Morphometrics and length-weight relationship in the blue swimming crab, *Portunus segnis* (Decapoda, Brachyura) from the gulf of Gabes, Tunisia

Ghailen HAJJEJ, Ayda SLEY, Othman JARBOUI

***Abstract*— This The morphometric characteristics and relative growth of the blue swimming crab *Portunus segnis* collected in the Gulf of Gabes were examined. A total of 634 individuals of *P. segnis* were analyzed, being 335 males and 299 females. The allometric relationships between the characters of this set suggest that most relationships are isometric. The carapace width/length- weight relationship was studied in both sexes of crab. The exponential values (b) for the carapace width-total weight relationship was distinct between the sexes with a positive growth pattern in weight for males, and a negative allometric pattern identified for females. Males were significantly larger and heavier than females, the expected pattern to many crabs. An analysis of variance indicates that there is a significant difference between sexes with respect to the carapace width-weight relationship. A correlation between carapace width and weight were encountered for males and females. The statistical analysis of chelar propodus length within sexes indicated a mirror-symmetry in this species, which provides more stability and balance to individuals. The condition factor ranged between 0.00691 and 0.34767 with a mean of 0.0582. The condition factor decreased with an increase in crab size.**

***Index Terms*—morphometric characteristics, relative growth, *Portunus segnis*, Gulf of Gabes.**

I. INTRODUCTION

Crabs belong to the brachyuran infra order family comprising more than 6,793 species peculiarly known for their ten legged creature (decapod) [23]. Among the species of this infra order, the blue swimming crab, *Portunus segnis* (Forskål, 1775), previously named as *P. pelagicus* (Linnaeus, 1758) [26] is one of the early lessepsian invaders which was recorded in Egypt (Mediterranean Sea) as early as in 1898, few years after the opening of the Suez Channel [15]. The term 'lessepsian migration' is used to describe the immigration of Red Sea biota into the Mediterranean Sea after the opening of the Suez Canal, in 1869. It is a 'phenomenon of unidirectional and successful biotic advance from the Red Sea to the Eastern Mediterranean [33].

We counted 6 Lessepsian species from the twelve exotic species reported in Tunisia [8]. *Portunus segnis* has been accidentally introduced in Tunisian waters may be as a result of maritime commerce and ballast transport. The first records of the presence in Tunisian waters of the lessepsian blue swimming crab is reported until now exclusively in the Gulf of Gabes since its declaration in Tunisian waters in 2014 [38]. In the Gulf of Gabes *P. segnis* continues to proliferate very rapidly it is reported in the governorate of Gabes, Medenine and Sfax.

In many areas throughout Asia, crab production is a significant industry especially in the Philippines, Vietnam, Indonesia, and elsewhere in Asia [39]. In Tunisia, It is a species caught accidentally by fishermen coastal fishing of the Gulf of Gabes. No fishing gears target this species because it is not commercialized and Tunisians are not familiar to consume this type of crab despite its economic importance in other countries. the crab *Portunus segnis* is part of the accompanied carcinofauna (bycatch) of trammel nets, targeting commercial-interest shrimp species (*Penaeus keraturus*) and cuttlefish (*Sepia officinalis*), and invisible net, beach seine and trawl fishing on the Gulf of Gabes.

In population studies, morphometric analysis provides a powerful complement to genetic and environmental stock identification approaches [10] and length-weight relationships allow the conversion of growth-in-length equations to growth-in-weight for use in a stock assessment model [28]. The length-width/weight relationship is regarded as more suitable for assessing not only fish, but also crustacean [44-45].

This study is the first investigations done in Tunisian waters on morphometric characters relationship of the blue swimming crab, *Portunus segnis*. Thus, in order to obtain information about the population biology of *Portunus segnis*, the present study aimed to: 1) characterize the relative growth of the species based on allometric changes of some morphometric characters in relation to the carapace width, and 2) also perceived to establish precise mathematical equations between the length and weight, width and weight, so that if one is measured, the other dimension could be computed. Importantly, this is the first study focusing on morphometric analysis of the *Portunus segnis* in the gulf of Gabes that will be useful in comparing the different stocks of the same species at different geographical locations.

