442	S	0.133	0.884	0.672	S
TEL:CL	0.639	0.401	0.097	NS	0.260	0.785	0.532	S
	Pendas, Johor							
	Male				Female			
TL:BW	1.272	2.348	0.717	S	1.914	2.830	0.950	S
PW:BW	0.084	1.717	0.690	S	0.570	2.286	0.928	S
PW:CL	0.733	0.338	0.111	S	0.519	0.572	0.675	S
TEL:CL	0.166	0.832	0.576	NS	0.142	1.094	0.817	S

Note: a= Intercept; b= Slope; r2= Correlation coefficient; BW=Weight; TL= Total Length; PW= Prosoma width; CL= Carapace Length; TEL=telson length; S=Significant; NS= Not significant

The morphometric relationship equations of males and females, values of correlation of coefficient (r^2) and values of allometric growth (b) of *C. rotundicauda* collected from Merlimau, Melaka and Pendas, Johor are given in Table 2. Allometric growth in TL-BW express as b–values indicated as negative allometric growth except female in Pendas population. The b values in Merlimau population was b = 1.736 for male and b = 2.391 for female with significant differences ($p < 0.05$) with correlation ($r^2 = 0.608$ and $r^2 = 0.729$) while in Pendas, Johor showed TL-BW growth increased proportionately with an isometric growth (b= 2.830) and strong correlation, $r^2 = 0.950$ in female but negative allometric growth, b=2.348 with high correlation, $r^2 = 0.717$ in male. The relationship between PW-BW also recorded negative allometry with b value for male (b = 1.835) in Merlimau nearly same with b value (b = 1.717) in Pendas while for female, Merlimau was followed isometric growth, (b = 2.605) but negative allometry for Pendas population (b = 2.286). A straight line on log 'a' (intercept) over 'b' (slop) of male and female of *C. rotundicauda* was produced uniform growth pattern of body dimensions with the advancement of growth in TL/PW-BW relationships in Merlimau and Pendas (Figure 4 & Figure 5).

The graph indicated a linearly relationship between PW-CL and TEL-CL (Figure 6&7). In Merlimau, Melaka the PW-CL relationship for males and females were isometric growth (b = 0.941, $r^2 = 0.442$) indicated that the increase of prosoma width is faster with the increase of carapace length. In Pendas, Johor the male *C. rotundicauda* showed low degree of correlation ($r^2 = 0.575$), with the b value of 0.8321 while for female high degree correlation ($r^2 = 0.8167$) with b value of 1.0939. The relationship of TEL-CL shows negative allometric growth (b < 1) with allometric coefficient, b = 0.4009 with low correlation coefficient $r^2 = 0.0966$ for male but isometric growth, b = 0.7847 with $r^2 = 0.5322$ for female in Melaka. The correlation coefficient (CC) values were recorded as

0.111 for males and 0.674 for females in Pendas, Johor. Regression analysis on PW-CL and TEL-CL relationships showed that as length-length and width- length relationships have isometric growth pattern with not significant ($p > 0.05$) in both populations.

