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Relative Growth and Morphometric Measurements as an index for Estimating Meat Yield of two edible crabs *Portunus pelagicus* and *P. sanguinolentus* from the coastal waters of Pakistan

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ABSTRACT: This paper deals with relative growth of long carapace width (LCW) and carapace length (CL) with reference to short carapace width (SCW) in two species of edible crabs, namely *Portunus pelagicus* and *P. sanguinolentus*. The relationship between SCW and CL was found negatively co-related in both the species. Size-weight relationship showed that males are heavier than similar sized females in both species. Meat yield was found higher in *P. pelagicus* than *P. sanguinolentus*. Male P. pelagicus had 40.1 to 51.3% (average 44.5% ± 2.41 SD) meat of the total body weight, whereas female P. pelagicus had 35.6 to 48.6% (average 41.9% ± 2.17 SD) meat. In case of male *P. sanguinolentus* the meat yield varied from 39.0 to 47.7% of the body weight while in female it varied from 32.1 to 43.8% (average 37.7% ± 2.31 SD). More than half of the total meat was found in the thorax. Female thorax yielded more meat (56 and 55% in *P. pelagicus* and *P. sanguinolentus*, respectively) than the male thorax (53 and 51% respectively). Male chalae yielded more meat (30 and 32% in *P. pelagicus* and *P. sanguinolentus*) than that of female (27 and 30%, respectively). Periopods yielded 15 to 17% meat only in both species.

KEYWORDS: Pakistan, Relative growth, Meat yield, *Portunus,* Carapace.

1 INTRODUCTION

The growth in crustacea is a discontinuous process involving a succession of moults separated by intermoults. During intermoults, the exoskeleton is rigid and facilitates accurate measurement. Allometric analysis is useful for taxonomists and ecologists interested in intra- and interspecific morphological variations. Several researchers have used allometric analysis to compare inter-specific variation among population of brachyuran crabs from different location [1], [2], [3], [4], [5].

In fisheries work it is sometimes desirable or even necessary to convert one dimension into other or body size into body weight. The size-weight relationship has a number of uses including the estimation of weight from size for individual crab and also estimation of standing crop biomass when the size-frequency distribution is known [6], [7].

Early studies of relative growth of brachyuran crabs were concentrated on benthic and burrowing species while recent studies have included swimming crabs belonging to the family Portunidae. Width-weight and length-weight relationships of portunid crabs have been studied by Olmi III and Bishop [8], Potter et al. [9], Du Preez and McLachalan [10], George et al. [11], Davidson and Marsden [12], Sumpton et al. [13], Sumpton [14], Sukumaran and Neelakantan [15], Atar and Secer [16], Ali et al. [17], Akin-Oriola et al. [18] and Al-Rumaidh et al. [19].

Study of relative growth and size-weight relationship of crustaceans in general and portunid crabs in particular have received very little attention here in Pakistan. Tirmizi and Aziz [20] studied relative growth of planktonic shrimp Sergestes semissis while presented length-weight relationship of two species of brachyuran crabs [21], namely Matuta planipes and M. lunaris belonging to family Clappidae. No work on relative growth and size-weight relationship of *Portunus* crabs from Pakistan has been published so far.

No analyses on the meat yield have so far been attempted on any brachyuran crabs of Pakistan except Akbar et al. [22] who studied condition index of *P. pelagicus* from the Karachi coast. This being the case, the Morphometric relationship between short carapace width (SCW) and long carapace width (LCW); SCW and carapace length (CL) and SCW and body weight (BW) of the two species of *Portunus* were studied. Also studied were amount of meat present in the crabs and the percentage composition of meat in various parts of the body.

2 Materials and Methods

The sampling was done twice in a month from January 2004 to December 2005. In the laboratory, crabs were sexed, measured and weighted. Only intermoults crabs with intact appendages were used. Berried females, crabs in ecdysis or recently moulted and those with broken appendages or damaged carapace or broken long spine (9th anterolateral tooth) were not included in the analysis.

Measurements of different body parts were taken with the help of divider and millimeter scale. Long carapace width was taken from the tips of ninth anterolateral teeth whereas SCW was taken from the bases of ninth anterolateral teeth. Carapace length (CL) was measured from anterior to posterior edge of carapace. Length of chelar propodus (CPL) was taken from the tip of propodus (fixed finger) to the base where it articulates with carpus. A total of 962 crabs (540 belonging to *Portunus pelagicus* and 422 to *P. sanguinolentus*) were studied for relative growth.

For the study of meat content, 502 crabs (282 *P. pelagicus* and 220 *P. sanguinolentus*) were sacrificed for determining the weight of meat present in the different parts of the body. After taking the wet weight of the intact crab, it was dissected and meat from the thorax, walking legs and cheliped was carefully removed manually and weighted separately on a top loading electronic balance to nearest 0.1 gram. The statistical analysis of the data, was done as described by Rasheed and Mustaquim [23].

3 Results

Relative Growth

3.1 Portunus pelagicus

A total of 540 *P. pelagicus* (280 males and 260 females) were used for study of relative growth. The size (SCW) of male and female crabs, ranged from 23 -135 mm (mean 73.87 mm ± 21.87 S.D.) and from 26-148 mm (mean 72.97 mm ± 24.01 S.D.) respectively. The weight of crabs varied from 2 - 380g (mean 70.53 g ± 64.27 S.D.) for males and from 2- 397g (mean 66.55 g ± 65.54 S.D.) for females.

3.1.1 Short Carapace Width And Long Carapace Width

Figures 1A-C illustrates the linear relationships between SCW and LCW. The regression equations are given in table 1. It is evident from the regression equations that allometric growth in male was negative and value b obtained for male was found significantly less than 1 ($t = 2.233$; $\alpha = 0.05$) but the growth was isometric in female and value b obtained for female was not significantly different from 1 ($t = 1.233$; $\alpha = 0.05$). Similarly the difference between male and female 'b' values was found statistically insignificant ($t = 0.724$; $\alpha = 0.05$). When the male and female data were combined, the value of b obtained was 0.9824, which is not significantly different from 1 ($t = 1.665$; $\alpha = 0.05$). The two variables were found strongly co-related (R^2 = 0.99).