II. MATERIALS AND METHODS

In order to determine some morphometric characters of the blue swimming crab (*Portunus segnis*) inhabiting the Gulf of Gabes, Tunisia, a total of 634 crab specimens were collected, between September 2015 and August 2016, using trammel nets, gill nets, purse seine, beach seine and creels, in random samplings of several size ranges. The population of *P. segnis* was sampled at twelve stations in the Gulf of Gabes (Figure 1).

In the laboratory, all of the sampled specimens were, washed for removing the mud and algae's and barnacles stuck to the

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external skeleton. Using observations of characteristic abdomen shapes (triangular in males and circular in females) and the appearance of the number of pleopods, the specimens were identified and sexed.

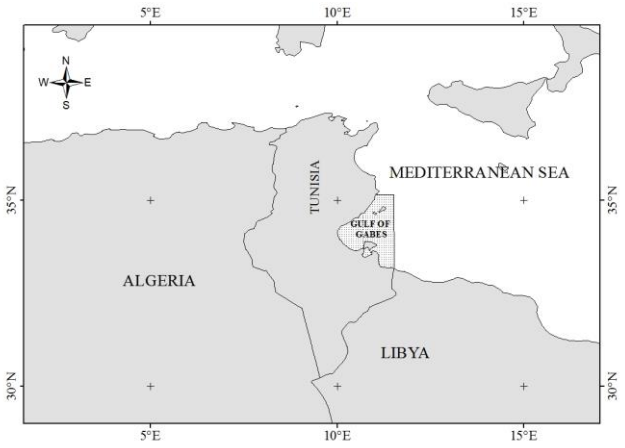

Figure 1: Study area in the Gulf of Gabes.

In total, 12 different morphometric characters were taken into consideration: carapace width including the pair of spines (CW), carapace length (CL), carapace depth (CD), right chelar propodus length (R_CPL), right chelar propodus height (R_CPH), left chelar propodus length (L_CPL), left chelar propodus height (L_CPH), antero-lateral border (ALB), postero-lateral border (PLB), frontal margin length (FML), abdomen length (AL) and abdomen width (AW) (Figure 2). All of the morphometric characters were measured using digital calipers (0.01 mm of precision) and the total body weight (TW), of the crab was determined to the nearest gram using a digital balance (1 g). Individuals missing one of the limbs were not weighed and excluded from analyses using the body weight.

Analyses of relative growth were performed separately for each sex based on allometric equation [24], $y= ax^b$, converted to the linear form by means of natural logarithm transformation $(y) = Ln\ (a) + b\ Ln(x)$, where y = dependent variables (CL, CD, ALB, PLB, FML, AL, AW), x = independent variable (CW), a = intercept on y axis, and b = allometric growth coefficient. Growth was classified as positively allometric when $b > 1$, negatively allometric when $b < 1$, or isometric when $b = 1$. Student's t-test was utilized to assess deviations from the isometric condition, with significance level $\alpha = 0.05$ [48]. The values of the correlation coefficient (r) were calculated to know the degree of association of the two variables involved, with the objective of establishing a mathematical relationship between the variables, so that if one variable is known, the other could be computed approximately. The variation between the regression coefficient (b) in male and female calculated using ANOVA (Analysis of variance).

Regression equations were calculated assuming an allometric growth equation ($Y = a + bX$), and growth ratios for the independent variable (CW) and the other variables (R_CPL, L_CPL, R_CPH, L_CPH) were determined by logarithmic transformation expressed as Y= log a+b log X. Analysis of variance (ANOVA) was also used to compare length and height measures of the right and left chelar propodus between sexes.