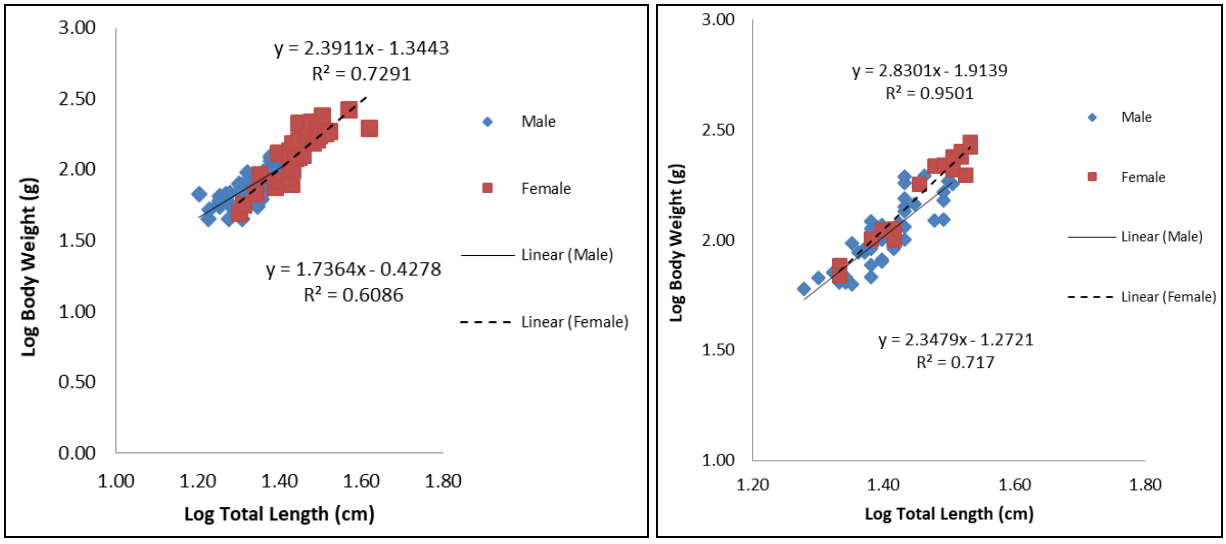

Fig 4: Total Length (BW)-weight (W) relationship of *Carcinoscorpius rotundicauda.* (A)Merlimau, Melaka and (B), Pendas, Johor.

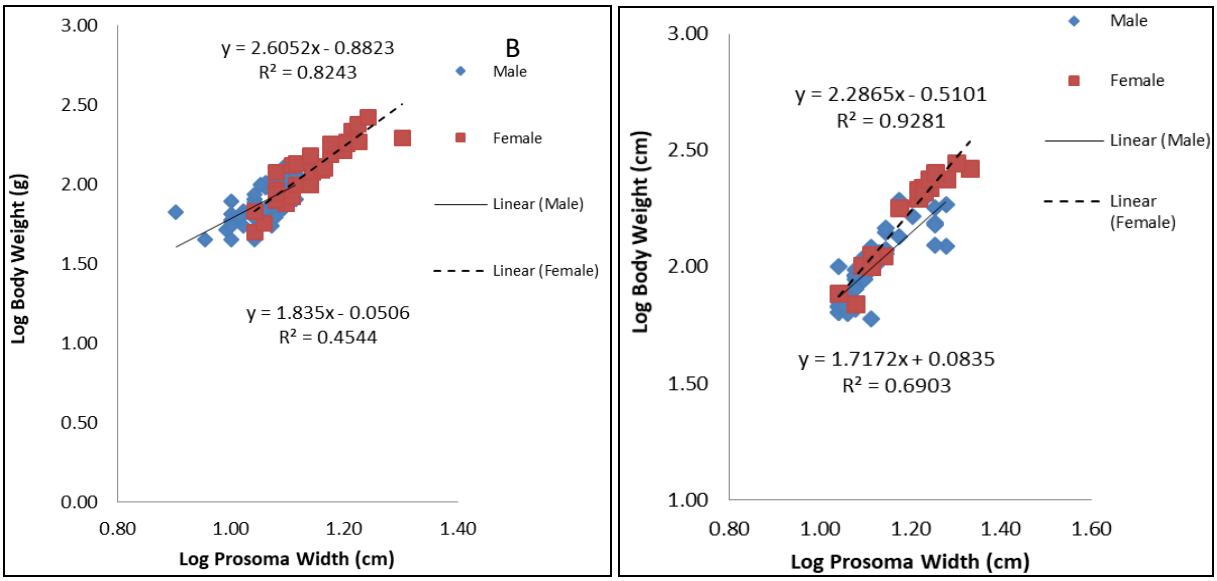

Fig 5: Prosoma width (PW)-weight (W) relationship of *Carcinoscorpius rotundicauda.* (A)Merlimau, Melaka and (B) Pendas, Johor.