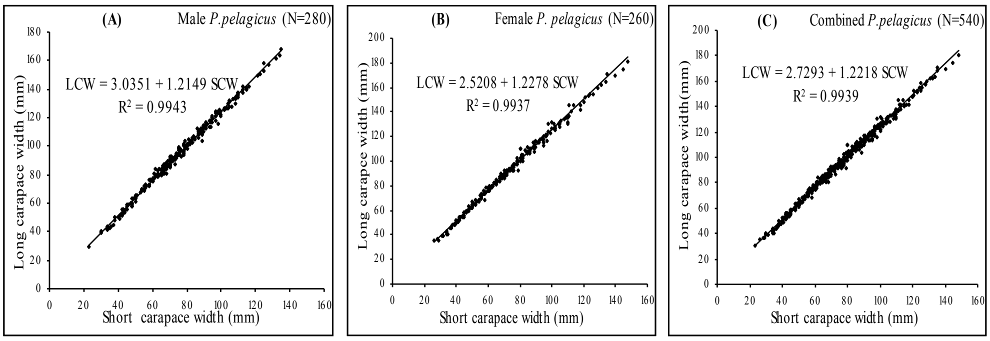

Fig. 1. Portunus pelagicus: linear relationship between short carapace width (SCW) and long carapace width (LCW) in (A) male, (B) female and (C) combined.

3.1.2 Short Carapace Width And Carapace Length

The relationships between SCW and CL are illustrated in figures 2 A-C for male and female *P. pelagicus*, while regression equations are given in table 1.

Table 1. Portunus pelagicus: summary of linear regression and log-transformed regression analysis. Short carapace width (SCW) and long carapace width (LCW) and carapace length (CL) of male, female and combined. b: regression coefficient (slope of the line), R^2: coefficient of determination, S.E. (b): standard error of b, t (b=1): student's t-test when b =1, t (b=b): student's t-test for comparison of two slopes b.

Y-Variable	Sex	Regression equations	R^2	b	S.E. (b)	t (b=1)	t (b=b)
Long carapace width (LCW)	Male	LCW = 3.0351 + 1.2149 SCW	0.994	0.9774	0.0101	2.233*	0.724
		Log LCW = log 0.141 + 0.9774 log SCW	0.994				
	Female	LCW = 2.5208 + 1.2278 SCW	0.993	0.9866	0.0108	1.233	
		Log LCW = log 0.126 + 0.986 log SCW	0.994				
	Combine	LCW= 2.7293 + 1.2218 SCW	0.993	0.9824	0.0105	1.665	……
		Log LCW = log 0.1333+ 0.982 log SCW	0.994				
Carapace length (CL)	Male	CL = 1.3641 + 0.5598 SCW	0.993	0.9551	0.0104	4.280*	0.032
		Log CL= log - 0.1534 + 0.955 log SCW	0.993				
	Female	CL = 1.3837 + 0.5586 SCW	0.995	0.9555	0.009	4.579*	
		Log CL = log - 0.1548 + 0.955 log SCW	0.995				
	Combine	CL = 1.3604 + 0.5591SCW	0.994	0.9554	0.0106	4.203*	…..
		Log CL = log -0.1546 + 0.9554 log SCW	0.994				

* significant (α = 0.05)

The values of b obtained from log-transformed data are 0.9551 for male and 0.9555 for female which are significantly less than one (t= 4.280 for male and 4.579 for female; α = 0.05) which indicates negative allometric growth for both male and female. The difference between male and female b was found insignificant (t= 0.032, α = 0.05). Hence the two data were pooled together (figure 2C). The regression equations for combined data are given in table 1 and the value of b (0.9554) was found significantly less than 1(t = 4.203; α = 0.05). The two variables were found strongly co-related (R^2= 0.99).

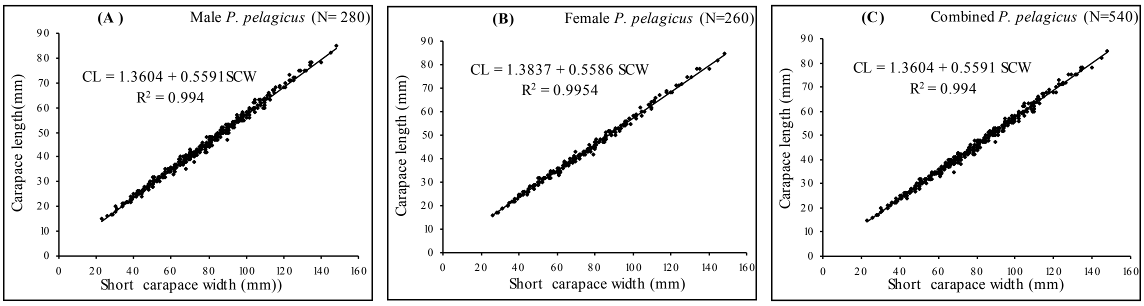

Fig. 2. Portunus pelagicus: linear relationship between short carapace width (SCW) and carapace length (CL) in (A) male, (B) female and (C) combined

3.1.3 Short Carapace Width And Body Weight

The relationships between SCW and BW for male and female *P. pelagicus* are shown in figures 3 A-C. The estimated value of b was 3.0278 for male and 2.9864 for female. Although the males appear to be slightly heavier than the females of equal size, but the values of b were not found significantly different from 3 (t = 0.591 for male and 0.346 for female; α = 0.05). This shows that there is cubic relationship between size and weight, hence the growth is isometric. Student's *t*-test was also performed to compare the two values of b and it was found that the difference was also insignificant statistically (t = 1.019; α = 0.05). The regression equations are given in table 2.

Table 2. Portunus pelagicus: summary of cubic regression and log-transformed regression analysis between short carapace width (SCW) in mm and body weight (BW) in g.

Y-Variable	Sex	Regression equation	R^2	b	S.E. (b)	t (b=3)	t (b=b)
Body weight (BW)	Male	$BW = 0.0001\ SCW^{3.0278}$	0.9873	3.0278	0.046	0.591	1.019
		$Log\ BW = -3.91 + 3.0278 \log SCW$	0.9873				
	Female	$BW = 0.0001\ SCW^{2.9864}$	0.9922	2.9864	0.0393	0.346	
		$Log\ BW = -3.864 + 2.9864 \log SCW$	0.9922				
	Combined	$BW = 0.0001 SCW^{3.0086}$	0.9892	3.0086	0.0447	0.192	….
		$Log\ BW = -3.894 + 3.0086 \log SCW$	0.9892				

The coefficient of determination (R^2) was found to be 0.99 indicating strong relationship between the two variables.