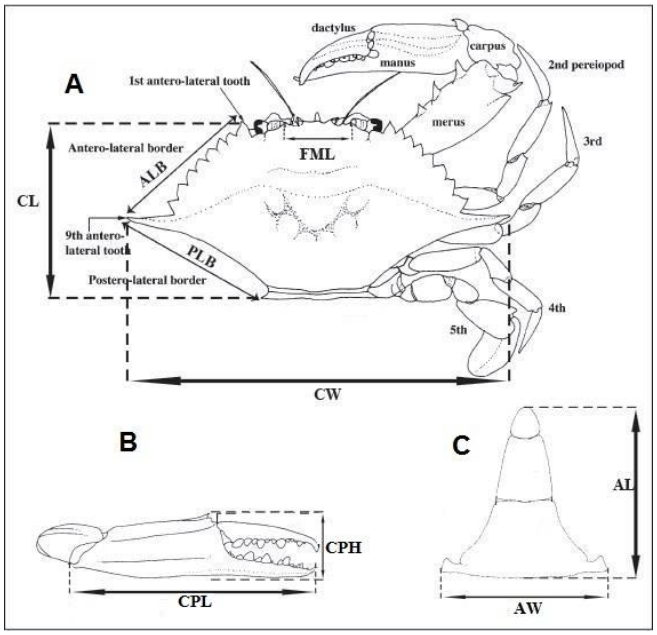

Figure 2: The measurements used for morphometric studies in *Portunus segnis*. A, Carapace in dorsal view; B, chela; C, abdomen; CW: carapace width; CL: carapace length; ALB: antero-lateral border; PLB: postero-lateral border; FML: frontal margin length; CPL: chelar propodus length; CPH: chelar propodus height; AL: abdomen length; AW: abdomen width.

The carapace length/carapace width -weight relationship was estimated using the log form of the allometric growth equation $W = aL^b$ [40], where W = expected total body weight, L = total carapace width, 'a' = y-intercept or the initial growth coefficient, and 'b' = the slope or growth coefficient. The values of constants of 'a' and 'b' were calculated by the least squares method. The statistical significance of 'b' was tested by Student's t-test, adopting a significance level of $P<0.05$.

The Fulton's condition factor (K) was calculated for both males and females (ovigerous and non-ovigerous were grouped) to the values of total samples by the formula $K= 100W/L^3$ [17] where W denoted as total body weight (g) and L denoted as carapace length/carapace width (cm). The variation in condition factors between the sexes was tested by Student's t-test ($P<0.05$).

III. RESULTS

A total of 634 crabs (335 males and 299 females) were analyzed in this study, with CW ranging from 39.26 to 155.5 mm (mean 106.41±28.17 mm) in males, and from 34.27 to 148.5 mm (mean 95.83±26.67 mm) in females. The mean TW of males was 110.84±75.41 g, and that of females was 68.47±46.07 g. (Table 1). The average size of males was significantly larger than females (Student's t-test = 23.06, $p < 0.05$). The carapace width-frequency (CW) distribution of the blue crab is shown in Figure 3.

Table 1: Length, width and weight characteristics of *Portunus segnis* caught in Gulf of Gabes.

		Length characteristics (mm)			Width characteristics (mm)			Weight characteristics (g)		
Sex	n	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max
Male	335	53.21±14.24	19.26	78.5	106.42±28.17	39.26	155.5	110.84±75.41	5.98	302.01
Female	299	47.61±12.81	18.24	75.35	95.83±26.67	34.27	148.5	68.47±46.07	2.95	204.32
Overall	634	50.57±13.87	18.24	78.5	101.69±28.00	34.27	155.5	90.65±66.26	2.95	320.19

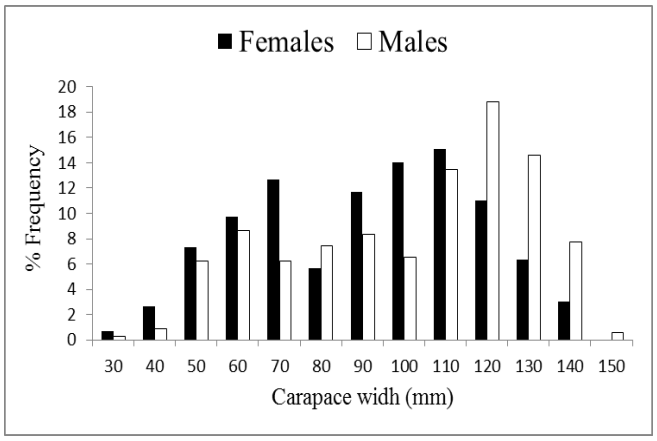

Figure 3: Size frequency distribution for males and females of *Portunus segnis* caught in Gulf of Gabes.

An overall analysis of the total weight-carapace width relationship of each sex showed a significant positive correlation between the variables, with the empirical points fit to the power function (R^2 > 0.93) (Table 2). Since the carapace width distribution was used for growth and stock estimates, carapace width-weight relationships for males and females were found out.