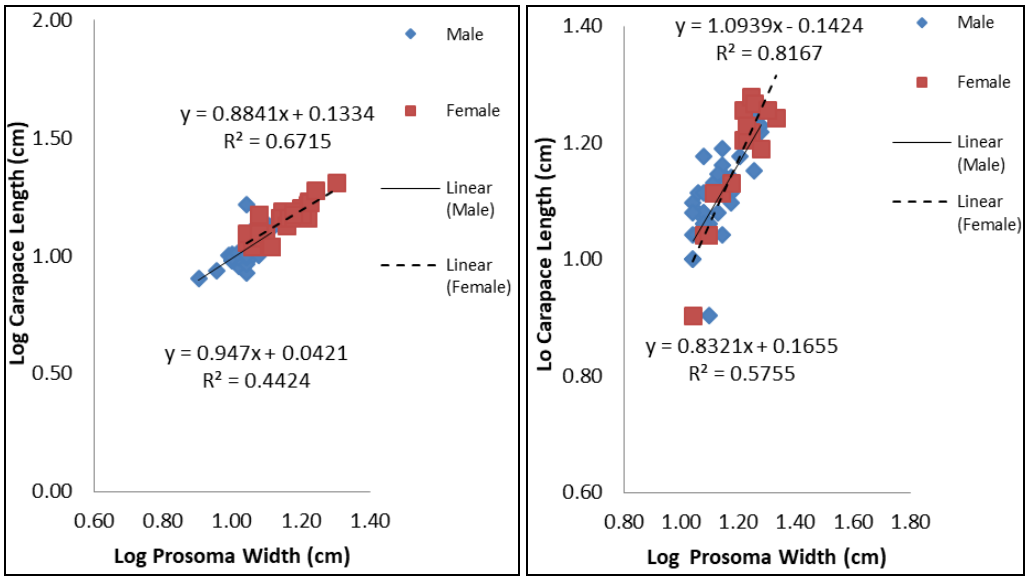

Fig 6: Prosoma width (CW)-Carapace Length (CL) relationship of *Carcinoscorpius rotundicauda.* (A)Merlimau, Melaka and (B) Pendas, Johor.

