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Morphometric Relationships in the Blue Swimming Crabs, (*Portunus pelagicus*) (Linnaeus, 1758) from the Palk Bay, Sri Lanka

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Authors' contributions

This work was carried out in collaboration among all authors. Author SSKH designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors SJWWMMPW and KHKB managed the analyses of the study. Author SJWWMMPW prepared the study area map. Author KHKB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The blue swimming crab (*Portunus pelagicus*) has become the focus of an important export-oriented fishery in Sri Lanka for a decade. The Palk Bay in the Northern coastal waters of Sri Lanka is one of the best-known fishing grounds for blue swimming crabs in Sri Lanka. This study was undertaken with the aim of establishing some morphometric relationships for *P. pelagicus* in the Palk Bay.

Biological sampling was conducted for five consecutive days per month from November 2014 - October 2015 in the Northern landing sites in the Jaffna District where the catch of Palk Bay blue swimming crab fishery was landed. *P. pelagicus* specimens were also randomly collected for laboratory analysis. The morphometric measurements of the specimens for the following parameters were undertaken: CW - carapace width with the spine, CWW - carapace width without spine, MW – mouth width, TL - total length, LCPL - left chelar propodus length, LMOV - left movable

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part Length, RMOV - right movable part length, LCPH - left chelar propodus height, RCPH - right chelar propodus height, ABW - abdominal width, ABL - abdominal length and BW - body weight. The least squared method was used to obtain the Length-Length (L-L) and Length-Weight (L-W) relationships.

Of the 65 L-L relationships obtained for *P. pelagicus* from the study, 34 relationships were correlated (r^2>0.5). The estimated relationships between BW and CW for males and females were BW=0.0001 $CW^{3.01}$ (r^2 =0.84) and BW= 0.0001 $CW^{2.90}$ (r^2 =0.86), respectively.

Positive allometric growth was observed for male *P. pelagicus*, whereas a negative allometric growth was observed for female *P. pelagicus*. Most of the morphometric relationships of *P. pelagicus* obtained in this study were not isometric.

Keywords: Portunus pelagicus; Palk bay; morphometric relationships; allometric growth; isometric growth.

1. INTRODUCTION

More than 4,500 living species of crabs have been reported worldwide [1]. Most crabs reach sexual maturity in 12 months with males growing to a larger size than females [2]. Blue swimming crab (*Portunus pelagicus*) is considered an important commercial species in many countries, such as Australia, Japan, India and Thailand [3]. In Sri Lanka, blue swimming crab has emerged to become an important export- oriented fishery for a decade. This species is abundant in the Northern waters of Sri Lanka. The Palk Bay and the Gulf of Mannar are the best-known fishing grounds in Sri Lanka for blue swimming crabs. However, the published information on *P. pelagicus* in Sri Lanka waters are scanty.

Growth in crustaceans is a discontinuous process involving a succession of moults separated by intermoult [4]. As growth progresses, certain dimensions of the crustacean's body grow much more than others, resulting in the phenomenon known as relative growth [5].

In population studies, morphometric analysis provides a powerful complement to genetic and environmental stock identification approaches [6]. The morphometric relationships of the species can be used to determine the well-being of individuals and to determine possible differences between the same species in different areas [7]. Length-weight relationships are important in fisheries management for growth comparative studies [8]. Also, the length-weight relationship is of great importance in fish stock assessment and can be used for estimating biomass of a species from the length frequency distribution and to convert growth-in-length equations to growth-in-weight [8, 9]. The study is an attempt to build the relationships among different morphological parameters of blue swimming crab. This is the first attempt in building such relationships for blue swimming crab in Sri Lankan waters. These relationships will be useful especially in comparing the growth, maturity and well-being of the same species at different geographical locations including aquaculture systems.

2. MATERIALS AND METHODS

2.1 Biological Data Collection

The biological data collection was conducted for five consecutive days per month mostly in the second week of the month at four blue swimming crab landing sites in the Jaffna District, Sri Lanka from November 2014 - October 2015 (Fig. 1). The catches of the fishing crafts operated in the blue swimming crab fishery in the Palk Bay were landed on the above landing sites. Accordingly, the carapace width and body weight with the sex of *P. pelagicus* were randomly measured and recorded. A vernier calliper was used for taking carapace width measurements, and the body weight of the crab was measured using a digital balance. Around 150 crabs were measured per day per site by the eight enumerators assigned for four sites. However, biological measurements were not obtained from the crabs which were found to be infected due to parasites or organ damaged. Moreover, biological measurements of *P. pelagicus* representing all maturity stages of male and female crabs were obtained.