The exponential values (b) for the carapace width-total weight relationship was distinct between the sexes with a positive growth pattern in weight for males (b = 3.14, t = 4.23; P <0.05), and a negative allometric pattern identified for females (b = 2.74, t = 6.28; P <0.05) (Figure 4). The exponential values (b) for carapace length-weight differ from 3, in both sexes. In males, the curve follows a positive growth pattern (b = 3.06, t = 2.05; P <0.05), whereas growth in females was negative allometric (b = 2.90, t = 2.73; P <0.05) (Figure 5). Data obtained for combined sexes indicated that the curve follows an isometric growth pattern for carapace width-total weight (b = 2.97, t = 0.72; P >0.05) and for carapace length-total weight relationships (b = 3.02, t = 0.92; P >0.05). The regression equations between male and female were tested for equality through analysis of variance, and it showed that the values of slope and elevation differ significantly at 1% level.

Allometric equations for relative growth obtained for males and females of *Portunus segnis* are indicated in table 3. The allometric relation between the set of characters studied suggested that growth in both males and females was isometric for most characters measured ($CL_{M,F}$/CW, $ALB_{M,F}$/CW, $PLB_{M,F}$/CW, AL_M/CW, AW_M/CW). In the case of $CD_{M,F}$/CW and $FML_{M,F}$/CW relationships between variables followed a negative growth pattern, while for AL_F/CW and AW_F/CW a positive allometric growth was identified. In the present study, the (b) constant for males was slightly larger than that of females. The highest coefficient value was the PLB/CW ratio in males (0.979) while the lowest was for ALB/CW in males (0.808).

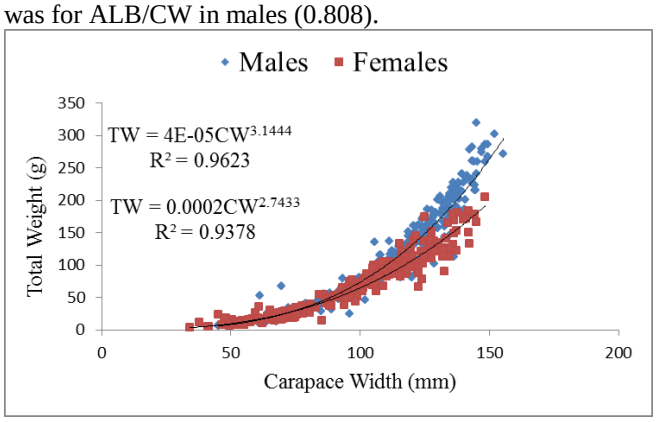

Figure 4: Carapace width-weight relationship in *Portunus segnis* caught in Gulf of Gabes.

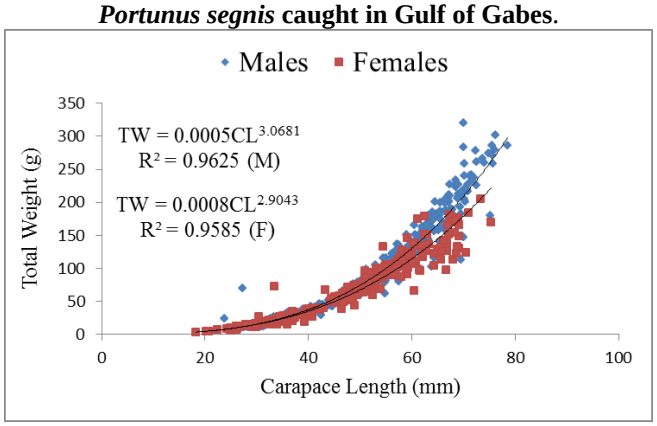

Figure 5: Carapace length-weight relationship in *Portunus segnis* caught in Gulf of Gabes.

The size range, mean, and standard errors of the right and the left chelar propodus for each sex are shown in Table 4. For females, the growth pattern obtained for the CW vs. CPL/ CPH were negative allometric (Table 5). For males, the relationship CW vs. CPL was positive allometric, while growth pattern obtained for CW *vs.* CPH was negatively allometrics (Table 5). The dimension that was most closely related to morphological sexual maturity among males was CPL. This result shows that the length of chelar propodus is more important than their height as an indicator of morphological sexual maturity in males. Indeed, the male chelar propodus length and female abdomen increased in size at a higher velocity than the carapace throughout the lifespan. The mean length and height of the right and left chelar propodus differed significantly between the sexes (P < 0.0001), being larger in males (Table 6). For both sexes, a variance analysis indicated that no significant difference showed between right and left of the chelar propodus length. For female, no significant difference revealed for the chelar propodus height, while in male, the right major chelar propodus height of this species is larger than the left one (Table 6).