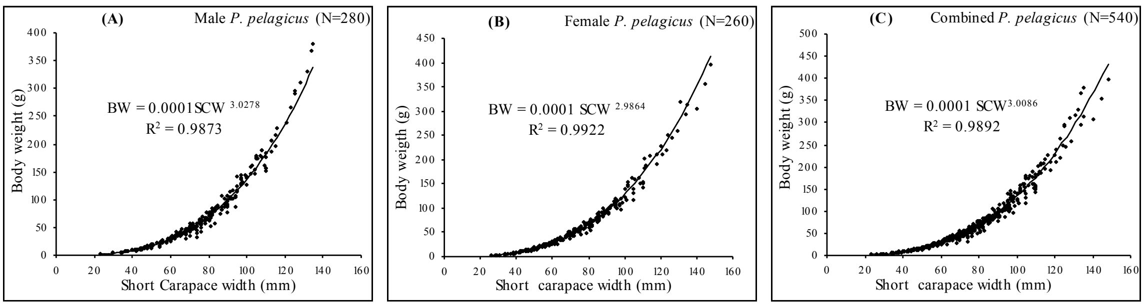

Fig. 3. Portunus pelagicus: cubic relationship between short carapace width (SCW) and body weight (BW) of (A) male, (B) female and (C) combined.

3.2 PORTUNUS SANGUINOLENTUS

Out of 422 *P. sanguinolentus* used for relative growth study, 214 were males and 208 were females. The short carapace width of the crabs ranged from 24 to 130 mm (mean 84.58 mm ± 17.34 S.D). The mean short carapace width of males was 88.08 mm ± 17.85 S.D. (range: 24 to 125 mm) and that of females 81.04 mm ± 16.09 S.D. (range: 28 to 130 mm).

3.2.1 SHORT CARAPACE WIDTH AND LONG CARAPACE WIDTH

Figures 4 A-B shows the linear and log-transformed relationships between SCW and LCW in male and female *P. sanguinolentus*. The regression equations are given in table 3.

Table 3. Portunus sanguinolentus: summary of linear regression and log-transformed regression analysis: (short carapace width (SCW) with long carapace width (LCW) and carapace length (CL) of male, female and combined. b: regression coefficient (slope of the line), R^2: coefficient of determination, S.E. (b): standard error of b, t (b=1): student's t-test when b=1, t (b=b): student's t-test for comparison of two slopes b.

Y-Variable	Sex	*Regression equations*	R^2	b	S.E. (b)	t (b = 1)	t (b = b)
Long carapace width (LCW)	Male	LCW = 2.565 + 1.2386 SCW	0.991	0.979	0.008	2.505*	2.468*
		Log LCW = log 0.144 + 0.9787 log SCW	0.9932				
	Female	LCW = 4. 0429 + 1.2272 SCW	0.9869	0.956	0.009	4.494*	
		Log LCW = log 0.191 + 0.9555 log SCW	0.9879				
Carapace length (CL)	Male	CL = 1.7825 + 0.517 SCW	0.9912	0.949	0.008	6.121*	1.245
		Log CL = log - 0.172 + 0.9498 log SCW	0.9933				
	Female	CL = 1.8386 + 0.5218 SCW	0.9903	0.956	0.008	6.151*	
		Log CL = log - 0.179 + 0. 9559 log SCW	0.9917				
	Combined	CL = 2.1084 + 0.5155 SCW	0.9895	0.952	0.009	5.314*	…..
		Log CL = log -0.1736 + 0.9516 log SCW	0.991				

*significant (α=0.05)

The value of regression coefficient b was found to be 0.9787 for male and 0.9555 for female. These values were found significantly less than 1 (t = 2.505 for male and 4.494 for female, α = 0.05), which shows that the growth was negative. The difference between male and female b values were also found significantly different (t = 2.468, α = 0.05) therefore the data of male and female crabs were not combined. The two variables in male and female were found strongly co- related (R^2= 0.99).

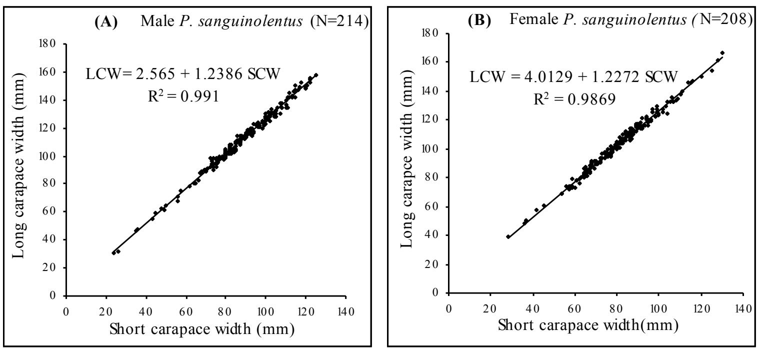

Fig. 4. Portunus sanguinolentus: linear relationship between short carapace width (SCW) and long carapace width (LCW) in (A) male and (B) female

3.2.2 SHORT CARAPACE WIDTH AND LONG CARAPACE LENGTH

The relationships between SCW and CL for male and female *P. sanguinolentus* are shown in figures 5 A-C. The regression equations, which are given in table 3, shows that the CL does not increase isometrically with respect to SCW. The value of regression coefficient b for male was found to be 0.9498 and that of female 0.9559, which are significantly less than 1 (t = 6.121 for male and 6.151 for female, α = 0.05) indicating negative allometry. Student's *t*-test revealed that the difference between male and female b values was insignificant (t = 1.248; α = 0.05) and therefore the two data were combined. The two variables were more strongly co related in male (R^2= 0.990) than those of female (R^2= 0.987). Figure 5C shows the linear relationship between carapace width and carapace length of the combined data and 5F shows log- transformed relationship of same variables.