2.2 Biological Sample Collection and Laboratory Analysis

Freshly caught blue swimming crab samples were purchased monthly from the fishermen operated in the Palk Bay blue swimming crab fishery between November 2014 and October 2015. The same inclusion and exclusion criteria which followed for biological sampling was followed in the biological sample collection too. The collected samples were preserved with ice and brought to the Marine Biology Laboratory of National Aquatic Resources Research and Development Agency (NARA), Colombo. In each crab, the total length (TL) (mm), carapace width (CW) (mm) and other size measurements were also described with the body weight (BW) (g) sex wise.

2.3 Carapace Width – Body Weight (CW-BW) Relationships

To establish the CW-BW relationships, the commonly used relationship, $BW = a\ CW^{b}$ was applied [10], where *a* is the intercept (condition factor) and *b* is the slope (growth coefficient). The CW and BW relationships for males, females and genders combined were separately obtained using CW and BW measurements obtained in the field as well as in the laboratory. The non-linear equations were first converted to linear equations with the natural log transformation. Then, the least square method was used to estimate the parameters, a and b. The R^2 value, the square of the correlation was estimated to determine the goodness of fit of the equation. The student's 't' test was used to determine whether exponent of CW - BW relationship for male and female blue swimming crab are significantly differed from '3'.

2.4 Length - Length (L-L) Relationships

The morphometric relationships between the following parameters were obtained (Fig. 2):

CW - Carapace Width with the spine

CWW -Carapace Width without spine

MW - Mouth Width

TL -Total length

LCPL -Left Chela-Propodus Length

RCPL -Left Chela-Propodus Length

LMOV -Left Movable part length

RMOV -Right Movable part length

LCPH- Left Chela-Propodus Height

RCPH -Right Chela-Propodus Height

ABW - Abdominal width

ABL -Abdominal length

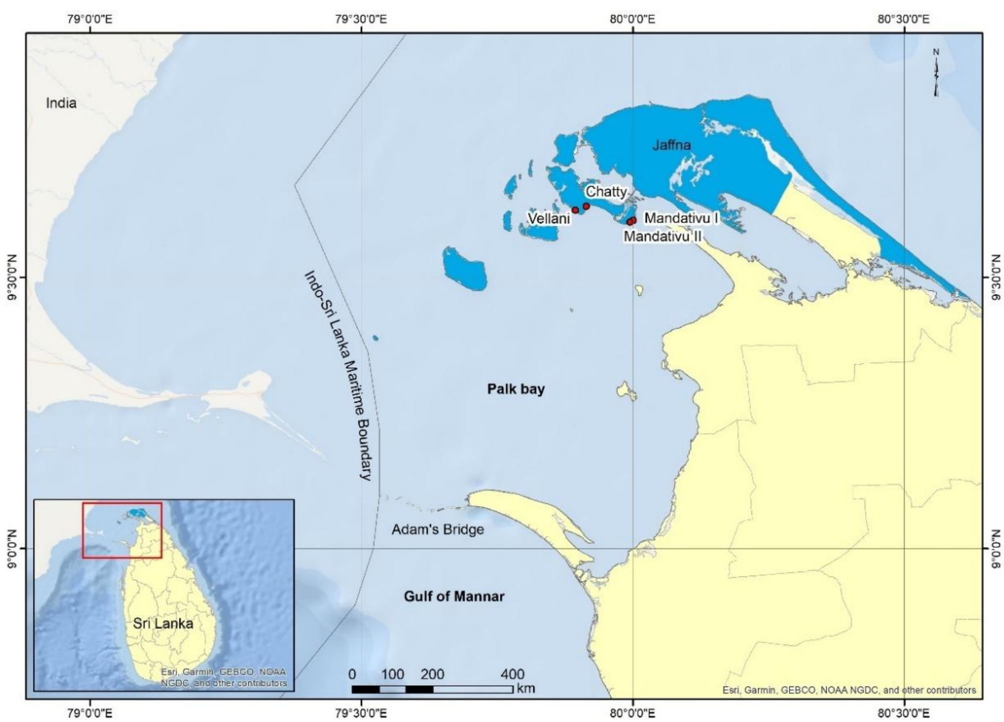

Fig. 1. A map of Palk Bay with sampling sites (Mandativu I, Mandativu II, Chatty, and Vellani) in Jaffna District in Northern Sri Lanka