The mean Fulton's condition factor (K) estimated from carapace length (K_{CL}) and width (K_{CW}), standard errors and ranges of both the sexes were presented in Table 7. In males, K_{CL} ranged between 0.00691 - 0.34767 and K_{CW} ranged between 0.00086-0.02287. In females, K_{CL} and K_{CW} ranged between 0.02993-0.19452 and 0.0022-0.03453 respectively.

Table 2: Carapace width/length-total weight relationship in males and females of *Portunus segnis* caught in Gulf of Gabes. *: significant.

Measurements	N	Logarithmic equation	R^2	Parabolic equation	R^2
Male	335				
CW-TW		Log TW = 3.1444 CW - 10.181	0.9623	$TW = 0.00004\ CW^{3.1444}$	0.962*
CL-TW		Log TW = 3.0681 CL - 7.6911	0.9625	$TW = 0.0005\ CL^{3.0681}$	0.962*
Female	299				
CW-TW		Log TW = 2.7433 CW - 8.4617	0.9378	$TW = 0.0002\ CW^{2.7433}$	0.937*
CL-TW		Log TW = 2.9043 CL - 7.1502	0.9585	$TW = 0.0008\ CL^{2.9043}$	0.958*
Pooled	634				
CW-TW		Log TW = 2.9796 CW - 9.47	0.9467	$TW = 0.000077\ CW^{2.9796}$	0.946
CL-TW		Log TW = 3.0227 CL - 7.5545	0.9601	$TW = 0.0005\ CL^{3.0227}$	0.960

Table 3: Allometric equations and correlation coefficient values between different variables in males (M), females (F) and combined sexes (CS) of *Portunus segnis*caught in Gulf of Gabes. *: significant.

Morphometric Characters	Sex	N	Parabolic equation	R^2	t (b=1)
Carapace Length (CL)	M	332	$CL= 0.4876CW^{1.004}$	0.962	0.173
	F	296	$CL= 0.685CW^{0.929}$	0.941	0.675
	CS	628	$CL= 0.5709CW^{0.970}$	0.952	1.710
Carapace Depth (CD)	M	332	$CD= 0.4035CW^{0.908}$	0.867	2.848*
	F	295	$CD= 0.5144CW^{0.855}$	0.822	2.415*
	CS	627	$CD= 0.4568CW^{0.881}$	0.849	2.184*
ALB	M	286	$ALB= 0.3571CW^{1.033}$	0.808	0.232
	F	273	$ALB= 0.3982CW^{1.011}$	0.923	0.198
	CS	559	$ALB= 0.3801CW^{1.021}$	0.862	0.132
PLB	M	286	$PLB= 0.4011CW^{1.002}$	0.979	0.107
	F	273	$PLB= 0.5688CW^{0.921}$	0.941	0.104
	CS	559	$PLB= 0.4667CW^{0.967}$	0.960	0.890
Frontal MarginLength (FML)	M	331	$FML= 0.3292CW^{0.871}$	0.964	3.767*
	F	291	$FML= 0.4392CW^{0.805}$	0.930	2.189*
	CS	622	$FML= 0.373CW^{0.843}$	0.949	2.520*
Abdomen Length (AL)	M	332	$AL= 0.2395XW^{1.031}$	0.968	0.759
	F	295	$AL= 0.2778CW^{1.095}$	0.923	3.650*
	CS	627	$AL= 0.2594CW^{1.045}$	0.948	2.597*
Abdomen Width (AW)	M	332	$AW= 0.2881CW^{1.036}$	0.933	1.430
	F	296	$AW= 0.3282CW^{1.101}$	0.937	7.486*
	CS	628	$AW= 0.3228CW^{1.015}$	0.932	0.858