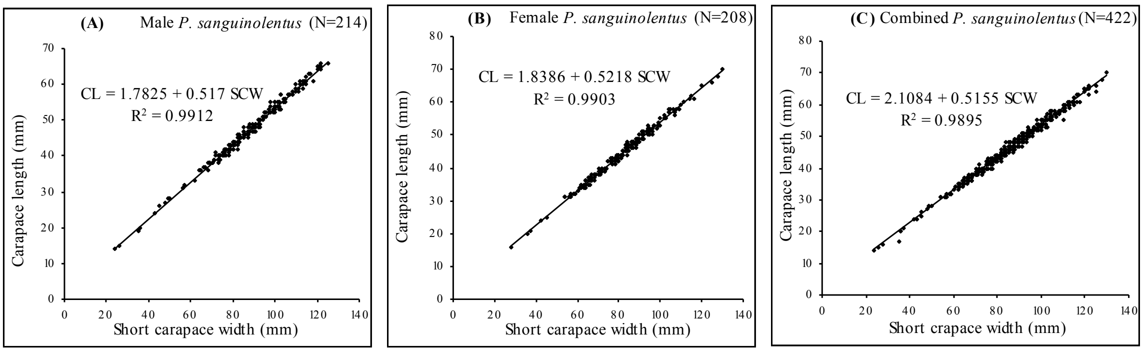

Fig. 5. Portunus sanguinolentus: linear relationship between short carapace width (SCW)and carapace length (CL) in (A) male, (B) female and (C) combined.

3.2.3 SHORT CARAPACE WIDTH AND BODY WEIGHT

The cubic relationships between short carapace width and body weight are shown in figures 6 A-B. The regression equations are given in table 4. The value of b for male was found to be 3.0223 and that of female 2.806, which shows that males are slightly heavier than females of the same size. The value of b obtained for male was not significantly different from 3 (t = 0.724, α = 0.05) whereas that of female was found significantly less than 3 (t = 6.592, α = 0.05) and this shows that the relationship between size and weight in female is negative. Student's *t*-test revealed that the difference between male and female b values was significant (t = 11.716; α = 0.05) and therefore data of male and female were not combined. The two variables were more strongly co related in male (R^2 = 0.990) than those of female (R^2= 0.987).

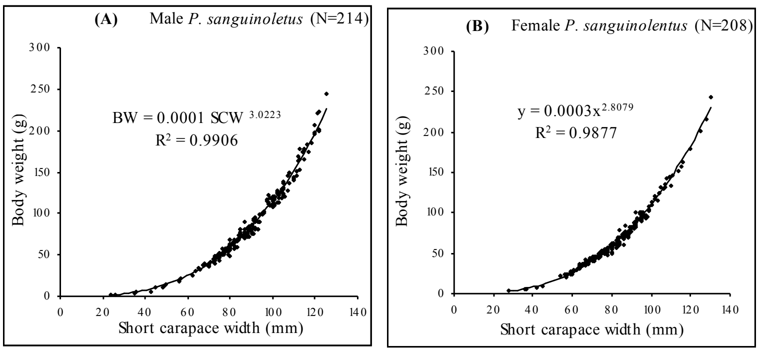

Fig. 6. Portunus sanguinolentus: cubic relationship between short carapace width (SCW) and body weight (BW) of (A) male and (B) female.

Table 4. Portunus sanguinolentus: summary of cubic regression and log-transformed regression analysis between short carapace width (SCW) in mm and body weight (BW) in g.

Y-variable	Sex	Regression equations	R^2	b	S.E. (b)	t (b = 3)	T (b = b)
Body weight (BW)	Male	$BW = 0.0001\ SCW^{3.0223}$	0.9906	3.022	0.031	0.724	11.71*
		Log BW = log - 3.984 + 3.0223 log SCW	0.9906				
	Female	$BW = 0.0003\ SCW^{2.8079}$	0.9877	2.808	0.029	6.592*	
		Log BW = log - 3.574 + 2. 808 log SCW	0.9877				

*significant (α=0.05)

MEAT YIELD

Meat from thorax, chela and periopods (legs) was extracted manually from a total of 602 crabs. Of these, 382 were *P. pelagicus* and 220 were *P. sanguinolentus*. The results are presented below.

3.2.4 PORTUNUS PELAGICUS

One hundred fifty seven male crabs weighing from 17 to 368 g (average 91.41g ± 65.67 S.D.) were dissected and the weight of meat was recorded separately for thorax, chelae and periopods of each crab. Table 5 gives the range, average and standard deviation of some morphological parameters as well as weight of meat present in different parts of the body of male and female *P. pelagicus*. The weight of the meat varied from 7.5 to 186.1 g (average 41.4 g ± 31.1 SD). The linear relationship between body weight and meat weight for male *P. pelagicus* is shown in figure 7A-B.

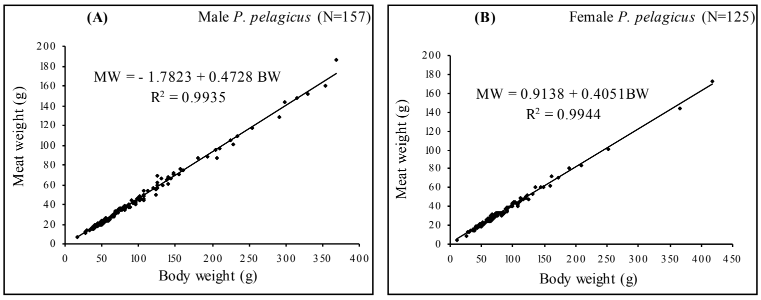

Fig. 7. Portunus pelagicus: linear relationship between body weight (BW) and meat weight (MW) in (A) male and (B) female crabs.

Table 5. Portunus pelagicus: range, mean and standard deviation (S.D.) of some parameters

Parameters	**Male (N =157) Range (mean ± S.D.)**	**Female (N = 125) Range (mean ± S. D.)**
Short carapace width (SCW) (mm)	52 - 134 (83.66 ± 16.34)	44 - 145 (82.25 ± 15.18)
Chelar propodus length (CPL) (mm)	35 - 142 (69.8 ± 20.8)	29 - 112 (58.84 ± 12.08)
Body Weight (BW) (g)	17 - 368 (91.41 ± 65.67)	11- 417 (80.9 ± 54.88)
Meat weight (MW) (g)	7.5 -186.1 (41.43 ± 31.1)	4.9 -173 (33.68 ± 22.29)
Thorax Meat (TM) (g)	4.8 - 87.2 (21.89 ± 14.9)	3 - 80.6 (18.87 ± 11.39)
Chelar meat (CM) (g)	0.9 - 33.2 (6.3 ± 5.28)	0.5 - 30.6 (4.82 ± 3.77)
Legs meat (LM) (g)	0.8 - 34.6 (7.08 ± 5.88)	0.8 - 32.6 (5.67 ± 4.05)

The regression equations are given in table 6. It is evident from the regression equation that value b obtained for male is significantly greater than 1 (t = 2.047; α = 0.05). In term of percentage, male crabs had 40.1 to 51.3% meat of the total body weight. The average of the percent meat was found to be 44.5 % ± 2.41 SD.