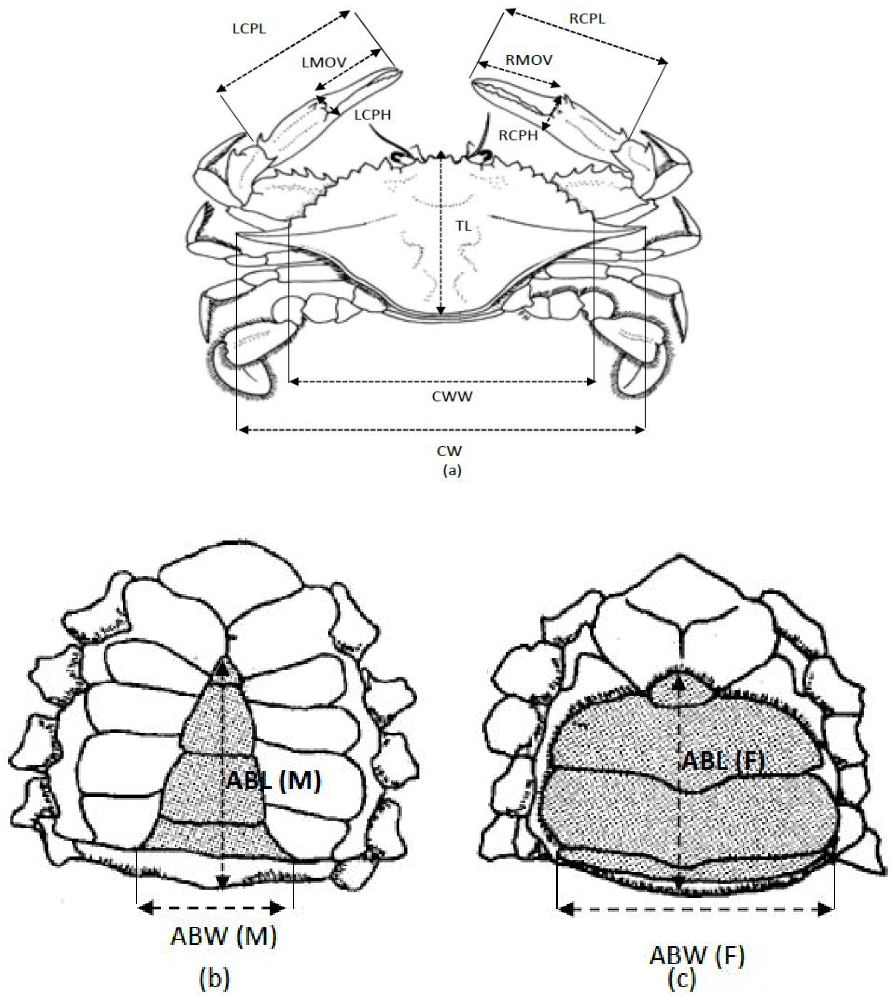

Fig. 2. The length measurements used for morphometric studies in *Portunus pelagicus* (Linnaeus, 1758) from Palk Bay, Sri Lanka

(a) CW-Carapace Width with the spine, CWW -Carapace Width without spine, MW – Mouth Width, TL-Total length, LCPL-Left Chela-Propodus Length, RCPL-Left Chela-Propodus Length, LMOV-Left Movable part Length, RMOV-Right Movable part Length, LCPH- Left Chela-Propodus Height, RCPH-Right Chela-Propodus Height, (b) ABW (M)- Male abdominal width, ABL (M) - Male abdominal length (c) ABW (F) - Female abdominal width, ABL (F) - Female abdominal length

In order to obtain morphometric relationships between parameters, an allometric growth given by the equation $y = a\,x^{b}$ was assumed. Where x and y are any two morphometric parameters listed above and a and b are constants. Then, the equation was converted to the linear form by means of natural log transformation. The least square method was used to estimate the parameters, a and b. Growth was classified as positively allometric when $b > 1$, negatively allometric when $b < 1$, or isometric when $b = 1$. Student's t – test was used to determine whether relationships are allometric or isometric, with significant level at $\alpha = 0.05$. The values of the correlation coefficient (r) were also computed to know the degree of association between the morphometric parameters.

3. RESULTS AND DISCUSSION

3.1 Biological Data Summary

Table 1 summarizes the biological data of blue swimming crabs collected in the field. The CW of male crabs ranged from 70-185mm whereas the CW of female crabs ranged from 67-185mm. The mean CW of females was significantly higher than the mean CW of males (unequal variances t test, p-value <0.001). However, the mean BW of males was significantly higher than the mean BW of females (unequal variances t test, p-value <0.001).

