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Allometry, condition factor and growth of the swimming blue crab *Portunus segnis* in the Gulf of Gabes, Southeastern Tunisia (Central Mediterranean)

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Abstract

Though the blue swimming crab *Portunus segnis* (Forskål, 1775) was an early mass migrant Lessepsian to Mediterranean Sea, found since decades in various areas, it has not reached southeastern Tunisian coasts (Gulf of Gabes) until very recently.

This paper studies the allometry, condition factor and growth of *P. segnis* along the Gulf of Gabes coasts. We collected samples in one year time (October 2015 to September 2016) using artisanal fishing gears as well as trawl net and processed 4971 crabs. The crab carapace width (CW) ranged from 45 to 168mm for males and 50 to 159mm for females. The crab carapace length (CL) was 22.02-89.20mm and 38.70-85.28mm, respectively for males and females. The carapace width-carapace length, carapace width-front, carapace width-carapace height and carapace width-weight relationships were studied in separate sexes of crab. The covariance analysis indicated a significant difference between the two sexes with respect to the carapace width-carapace length and the carapace width-weight relationships. The condition factor ranged from 0.0042 to 0.0118 with a mean of 0.0078. The condition factor decreased with increasing crab size. The Von Bertalanffy growth parameters $CW\infty$, K and t_0 were estimated on the basis of Length-frequency modal progression analysis methods. The mean values of $L\infty$ (mm), K (year^{-1}) and t_0 were respectively, 206.48mm, 1.34 and -0.130 for males;183.89mm, 1.42 and -0.127 for females and, 190.60mm, 1.02 and -0.177 for combined sexes.

Keywords: Allometry; Condition factor; Growth; *Portunus segnis*; Central Mediterranean.

Introduction

Ever since the Suez Canal was established (in 1869), hundreds of Indo-Pacific marine species, called Lessepsians, have migrated from the Red Sea to the Mediterranean (Galil *et al*., 2002), where they massed into new areas only to change the composition of local ecological system or in some cases modify regional biodiversity (Por, 2010; Galil, 2007 & 2011; Katsanevakis *etal*., 2014). Most of alien crustacean species which entered eastern and western Mediterranean had crossed Suez Canal (Galil *et al*., 2002).

The blue swimming crab, *Portunus segnis* (Forskål, 1775), previously named as *P. pelagicus* (Linnaeus, 1758) (Lai *et al*., 2010), is very prevalent in Indo-pacific region, particularly in tropical and subtropical waters (Romano & Zeng, 2008). it existed in eastern Mediterranean, eastern Africa, Pakistan, the Red Sea and the Persian Gulf (Ropme, 1999). A few decades ago, it started to cross the Suez Canal towards the eastern Mediterranean Sea, as a Lessepsian migrant (Ekman, 1967; Özcan *et al*., 2005; Yokes *et al*., 2007) and to settle as far north as the northern Tyrrhenian Sea (Crocetta, 2006). it lives in a wide range of inshore and continental shelf areas, including sandy, muddy, algal and sea grass habitats, from the intertidal zone to at least 50 m depth. It is usually found in large numbers in shallow bays with sandy bottoms. *P. segnis* constitutes a major part of fisheries in Iran and other southeastern Asia countries (Williams, 1974; Batoy *et al*. 1987; Atar & Sector, 2003, Wu *et al*., 2010; Hosseini *et al.*, 2014).

The presence of *P. segnis* in the Tunisian waters was first reported in October 2014 when few crabs were collected in shallow sandy areas mostly covered by seagrass and algal beds (Rifi *et al*., 2014; Rabaoui *et al*., 2015). Rabaoui *et al.* (2015) have presented some biological aspects of *P. segnis* in the Gulf of Gabes (The mean carapace length, the relationships between the size and weight, the mean egg number (fecundity) and the correlations between fecundity and size/weight). In late August 2015, *P. segnis* increased enormously in number in the coastal areas of the Gulf of Gabes (Crocetta *et al*., 2015) and covered much greater areas in the southeastern Tunisian coasts. They are currently sold in the main local markets.