Table 6. Portunus pelagicus: summary of linear regressions and log-transformed regression analysis between meat yield (MW) and body weight (BW) of male and female crabs. b: regression coefficient (slope of the line), R^2: coefficient of determination, S.E. (b): standard error of b, t (b=1): student's t-test when b=1, t (b=b): student's t-test for comparison of two slopes b .

Variable	**Sex**	***Regression equations***	**R^2**	**b**	**S.E. (b)**	**t (b=1)**	**t (b=b)**
BW x MW	Male	MW = -1.7823 + 0. 4728 BW	0.993	1.043	0.021	2.04*	2.369*
		Log MW = log -0.4324 + 1.0432 log BW	0.993				
	Female	MW = 0.9138 + 0.4051BW	0.994	0.983	0.021	0.74	
		Log MW = log -0.3486 + 0.9838 log BW	0.99				

* significant (α=0.05)

In case of female *P. pelagicus*, a total of 125 crabs were dissected. Their body weight varied from 11 to 417 g (average 80.9g ± 54.88 SD.) and the weight of the meat varied from 4.9 to 173 g (average 33.7 g ± 22.29 SD.). Figures 7B shows the linear relationship between body weight and meat weight of female *P. pelagicus*. The regression equations, which are given in table 6 show that value b obtained for female is not different significantly from 1 (t = 0.736; α = 0.05). The difference between male and female b values was found statistically significant (t = 2.368; α = 0.05). The female crabs, on average, yielded 41.93 % ± 2.17 SD. meat of the total body weight (range: 35.6 % to 48.63%).

Most of the meat was found in the thorax (56 % in female and 53 % in male) followed by chelae (30% in male and 27 % in female) and Periopods (17 % each in male and female). The percentage composition of meat yield in male and female *P. pelagicus* is shown in figure 8.

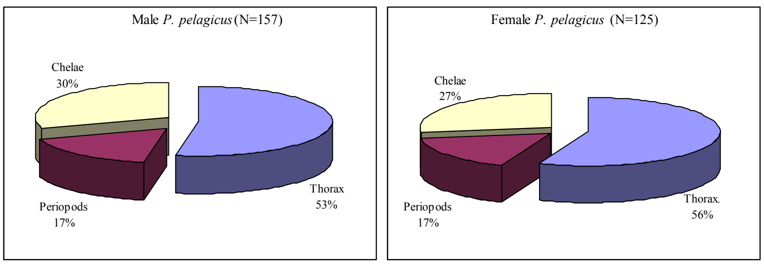

Fig. 8. Portunus pelagicus: percentage composition of meat in different parts of the body in male and female crabs.

The thorax of female yielded more meat than that of male whereas male chelae had more meat than that of female. In periopods, the amount of meat in term of percentage was almost same in both the sexes. The cubic relationship between SCW and thorax meat weight for male and female *P. pelagicus* is shown in Figure 9.

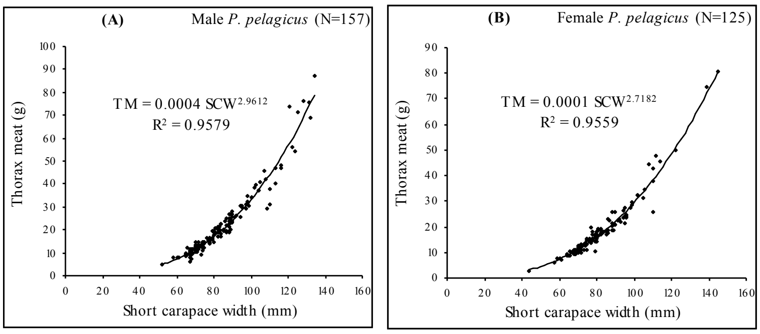

Fig. 9. Portunus pelagicus: cubic relationship between short carapace width(SCW) and thorax meat (TM) in (A) male and (B) female crabs.

The regression equations, which are given in table 7 show the rate of increase in SCW and weight of the meat in the thorax is same in male and value b obtained is insignificantly different from 1 (t = 0.784; α = 0.05) but in female the rate of growth is negative and value b obtained for female is statistically significantly different from 3 (t = 6.308; α = 0.05). The difference between male and female b values was found statistically significant (t = 9.843; α = 0.05).

Table 7. Portunus pelagicus: summary of cubic regression and log transformed regression analysis between short carapace width (SCW) with thorax meat (TM) and chelar propodus length (CPL) and chelar meat (CM) in male and female crabs. b: regression coefficient (slope of the line), R^2: coefficient of determination, S.E. (b): standard error of b, t (b=1): student's t-test when b=1, t (b=b): student's t-test for comparison of two slopes b .

Variable	Sex	Regression equations	R^2	b	S.E. (b)	t (b=3)	t (b=b)
SCW x TM	Male	$TM = 0.0004\ SCW^{2.9612}$	0.958	2.961	0.049	0.784	9.843*
		Log TM = log -4.4035 + 2.9612 log SCW	0.958				
	Female	$TM = 0.0001\ SCW^{2.7182}$	0.956	2.718	0.044	6.308*	
		Log TM = log -3.9667 + 2.7182 log SCW	0.956				
CPL x CM	Male	$CM = 0.0002\ CPL^{2.3976}$	0.947	2.397	0.067	8.939*	9.769*
		Log CM = log -3.6888 + 2.397 log CPL	0.947				
	Female	$CM = 0.00005\ CPL^{2.7788}$	0.951	2.778	0.053	4.195*	
		Log CM = log -4.2846 + 2.7788 log CPL	0.951				

*significant (α=0.05)

Figure 10 shows the cubic relationship between chelar propodus length and chelar meat weight for male and female *P. pelagicus.* The regression equations are given in table 8. The estimated value of b was 2.397 for male and 2.778 for female. The values of b were found significantly less than 3 (t = 8.939 for male and 4.195 for female; α = 0.05). Student's *t*-test was also performed to compare the two values of b and it was found that the difference was also significant statistically (t = 9.769; α = 0.05).