3.2 Morphometric Data Summary

Table 2 summarises the values of morphometric parameters obtained at the Marine Biology Laboratory of NARA. In order to obtain the values for morphometric parameters, seven hundred two crab specimens (females – 396 and males – 306) were analysed.

3.3 CW - BW Relationships

The scatter plots between CW and BW of males, females and combined sexes are shown in Figs. 3, 4 and 5, respectively. The estimated CW - BW relationship for male blue swimming crab was.$BW = 0.0001CW^{3.01}$ The R^2 value was 0.84. The ‘t’ test confirmed that exponent (b value) of CW - BW relationship significantly differed from ‘3’ (α= 0.05). The estimated CW - BW relationship for female blue swimming crab was $BW = 0.0001CW^{2.90}$. The R^2 value was 0.86. The ‘t’ test confirmed that exponent of CW - BW relationship for female blue swimming crab also significantly differed from ‘3’ (α= 0.05). Accordingly, a positive allometric growth was observed for male blue swimming crab, whereas a negative allometric growth was observed for female blue swimming crab. The estimated CW - BW relationship for genders combined was.$BW = 0.0001CW^{2.97}$ The R^2 value was 0.84. All CW - BW relationships mentioned above were significant at 0.001 level.

The study revealed that the growth of *P. pelagicus* in Palk Bay is not isometric and positive allometric growth and negative allometric growth were, respectively observed for male and female crabs. As observed, the exponential value (b) in the CW - BW relationships of male and female crabs showed a considerable difference. When *b* value was less than 3, body becomes slimmer with increasing length, and growth becomes negatively allometric whereas when *b* is greater than 3, body becomes heavier showing a positive allometric growth and reflecting optimum conditions for growth [4,11]. The observed differences in the CW - BW relationships between male and female blue swimming crabs are in agreement with some studies conducted in the Indian Ocean region [4, 12]. However, it has been observed that males followed an isometric growth pattern, whereas in females a significant deviation from isometric growth [9]. A number of factors such as sex, maturity, environment, food availability and feeding habits determine the CW - BW relationship and also other morphometric relationships of crabs [9,13,14].

3.4 L-L Relationships

Fig. 6 shows the scatter plot of L-L relationships of blue swimming crabs, whereas Table 3 summarises the morphometric relationships of blue swimming crabs. Except fourteen relationships, other morphometric relationships were allometry.

Morphometrics and length–weight relationships are widely used in fisheries. Especially, they have been used to study population characteristics and the stock assessment of commercially important species [9,15]. Though crab specimens used in the study represented all maturity stages in the life cycle of the blue swimming crab and were considered in the study for developing morphometric relationships, the occurrence of different growth rates between distinct parts or organs of the body are possible [5]. The weak relationships obtained between some morphological parameters could perhaps be due to this nature of growth in different maturity stages.

Some studies have confined or focused to obtain morphometric relationships of sexually matured crabs [4, 16, 17]. A considerable variation in the growth pattern of crabs has been observed between males and females and different results have been obtained accordingly [4,9,18]. However, this factor was taken into consideration in the study when developing the relationships between carapace width and body weight of *P. pelagicus.*

The morphometric relationships obtained for *P. pelagicus* in the present study can be used for comparing the different stocks of this crab at different geographical locations [6,9]. Accordingly, the results of the study could perhaps be used for morphological identification of the stock structure of *P. pelagicus* in Sri Lankan waters. In particular, the results will be beneficial in comparing the stocks of *P. pelagicus* in the Palk Bay and Gulf of Mannar.

Table 1. Summary in biological data of *Portunus pelagicus* collected in Palk Bay, Sri Lanka: from November, 2014 to October, 2015

Sex	No.	CW (mm)		BW (g)	
		Range	Ave. ± Std dev	Range	Ave ± Std dev
Male	13,055	70 - 185	133.5 ± 17.3	31 - 573	184.4 ± 67.5
Female	21,685	67 - 185	135.1 ± 14.4	31 - 572	169.8 ± 62.0
Combined	34,740	67 - 185	134.6 ± 15.5	31 - 573	179.4 ± 67.1