IV. DISCUSSION

The maximum CW in *P. segnis* varies substantially among different populations. There is strong evidence that abiotic variables related to the local climate have the strongest influence on this parameter, as previously stated in the literature [3]. The results of the total weight-carapace width relationship analysis in *P. segnis* indicate that in juvenile's crabs, weight gain is almost uniform; males are heavier than females since reached 80 mm carapace width and since 42 cm carapace length. It is assumed that in adult stage, males of *P. segnis* can invest more energy in growth in order to protect the females, as well as to compete for them. On the other hand, females direct a large portion of the energy budget to the eggs production [25]. Nevertheless, [9] and [32] reported that males are heavier than females at any given length. In the present study, the larger body size of adult males was considered a secondary sexual dimorphism for *P. segnis*. [46] and [23] reported that male of *P. segnis* are heavier than female in coasts of Persian Gulf. The sexual dimorphism in

weight that was recorded in the present study is a typical pattern for many brachyuran crabs [36-2]. The tendency of males to be heavier than females is also in accordance with previous studies on portunids such as *P. pelagicus* [44], *P. sanguinolentus* [44] and *Scylla serrate* [34]. Weight-size relationships can provide useful information about the increase in weight of a population and this parameter could also be important for comparative studies between populations [29].

Table 4: Size ranges related to length and height of Chelarpropodus in each sex of *Portunus segnis*caught in Gulf of Gabes.

ChelarPropodus	Sex	Right			Left		
		Mean ± SE	Min	Max	Mean ± SE	Min	Max
Length	M	82.5±30.50	25	145	80.71±32.03	24	152.91
	F	56.16±17.26	6.41	92.4	52.83±17.14	19.7	93.15
Height	M	15.97±4.73	6	24.5	14.51±4.26	5.5	21.04
	F	14.05±4.56	5.1	24.33	12.37±3.89	4.6	24.77

Table 5: Formula and statistics for linear regressions of chelarpropodus length and height on carapace width for males and femalesof *Portunus segnis*caught in Gulf of Gabes.

Relationship	Sex	Equation	R^2	'*F*' value	Remarks
CW - R_CPL	F	y = 0.3491x + 32.709	0.8894	85.7413	Significant at 5% level
CW - L_CPL	F	y = 0.345x + 31.255	0.8892	88.2122	Significantat 5% level
CW - R_CPH	F	y = 0.0867x + 8.3665	0.8052	336.2970	Significantat 5% level
CW - L_CPH	F	y = 0.0746x + 7.727	0.7973	348.6744	Significantat 5% level
CW - R_CPL	M	y = 1.0831x - 33.397	0.9608	6.5025	Significantat 5% level
CW - L_CPL	M	y = 1.0845x - 33.938	0.9712	6.8094	Significantat 5% level
CW - R_CPH	M	y = 0.1582x - 0.7529	0.8796	229.4898	Significantat 5% level
CW - L_CPH	M	y = 0.1393x - 0.2114	0.9059	288.3684	Significantat 5% level

Sexual dimorphism, defined as the morphological differentiation of sexually mature females and males [13]. One of the most easily recognised forms of sexual dimorphism is sexual size dimorphism, the difference in adult body size between females and males, resulting from sex-specific differences in growth rate and growth duration [6-1].

In brachyuran crabs chela in males and abdomen in females are considered as secondary sexual characters because of their functions in reproduction [23]. The positive allometry found for the male chelar propodus indicates the possibility of a greater energy investment in the development of this structure after the pre-pubertal stage [22]. In the present study, the length and height of both chelipeds differed between the sexes, implying sexual dimorphism, considering the size of the chelipeds. The presence of a larger cheliped is especially important for males, because the chelae that are used in intra- or interspecific combats can achieve disproportionately large sizes [11]. Another adaptive advantage may be obtained during the breeding season, when males compete with each other for females, which are held and manipulated with the chelar propodus during the entire copulatory sequence [21-37]; or, alternately, may be related to feeding behavior [47]. Different selection pressures as well as phylogenetic and developmental constraints may jointly determine the structure and size of chelipeds in decapod Crustacea [5]. Within sexes, paired measurements (length and height) of chelar propodus did not show significant differences, indicating a mirror-symmetty in *P. segnis* off Tunisian coasts, except for the height of chelipds in males ($P < 0.0001$). This type of symmetry has been observed in other portunid species, such as *Portunus spinicarpus* [41]; whereas others, such as *C. ornatus* and *Portunus depressifrons* are strongly heterochelic, with the right cheliped rnarkedly larger than the left in both sexes [20]. [43] think that symmetric individuals outcompete their asymmetric counterparts, since biomechanical advantages of symmetric individuals allow them more stability and balance during conspecific fighting. The mirror-symmetry of this species probably explains the species' ecological success in the gulf of Gabes.