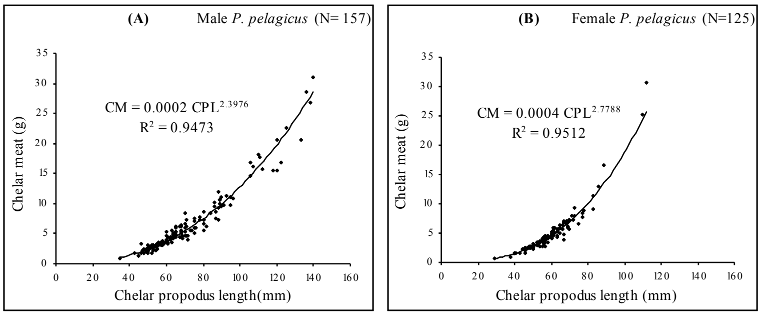

Fig. 10. Portunus pelagicus: cubic relationship between chelar propodus length (CPL) and chelar meat (CM) in (A) male and (B) female crab.

3.2.5 PORTUNUS SANGUINOLENTUS

The male crabs used for meat yield analysis numbered 112. Table 8 presents the range, mean and standard deviation of some morphological parameters as well as meat weight in male and female *P. sanguinolentus*. The smallest male crab was 20g in weight and yielded 7.8 g meat whereas the largest crab weighing 247g yielded 109.4g of meat. The average weight of the male crabs was found to be 90.36 g ± 46.88 S.D. and average weight of the meat was estimated to be 39.38 g ± 21.28 S.D. In term of percentage, the male *P. sanguinolentus* yielded 43.2 % ± 1.96 S.D. meat of the total body weight (range 39 % to 47.73 %). The linear relationship between body weight and meat weight of male *P. sanguinolentus* is shown in figure 11A.

Table 8. Portunus sanguinolentus: range, average and standard deviation of different parameters

Parameters	**Male (N =157) Range (mean ± S.D.)**	**Female (N = 125) Range (mean ± S. D.)**
Short carapace width (SCW) (mm)	56 - 122 (89.29 ± 13.87)	54 - 130 (82.25 ± 15.18)
Chelar propodus length (CPL) (mm)	38 - 105 (67.88 ± 14.01)	30 - 85 (57.06 ± 10.22)
Body Weight (BW) (g)	20 - 247 (90.36 ± 46.88)	19 - 222 (79.21 ± 39.99)
Meat weight (MW) (g)	7.8 - 109.4 (39.68 ± 21.28)	6.5 - 86.3 (29.97 ± 15.36)
Thorax Meat (TM) (g)	4.4 - 51 (19.97 ± 9.94)	4.2 - 49.2 (16.4 ± 8.19)
Chelar meat (CM) (g)	0.9 - 21.9 (6.39 ± 3.89)	0.8 - 12.3 (4.42 ± 2.54)
Legs meat (LM) (g)	1.4 - 21 (6.66 ± 4.02)	0.6 - 14 (4.55 ± 2.43)

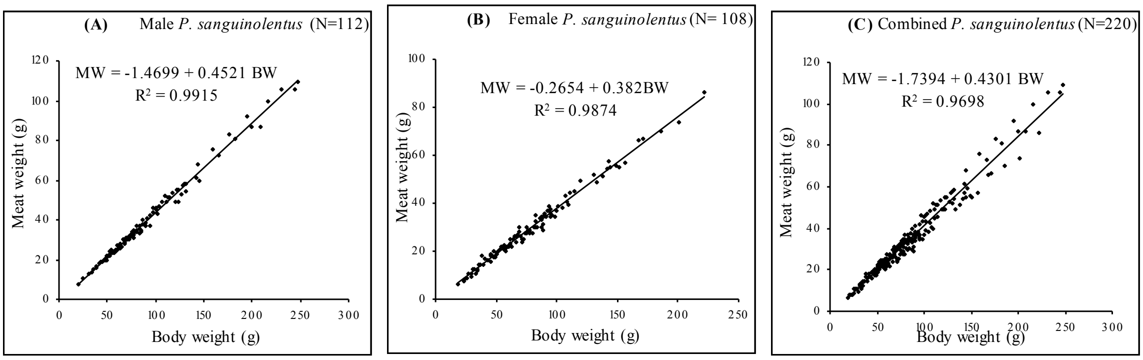

Fig. 11. Portunus sanguinolentus: linear relationship between body weight (BW) and meat weight (MW) in (A) male, (B) female and (C) combined.

The regression equations are given in Table 9.

Table 9. Portunus sanguinolentus: summary of linear regression and log-transformed regression analysis of body weight (BW) and meat weight (MW) of male and female crabs, b: regression coefficient (slope of the line), R^2 = coefficient of determination, S.E. (b): standard error of b, t (b=1) = student's t-test when b=1), t (b = b): student's t-test for comparison of two slopes b.

Variable	Sex	Regression equations	R^2	b	S.E. (b)	t (b=1)	t (b=b)
BW x MW	Male	MW = -1.4699 + 0.4521BW	0.991	1.038	0.018	2.107*	0.782
		Log MW = log -0.4377 + 1.038 log BW	0.993				
	Female	MW = -0.2654 + 0.382 BW	0.987	1.020	0.029	0.695	
		Log MW = log -0.4615 + 1.020 log BW	0.983				
	Combined	MW = -1.7394 + 0.4301BW	0.969	1.047	0.037	1.261	…
		Log MW = log -0.482 + 1.047 log BW	0.973				

* significant (α= 0.05)

The female crabs used for meat yield analysis were 108 in number weighing from 19 to 222 g. The weight of meat extracted varied from 6.5 to 86.3 g. The average weight of the female crabs was found to be 79.89 g ± 39.94 S.D and the average meat weight was 29.98 g ± 15.31 S.D. On the whole the female *P. sanguinolentus* yielded 37.7 % ± 2.31 S.D. meat of the total body weight (range: 32.1 % to 43.8%). The linear relationship between body weight and meat weight for female *P. sanguinolentus* are shown in figures 11B. The difference between male and female 'b' values was found insignificant (t = 0.782, α = 0.05), hence the two data were pooled together and figure 11C is the scattered diagram of combined data. The regression equation for combined data is given in table 9.

In *P. sanguinolentus,* more than half of the total meat was found in thorax (55% in female and 51 % in male) followed by chelae (32 % in male and 30 % in female) and periopods (17 % in male and 15% in female). Figure 12 shows the percentage distribution of meat in male and female *P. sanguinolentus.* Female *P. sanguinolentus* had more meat in thorax than that of male while chela and periopods of male yielded more meat than those of female.