CW - Carapace Width and BW - Body Weight

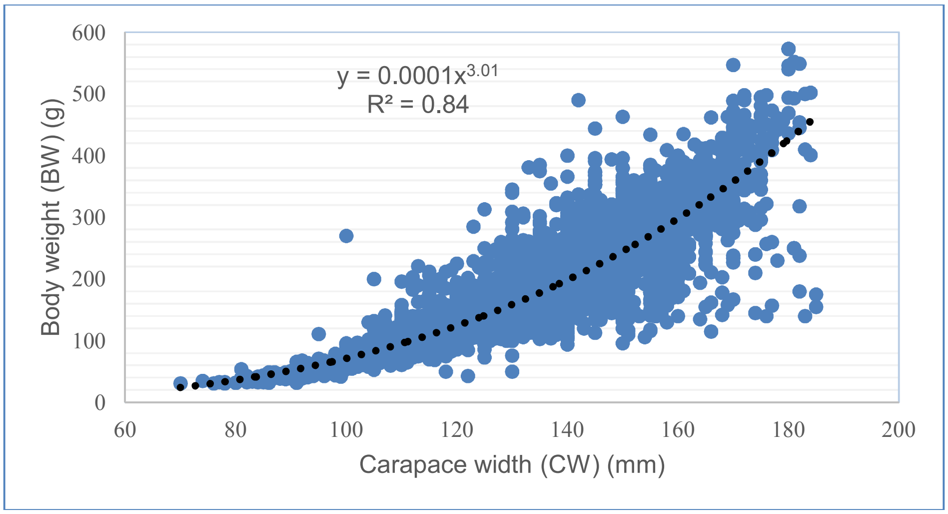

Fig. 3. Carapace Width (CW) – Body Weight (BW) relationship of male *Portunus pelagicus* in the Palk Bay, Sri Lanka

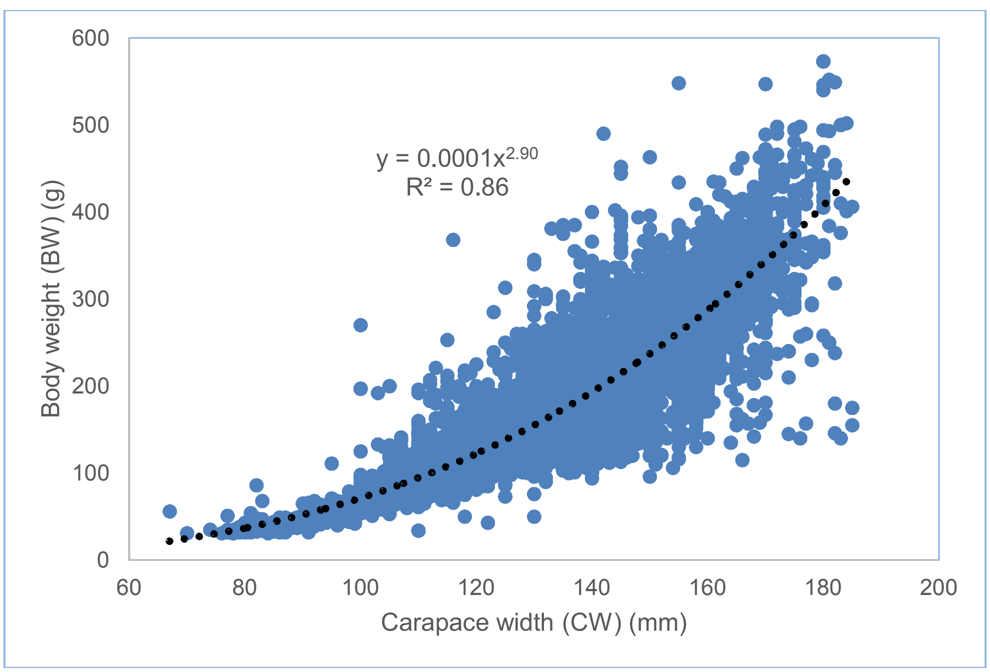

Fig. 4. Carapace Width (CW) – Body Weight (BW) relationship of female *Portunus pelagicus* in the Palk Bay, Sri Lanka

Table 2. Summary in morphometric sample analysis of *Portunus pelagicus* in the Palk Bay, Sri Lanka: from November, 2014 - October, 2015