This work aimed to study some morphometric relationships of blue swimming crab (*P. segnis*) in the Gulf of Gabes (Southern Tunisia, Central Mediterranean). To the best of our knowledge, it is the first attempt to study age and growth of this alien crustacean in the Mediterranean Sea.

Material and Methods

The study is focused on the Gulf of Gabes coasts (southeastern Tunisia) (Fig. 1). *P. segnis* samples were caught on a monthly basis from October 2015 to September 2016 at major trawler harbors as well as on small fishing boats (using trammel nets and gillnets). Sample crabs of several size ranges were moved to the laboratory in coolers and stored in a deep freezer for further analysis. In order to study sexes separately, sample crabs were sexed based on abdomen shape: male crabs have a V-shaped abdomen, while females' abdomens is rather round-shaped (Dai &Yang, 1991).

Digital calipers with an accuracy of 0.01 mm and a digital balance (0.001 g) were used to measure lengths, and the total weight of the crab, respectively. Carapace width (CW), carapace length (CL), carapace height (CH), frontal margin (Fr), anterolateral edge (AE) and total weight (BW) of crabs were measured. Carapace width (CW) corresponds to the distance between the tips of the posterior most lateral carapace spines (Fig. 2) and Carapace length (CL) was measured dorsally along the midline, between the frontal notch and the posterior margin of the carapace. The carapace height (CH) was measured as the bulge corresponding to the thickness of the body of the crab. Frontal margin (Fr) corresponds to the distance between the first left tooth and the first right tooth. Anterolateral edge (AE) corresponds to the distance between the tip of the posterior most lateral carapace spine (9^{th} lateral tooth) and the first left/right tooth.

Regression equations were calculated assuming an allometric growth equation ($Y= aX^b$) converted to the linear form by means of natural logarithm transformation (Y) = Ln (a) + b Ln(X), where y = dependent variables (CL, CH, Fr, AE), X = independent variable (CW), a = intercept on y axis, and b = allometric growth coefficient,

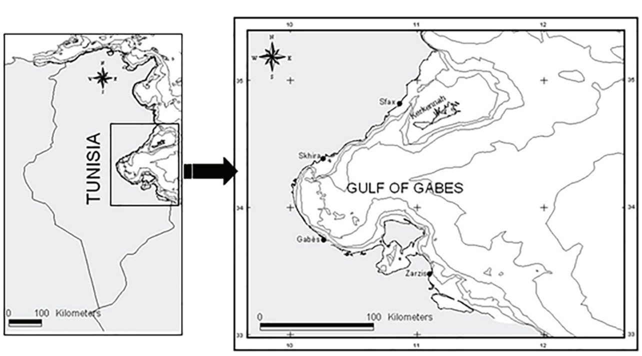

Fig. 1: Gulf of Gabes (Tunisia).

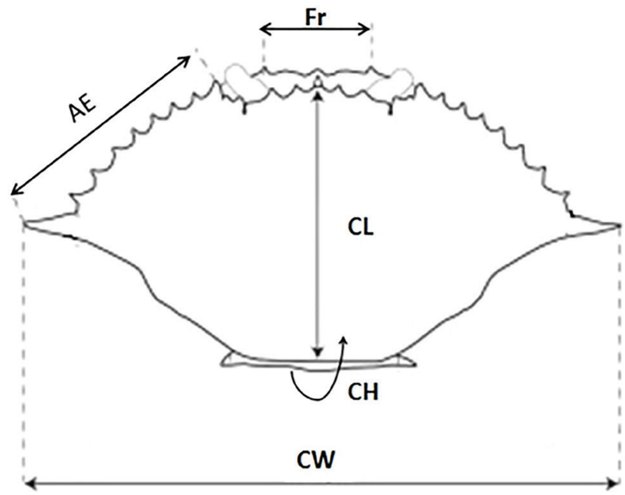

Fig. 2: Schematic drawings highlighting morphological measurements and abbreviations on *P. segnis.*

to determine the relationship, if any, between different morphometric characters in males and females and in combined sexes. Regression analyses were conducted using standard least squares (Sokal & Rohlf, 1995), and differences between regression coefficients were analyzed with an F test. Data were computed using Statistica®software (Statsoft, 1992). Then, allometric relationships were compared using t-test bearing on the slopes (tpe) and the position (tpo) of logarithmic equations for a risk of 5% as recommended by Mayrat (1959).