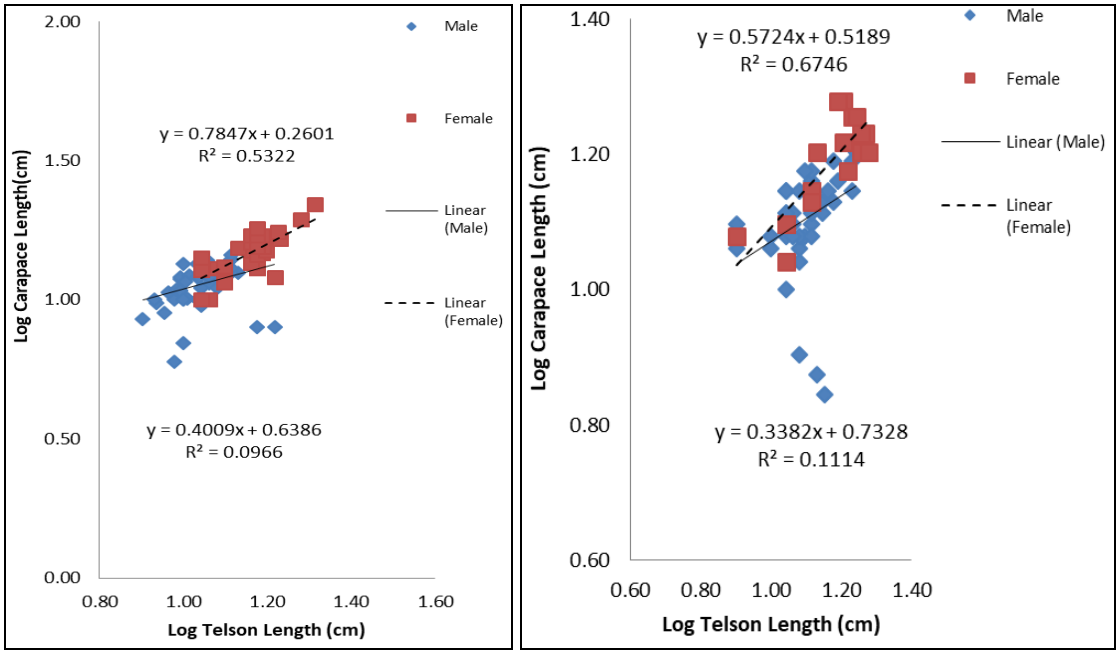

Fig 7: Telson Length (TEL)-Carapace Length (CL) relationship of *Carcinoscorpius rotundicauda.* (A)Merlimau, Melaka and (B), Pendas, Johor.

Discussion

Carcinoscorpius rotundicauda is considered as threatened species [3] and unfortunately in Malaysia has not been gazetted under conservation laws. These data represent important background data for *C. rotundicauda* including length/width-weight and length/width-length relationships on the west coast of Peninsular Malaysia. Variation in length, width and weight of data captured *C. rotundicauda* varied in size indicating that horseshoe crab populations range from immature specimens to maturity. Differences in maturity level of the *C. rotundicauda* among populations could be related with reproductive activities [2]. The allometric analysis shows that male and female *C. rotundicauda* in Merlimau, Melaka and Pendas were grows at different rate from the rest of the body. Differences in b-values were found in relation to sex of horseshoe crab with b-values of females were higher than males, as females exhibited slightly more growth than males with statistically significant (p<0.05). Despite the body form pattern of organism will described by growth allometric parameter, b value also have impact in catching of variation size at that sampling area [7].

Application of length and width against weight relationships is most important way to estimate the growth rate and condition of horseshoe crabs. the life cycle and histories from different region of one species is detected through total length and body weight relationship [10] while the age of horseshoe crab will be grew older as increases the value of prosomal width which is refer to increases the size of horseshoe crab [15]. The minimum size of maturity 12.1 cm to 15.6 cm prosoma width [8]. Therefore most *C. rotundicauda* captured were mainly populations of adults horseshoe crabs. Horseshoe crabs growth pattern could be classified as logarithmic growth. The log-transformed data for length-weight and width-weight relationships for both male and female horseshoe crabs from Merlimau and Pendas showed the increment of body weight more slowly than the PW and TL except length-weight relationships in Pendas and width-weight relationship in Merlimau for female which display an increment of body with good condition. These indicated that the environment along western coastal area is suitable for growth of horseshoe crabs in the future [16]. The weight of the matured female *C. rotundicauda* would be mainly influenced by the present of the eggs and fat content which varies among seasons [2] rather than the size of the carapace. Similar with previous study reported that PW/TL-BW on horseshoe crabs are negative allometry after molting phase [6].

Merlimau and Pendas populations of *C. rotundicauda* shows isometric growth pattern (b=1) in length/width-length relationships in both populations. The variation in length/width-length relationship associated with habitats differences in *C. rotundicauda* [14]. The length–length relationship in horseshoe crabs can be affected by seasonal effect and the discrepancies of habitat conditions in different locations [11]. The favourable environments allowing the growth of marine organisms have isometric in all their body part [4]. The growth of *C. rotundicauda* could indirectly be influenced by population density, feeding efficiency, food availability, and local environmental [9].

Conclusion

Overall, the different body part of the two population of *C. rotundicauda* from Merlimau, Melaka and Pendas, Johor clearly showed significant similarities between populations. Relationships between the width/ length-weight and width/length-length were found linear as evident in the present study. The advancement in the field of morphometric data should be a priority in the future by conducts the sampling activities regularly.

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