	Morphometric parameters											
	MW	**CW**	**CWW**	**TL**	**ABL**	**ABW**	**LCPL**	**LCPH**	**LMOV**	**RCPL**	**RCPH**	**RMOV**
Sample size	656	702	700	702	700	699	682	683	679	689	689	687
Minimum value	11.0	66.0	53.0	31.0	22.0	23.0	16.0	9.0	16.0	17.0	8.0	13.0
Maximum value	32.0	177.0	142.0	99.0	71.0	84.0	126.0	38.0	61.0	129.0	33.0	58.0
Average value	23.4	128.2	102.7	58.0	45.2	43.7	79.2	19.0	37.3	79.7	20.4	36.9
Standard deviation	3.3	16.9	14.3	8.7	7.3	6.7	16.3	3.6	7.4	16.7	4.1	7.6

CW-Carapace Width with the spine, CWW -Carapace Width without spine, MW – Mouth Width, TL-Total length, LCPL-Left Chela-Propodus Length, RCPL-Left Chela-Propodus Length, LMOV-Left Movable part Length, RMOV-Right Movable part Length, LCPH- Left Chela-Propodus Height, RCPH-Right Chela-Propodus Height, ABW-Abdominal Width, ABL- Abdominal Length

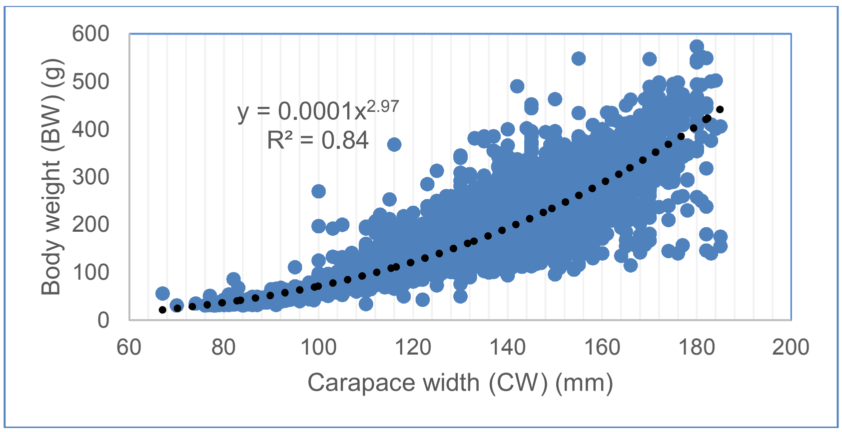

Fig. 5. Carapace Width (CW) – Body Weight (BW) relationship for genders combined *Portunus pelagicus* in the Palk Bay, Sri Lanka

Table 3. Some morphometric relationships of blue swimming crab in the Palk Bay, Sri Lanka (n: sample size, R^2: Coefficient of determination, b: Regression coefficient (slope of the line), t (b=1): student's t-test when b =1)

Variables	n	Power function	R^2	t (b=1)	Allometry level
MW & CW	656	$CW = 8.33MW^{0.87}$	0.85**	9.23	-
MW &CWW	656	$CWW = 5.70MW^{0.92}$	0.86**	5.70	-
MW & TL	656	$TL = 3.48MW^{0.89}$	0.76**	5.48	-
MW & ABL	656	$ABL = 1.70MW^{1.04}$	0.79**	-1.88	=
MW & ABW	656	$ABW = 2.16MW^{0.95}$	0.79**	2.37	-
MW & LCPL	656	$LCPL = 1.81MW^{1.19}$	0.57**	-4.69	+
MW & LCPH	656	$LCPH = 0.84MW^{0.98}$	0.51**	5.00	-
MW & LMOV	656	$LMOV = 0.96MW^{1.16}$	0.63**	-4.43	=
MW & RCPL	656	$RCPL = 2.07MW^{1.15}$	0.54**	-3.56	=
MW & RCPH	656	$RCPH = 1.03MW^{0.94}$	0.43	1.34	=
MW & RMOV	656	$RMOV = 0.73MW^{1.24}$	0.67**	-7.06	+
CW & CWW	700	$CWW = 0.70CW^{1.03}$	0.94**	-3.15	+
CW & TL	700	$TL = 0.43CW^{1.01}$	0.85**	-0.61	=
CW & ABL	700	$ABL = 0.16CW^{1.17}$	0.87**	-9.61	+
CW & ABW	699	$ABW = 0.23CW^{1.08}$	0.88**	-5.26	+
CW & LCPL	682	$LCPL = 0.13CW^{1.32}$	0.59**	-7.58	+
CW & LCPH	683	$LCPH = 0.08CW^{1.11}$	0.54**	-2.92	+