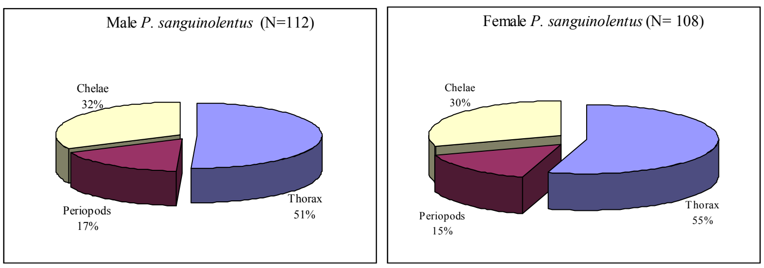

Fig. 12. Portunus sanguinolentus: percentage composition of meat in different parts of the body in male and female.

The cubic relationship between SCW and thorax meat of male and female *P. sanguinolentus* are shown in figures 13 A-B. The regression equations, which are given in table 10, show that the thorax meat does not increase isometrically with respect to SCW. The value of regression coefficient b for male was found to be 2.9042 and that of female 2.6542, which are significantly less than 3 (t = 1.902 for male and 6.529 for female, $\alpha = 0.05$). Student's *t*-test revealed that the difference between male and female b values was also significant (t = 9.259; $\alpha = 0.05$).

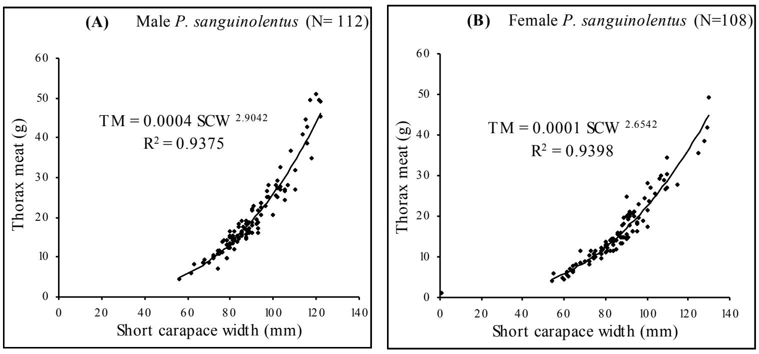

Fig. 13. Portunus sanguinolentus: cubic relationship between carapace width (CW) and thorax meat (TM) of (A) male and (B) female crabs.

Table 10. Portunus sanguinolentus: summary of cubic regression and log-transformed regression analysis of meat yield and morphometric relationship between short carapace width (SCW) and thorax meat (TM) and chelar propodus length (CPL) and chelar meat (CM) in male and female crabs. b: regression coefficient (slope of the line), R^2 = coefficient of determination, S.E. (b): standard error of b, t (b=1) = student's t-test when b=1), t (b= b): student's t-test for comparison of two slopes b.

Variable	Sex	Regression equations	R^2	b	S.E. (b)	t (b=3)	t (b=b)
CW x TM	Male	$TM = 0.0004\ CW^{2.9042}$	0.937	2.904	0.050	1.902*	9.259*
		Log TM = log -4.3969 + 2.904 log CW	0.937				
	Female	$TM = 0.0001\ CW^{2.6542}$	0.939	2.654	0.052	6.528*	
		Log TM = log -3.9578 + 2.6542 log CW	0.939				
CPL x CM	Male	$CM = 0.0005\ CPL^{2.7468}$	0.951	2.746	0.055	4.568*	6.956*
		Log CM = log -4.2692 + 2.7468 log CPL	0.951				
	Female	$CM = 0.0002\ CPL^{2.9833}$	0.939	2.983	0.059	$0.278^{i.s}$	
		Log CM = log - 4.6187 + 2.9833 log CPL	0.939				

* significant (α= 0.05)

Figures 14 A-B show the cubic relationship and between chelar propodus length and chelar meat of male and female *P. sanguinolentus.* It is evident from the regression equations, which are given table 10, that the value b obtained for male is significantly less than 3 (t = 4.568; $\alpha = 0.05$) but in female the value b obtained is not significantly different from 3 (t = 0.278; $\alpha = 0.05$). The difference between male and female b values was found statistically significant (t = 6.956; $\alpha = 0.05$).

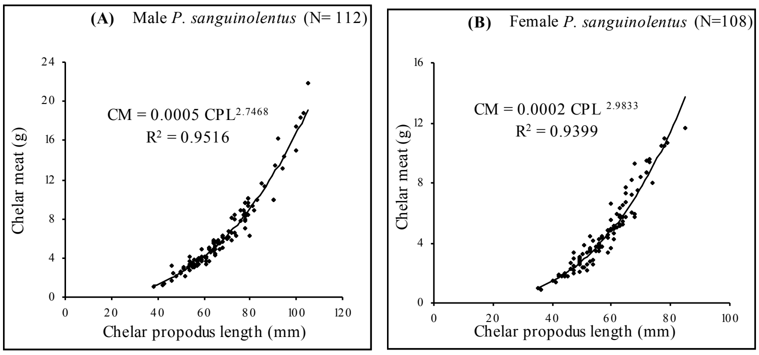

Fig. 14. Portunus sanguinolentus: cubic relationship between chelar propodus length (CPL) and chelar meat (CM) in (A) male and (B) female crabs.

4 DISCUSSION

During present investigation, relative growth of LCW with reference to SCW was found isometric only in female *P. pelagicus* while in male it was slightly negative, However the difference between males' and females' regression coefficient was found insignificant ($\alpha = 0.05$). This result differs from that of Potter *et al*. who studied biology of *Portunus pelagicus* in an Australian estuary. They found significant differences ($P < 0.001$) between the slope of the regression equation relating carapace width from the base of the large lateral spine (= SCW of the present study) and from the tip of these spines (=LCW of the present study) in males and females. According to them the regression equation for males is $CW_1 = -5.2513 + 0.8840$ CW ($n = 326$, $r = 0.99$) and for females is $CW_1 = -2.6865 + 0.8480$ CW ($n = 542$, $r = 0.99$); where CW_1 is the short carapace width and CW is the long carapace width. Unfortunately Potter *et al*. presented the data without logarithmic transformation and therefore the allometric status of the carapace growth is not obvious. However from the regression equations it is evident that the length of the long spines (*i.e.* ninth anterolateral teeth of carapace) is much shorter in Australian specimens than those of Pakistani specimens. For instance, a male *P. pelagicus* of 100 mm short carapace width is expected to have 119 mm long carapace width in Australia whereas a male *P. pelagicus* of the same short carapace width is expected to have 124.5 mm long carapace width (according to regression equation given in the result of the present study). Hence the combined length of the two long spines in Australian specimen is estimated to be 19 mm as against 24.5 mm of Pakistani specimens.