Besides the cheliped, the most distinct sexual dimorphic character of crabs is the broad abdomen of the female which serves as the brood chamber [21]. Most crabs belonging to the infraorder Brachyura exhibited a wider abdomen wider in females compared to males of the same species. The positive allometric growth of the abdomen in the females of *Portunus segnis* of Tunisian waters correspond to the increase in the reproductive potential of the females. This characteristic has also been verified in other brachyuran species [37-14-30]. On the other hand, according to this study the relationship AL *vs* CW showed an isometric growth for males. This result was recorded for different brachyuran crabs such as *Eriphia gonagra* [18]; *Sesarma rectum* [27]; *Panopeus austrobesus* [30] and *Menippe nodifrons* [7]. According to [42], changes in the shape of the carapace might be related to a better accommodation of the gonads after the individuals reached sexual maturity, which also might be related to the results obtained in the present study for the same relationship (AW *vs* CW).

Table 6: Chelarpropodus length and Height relationship in males and females of *Portunus segnis* from the gulf of Gabes based on a variance analysis (ANOVA). CPL: chelarpropodus length, CPH: chelarpropodus height, R_ : right, L_ : left, M : male, F : female.

Relationship	'Z' value	Remarks	'P' value
R_CPL (M) - L_CPL (M)	0.1617	Not significant	P = 0.8716
R_CPL (F) - R_CPL (M)	7.361	Significantat 5% level	P < 0.0001
L_CPL (F) - L_CPL (M)	8.2879	Significantat 5% level	P < 0.0001
R_CPL (F) - L_CPL (F)	0.4515	Not significant	P = 0.6519
R_CPH (M) - L_CPH (M)	9.0728	Significantat 5% level	P < 0.0001
R_CPH (F) - R_CPH (M)	14.4896	Significantat 5% level	P < 0.0001
L_CPH (F) - L_CPH (M)	12.8541	Significantat 5% level	P < 0.0001
R_CPH (F) - L_CPH (F)	1.8605	Not significant	P = 0.0636

Table 7: Fulton's condition factor (K) of *Portunus segnis* from the gulf of Gabes during study period.

Sex		K_{CL}			K_{CW}		
	n	Mean ± SE	Min	Max	Mean ± SE	Min	Max
Males	299	0.0608±0.0195	0.00691	0.34767	0.0075± 0.00164	0.00086	0.02287
Females	335	0.0554± 0.0119	0.02993	0.19452	0.0069± 0.0026	0.0022	0.03453
Overall	634	0.0582± 0.165	0.00691	0.34767	0.0072± 0.00221	0.00086	0.03453

In addition, in this species sexes are easily differentiated by the colour pattern of their exoskeleton. Males are brilliantly coloured with bright blue, and females have a dull brown colour. This unique feature is not seen in other common portunids [23].

The condition factor of the females found to be higher than that of males sampled during study period. These results are similar to those reported for the species at the Persian Gulf [32]. The result is in accordance with other studies on some species of brachyurans, such as *Ocypode macrocera* [12], *Callinectes danae* [2], *C. Sapidus* [4], *Dilocarcinus pagei* [35] and *Ucides cordatus* [36]. The condition factor is strongly influenced by the environment factors, gonad development, feeding and growth rate, degree of parasitism of the biota. It is interesting to note that a dimorphism in the metabolic rates, nutritional aspects, stage of maturity and time of recruitment might also affect sexual differences of the condition factor [36-16].

A considerable proportion of data presented in this study represents new information for this species that has recently invaded the Tunisian coasts. The documented morphometric information will help in further comparative studies for other swimming crab species. Our study confirms sexual dimorphism with regard to body size, and provides first statistical evidence for the existence of sexual dimorphism with regard to chelar propodus and abdomen sizes in *Portunus segnis* of Tunisian waters.

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