Variables	n	Power function	R^2	t (b=1)	Allometry level
CW & LMOV	679	$LMOV = 0.06CW^{1.31}$	0.68**	-8.87	+
CW & RCPL	689	$RCPL = 0.17CW^{1.26}$	0.57**	-6.23	+
CW & RCPH	689	$RCPH = 0.10CW^{1.09}$	0.49	-2.13	+
CW & RMOV	687	$RMOV = 0.05CW^{1.38}$	0.73**	-11.84	+
CWW & TL	700	$TL = 0.70CWW^{0.95}$	0.84**	-6.15	-
CWW & ABL	700	$ABL = 0.28CWW^{1.10}$	0.85**	-5.56	+
CWW & ABW	699	$ABW = 0.38CWW^{1.02}$	0.87**	-1.48	=
CWW & LCPL	682	$LCPL = 0.24CWW^{1.25}$	0.60**	-6.43	+
CWW & LCPH	683	$LCPH = 0.13CWW^{1.07}$	0.56**	-1.80	=
CWW & LMOV	679	$LMOV = 0.12CWW^{1.23}$	0.68**	-6.98	+
CWW & RCPL	689	$RCPL = 0.30CWW^{1.20}$	0.58**	-5.12	+
CWW & RCPH	689	$RCPH = 0.18CWW^{1.02}$	0.48	-0.47	=
CWW & RMOV	687	$RMOV = 0.09CWW^{1.31}$	0.74**	-10.23	+
TL & ABL	700	$ABL = 0.83TL^{0.98}$	0.74**	0.69	=
TL & ABW	699	$ABW = 0.93TL^{0.95}$	0.81**	2.99	-
TL & LCPL	682	$LCPL = 0.82TL^{1.12}$	0.54**	-3.03	+
TL & LCPH	683	$LCPH = 0.36TL^{0.97}$	0.52**	0.81	=
TL & LMOV	679	$LMOV = 0.44TL^{1.09}$	0.59**	-2.63	+
TL & RCPL	689	$RCPL = 0.91TL^{1.10}$	0.52**	-2.43	+
TL & RCPH	689	$RCPH = 0.44TL^{0.94}$	0.45	1.46	-
TL & RMOV	687	$RMOV = 0.32TL^{1.16}$	0.64**	-4.84	+
ABL & ABW	699	$ABW = 1.59ABL^{0.87}$	0.88**	10.76	-
ABL & LCPL	682	$LCPL = 2.76ABL^{0.88}$	0.42	3.12	-
ABL &LCPH	683	$LCPH = 0.76ABL^{0.84}$	0.50**	4.86	-
ABL & LMOV	679	$LMOV = 1.20ABL^{0.90}$	0.51**	3.05	-
ABL & RCPL	689	$RCPL = 2.86ABL^{0.87}$	0.43	3.41	-
ABL & RCPH	689	$RCPH = 0.88ABL^{0.82}$	0.45	5.13	-
ABL & RMOV	687	$RMOV = 0.91ABL^{0.97}$	0.57**	0.98	=
ABW & LCPL	682	$LCPL = 2.05ABW^{0.96}$	0.44	0.91	=
ABW & LCPH	683	$LCPH = 0.60ABW^{0.91}$	0.50**	2.59	-
ABW & LMOV	679	$LMOV = 0.99ABW^{0.96}$	0.51**	1.24	=
ABW & RCPL	689	$RCPL = 2.13ABW^{0.95}$	0.44	1.11	=
ABW & RCPH	689	$RCPH = 0.66ABW^{0.90}$	0.46	2.62	-
ABW & RMOV	687	$RMOV = 0.69ABW^{1.05}$	0.57**	-1.40	+
LCPL & LCPH	682	$LCPH = 1.79LCPL^{0.54}$	0.38	17.40	-
LCPL & LMOV	679	$LMOV = 1.18LCPL^{0.79}$	0.73**	11.39	-
LCPL & RCPL	682	$RCPL = 1.97LCPL^{0.85}$	0.71**	7.36	-
LCPL & RCPH	682	$RCPH = 2.84LCPL^{0.45}$	0.23	17.36	-
LCPL & RMOV	682	$RMOV = 1.15LCPL^{0.79}$	0.69**	9.99	-
LCPH & LMOV	679	$LMOV = 4.31LCPH^{0.73}$	0.49	9.34	-
LCPH & RCPL	683	$RCPL = 13.80LCPH^{0.59}$	0.27	10.80	-
LCPH & RCPH	683	$RCPH = 4.53LCPH^{0.51}$	0.23	13.65	-
LCPH & RMOV	679	$RMOV = 4.86LCPH^{0.69}$	0.40	9.60	-
LMOV & RCPL	679	$RCPL = 3.78LMOV^{0.84}$	0.60**	5.87	-
LMOV & RCPH	679	$RCPH = 2.66LMOV^{0.56}$	0.31	13.41	-
LMOV & RMOV	679	$RMOV = 1.40LMOV^{0.91}$	0.76**	4.76	-
RCPL & RCPH	689	$RCPH = 2.17RCPL^{0.51}$	0.30	16.58	-
RCPL & RMOV	687	$RMOV = 1.15RCPL^{0.79}$	0.67**	9.95	-
RCPH & RMOV	687	$RMOV = 4.78RCPH^{0.68}$	0.42	10.79	-