Such variation of carapace in portunid crabs caused [24] to differentiate taxonomically a long-spined sub species from that with typical spine in the blue crab, *Callinectes sapidus* from United States. Chace and Hobbs [25], from West Indies, stated that the extreme variants of long-spine and typical spines of *C. sapidus* might be designated as distinct species. However, Williams [26], who re-examined the status of *C. sapidus,* concluded that it is a single species, which has diverged into poorly defined population in certain areas of its range. The morphological variation was found in adult female *C. sapidus* from year to year within Delaware Bay and also from one area to another by Porter [27] who suggested salinity, temperature, and food abundance as possible causative factors.

The relationship between SCW and CL was found negatively co-related in both the species during present investigation which means that the carapace increases more rapidly in width than in length. This result of the present study partially agrees with that of Al-Rumaidh *et al*. who studied *P. pelagicus* from Bahraini waters. They examined *P. pelagicus* from three areas designated as A, B and C. The crabs from areas A and B exhibited isometric growth of carapace length with respect to carapace width, while those from area C had negative allometric growth and the value of b was significantly less than 1.

Results of the present study regarding size-weight relationship replicate the result of earlier studies that males are heavier than similar sized females in *P. pelagicus and P. sanguinolentus*. Sukumaran and Neelakantan, studied relationship between carapace width and body weight and carapace length and body weight in *P. pelagicus* and *P. sanguinolentus* from the Karnataka coast, India. The values of regression coefficient (b) were found very close to 3 in both the species. Analysis of covariance revealed that there was no significant difference ($P<0.05$) between regression equation in males and females of *P. sanguinolentus* whereas significant difference ($P<0.05$) was observed between males and females in *P. pelagicus* (which is other way round in present study). They, however, concluded that males are heavier than females at any given length in these two species of *Portunus* crab. Potter *et al.*, in their study of *P. pelagicus* from an Australian estuary observed significant difference in the slopes in regression equation relating body weight (w) and carapace width measured between the tip of the lateral spines (= LCW) between males and females. The log transformed regression equations given by potter *et al* are: log W

= log 2.56 X 10^{-5} + 3.260 log CW (n = 694; r = 0.99) for males and log W = log 5.97 X 10^{-5} + 3.056 log CW (n = 1076; r = 0.99) for females. Theses equations show that the males have a greater b values (3.260) than that of females (3.056). The relationship between carapace width and body weight of the blue swimming crabs *P. pelagicus* in Bahraini waters was studied by Al-Rumaidh *et al.*. They collected 2070 males and 3005 females *P. pelagicus* over a period of 14 months (March 1999 to April 2000) and observed that males were slightly heavier than females at 20 mm carapace width, becoming heavier above 60 mm carapace width.

Results of the present investigation show much higher meat yield in *P. pelagicus* than those reported earlier. From southeast Queensland, Australia, [28] reported that the meat yield of *P. pelagicus* was 39% of the body weight, which is less than that of present study (*i.e.* 43.4%). Similarly Akbar *et al*. (1988), who studied condition index of *P. pelagicus* from the Karachi coast, stated that "on average about 23.81 percent (in the male) and 23.17 percent (in the female) edible meats can be extracted". Akbar *et al.* (1988) extracted meat only from the thorax and cheliped and not from the periopods (walking legs). They weighted the crabs and meat after drying them in an oven at 110˚ (unit not mentioned). The difference in the results may be attributed to different methodology used in the present investigation Akbar *et al.*.

A comparison of meat yield of different brachyuran crabs is presented in table 11, which shows that *P. pelagicus* yields 43.4 % meat of the total body weight followed by *P. sanguinolentus* (41.01%). The low meat yield in other species may be due to legs (periopods) meat which is not considered usually in the analyses [29]. For instance George *et al*. (1986), who estimated meat yield in *Scylla serrata* from India, stated that after removing the carapace, gills, intestine and eggs, the meat was picked up and weighted. There is no mention of chelae and legs and it is not clear whether the meat from these appendages was included in the total meat yield analyses. On the other hand Hattori *et al*. [30] clearly mention that the meat present in the carapace, chelae and legs of *Callinectes bocourti* (from Sao Paulo, Brazil) were taken into account. They found that *C. bocourti* contain 23.4% meat of the body weight as against 10% recorded for *C. sapidus* by Ward [31], from USA. Hattori *et al*. took the wet weight of the crab which was then cooked in water at 100 ˚C for 20 minutes. The meat was then removed from claws, legs and body and the weight was recorded.

Table 11. A comparison of average value of total meat yields in commercially exploited portunid and other crabs.

Family	**Species**	**Meat Yield (%)**			References
		Male	**Female**	**Total**	
Portunidae	*Portunus sanguinolentus* (Herbst, 1783)	43	37	41. 01	Present study
	Portunus pelagicus (Linnaeus, 1758)	44	42	43. 4	Present study
	Portunus pelagicus (Linnaeus, 1758)	23.8	23.2	…	Akbar *et al*. (1988a)*
	Portunus pelagicus (Linnaeus, 1758)	…	…	39	Brown, (1986)
	Scylla serrata (Forskal, 1755)	…	…	29	Brown, (1986)
	Scylla serrata (Forskal, 1755)	…	…	16.16	George *et al*. (1986)
	Scylla serrata (Forskal, 1755)	…	…	21. 9	George and Gopakumar (1987)
	Charybdis natator (Herbst, 1794)	…	…	35	Sumpton (1990b)
	Callinectes sapidus Rathbun, 1896	…	…	10	Ward (1990)
	C. bocourti A. Milne Edwards, 1879	28. 5	22. 1	23. 4	Hattori, *et al* (2006)
Gecarcinidae	*Cardisoma guanhumi* Latereille, 1825	18	21. 5	…	Hattori, *et al* (2006)
Ocypodidae	*Ucides cordatus* (Linnaeus, 1763)	25. 4	21. 1	23. 2	Hattori, *et al* (2006)

* Only claws and thorax meat, leg meat not included.

The different methodology used by different authors to calculate amount of meat present in the crab makes it difficult to compare their results. However, it appears that it is *P. pelagicus* which contains more meat (in terms of percentage of body weight) than other brachyuran species studied so far.

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