*CW-Carapace Width with the spine, CWW -Carapace Width without spine, MW – Mouth Width, TL-Total length, LCPL-Left Chela-Propodus Length, RCPL-Left Chela-Propodus Length, LMOV-Left Movable part Length, RMOV-Right Movable part Length, LCPH- Left Chela-Propodus Height, RCPH-Right Chela-Propodus Height, ABW-Abdominal Width, ABL- Abdominal Length, n: number of individuals; = isometry; + positive allometry; - negative allometry. The morphometric relationships which are correlated are indicated by "**" (R^2>0.5).*

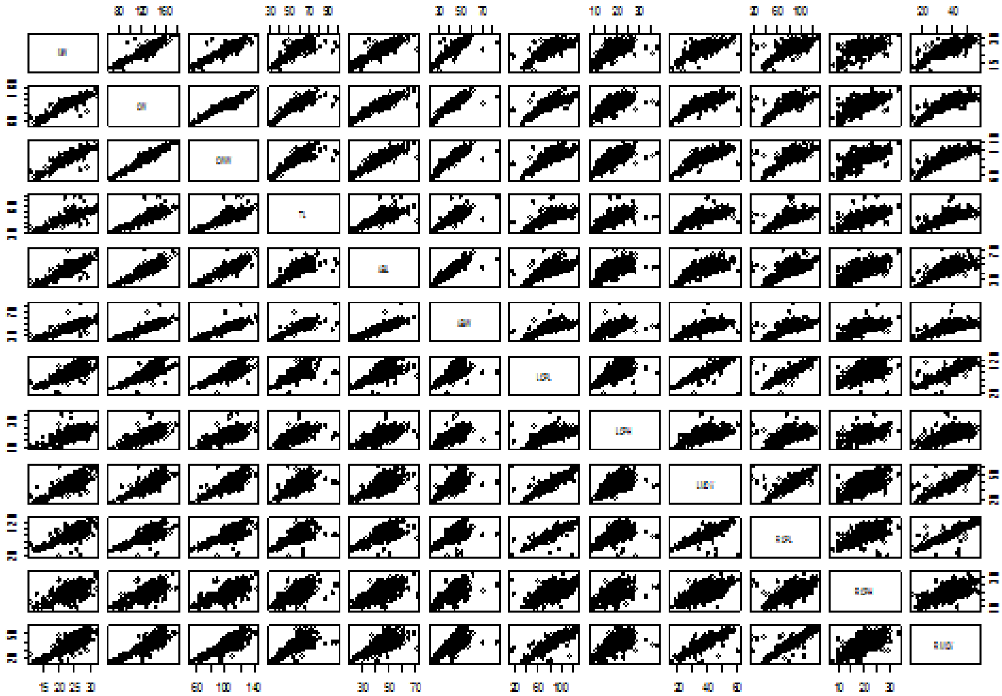

Fig. 6. Scatter plot of length-length relationships of *Portunus pelagicus* in the Palk Bay, Sri Lanka (CW-Carapace Width with the spine, CWW -Carapace Width without spine, MW – Mouth Width, TL-Total length, LCPL-Left Chela-Propodus Length, RCPL-Left Chela-Propodus Length, LMOV-Left Movable part Length, RMOV-Right Movable part Length, LCPH- Left Chela-Propodus Height, RCPH-Right Chela-Propodus Height, ABW- Abdominal width, ABL - Abdominal length)

4. CONCLUSION

The growth of *P. pelagicus* in the Palk Bay, Sri Lanka is not isometric and positive allometric growth and negative allometric growth were, respectively observed for male and female blue swimming crabs. Moreover, many morphometric relationships of *P. pelagicus* that were obtained in this morphometric study were not isometric. The results of the study could be made use for population studies and stock assessments of *P. pelagicus.*

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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