The carapace width-weight relationship was estimated using the log form of the allometric equation $BW=aCW^b$, where BW=expected weight, a = y-intercept or 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. Differences between sexes in the carapace width-weight relationship were tested by ANOVA® [the t-test bearing on the slopes (tpe) and the position (tpo) for a risk of 5% as recommended by Mayrat (1959)]. The parameters of each allometric relationship are presented in parabolic and logarithmic equations, so as to allow comparison with results found in the literature.

The condition factor is usually used in order to compare the condition, heaviness or well-being of marine organisms. It is based on the hypothesis that heavier fish of a given length are in a well physiological condition (Bagenal & Tesch, 1978). The Fulton's condition factor (K) was calculated from $K= (BW/CW^3)*100$ for both females (ovigerous and non-ovigerous pooled) and males separately (Fulton, 1911); where BW denoted total body weight (g) and CW denoted Carapace width (mm). The variation in condition factor between sexes was tested using Student's t-test ($P<0.05$).

The age and growth of *Portunus segnis* were determined based on the length frequency distributions (LFDs), which have been shown to be useful in crustacean studies (e.g. Ben Mariem, 2004; De Pasquier & Pérez, 2004; Ben Hadj Hamida-Ben Abdallah *et al.,* 2010).

Data on carapace width (CW, mm) of swimming blue crab in the Gulf of Gabes were collected on a monthly basis from trawling and small scale fishing boats' catches. The lfd's analyzed indiscriminately for all the ports together.

Length frequency data were analyzed using the software package FiSAT II (FAO/ICLARM Stock Assessment Tools). Monthly LFDs of each sex were constructed separately in 1-cm classes. This scale was the most useful for the mode detection according to data's preliminary analyses (Ben Hadj Hamida-Ben Abdallah *et al.*, 2010).

A series of normal distribution components was fitted to the frequency distribution of each sex group, using the computer analysis based on Bhattacharya and Normsep's methods implemented in the FiSAT II software package. The results of the first method were automatically used as the input of Normsep's likelihood method. To find the optimal combination for the distributions, the differences between the observed and expected frequencies were minimized using the method of least squares. Bhattacharya's method, implemented from the package FiSAT (Gayanilo *et al.,* 1996), was used to identify the modes in the polymodal length-frequency distributions of male and female crabs. All the identified size/age groups were derived from at least three consecutive points, and selection of the best results was based on the following criteria: (a) the values of separation index (SI) for the different age groups; (b) the number of the identified age groups and (c) the standard deviation (SD) (Gayanilo *et al.,* 1989). Hereinafter, cohorts are referred to as modes, because in a normal distribution the mean for each cohort is equivalent to the mode or median.

It is assumed that the standard deviation of the mean length increased as new age groups were detected (Sullivian *et al.,* 1990) and that the coefficient of variation has a fixed value of 3.5%, as found in a prior data analysis. The separation index of age class (SI) was used to separate the different cohorts (Sparre & Venema, 1998). The SI between different modes exceeded 2 in all cases, which meets the required minimum distance between distributions. If SI<2, it is not feasible to separate the normal components of the observed frequencies (Sparre & Venema, 1995).

Having calculated the monthly LFD's mean and standard deviations, and determined the mean size-at-age (Length-at-age), Von Bertalanffy growth formula is fitted using ELEFAN 1 already implemented in FiSAT II package. This Von Bertalanffy model is a useful expression of growth for crustacean species [Silliman (1969), Parrack (1979), Garcia & Le Reste (1987)]. It is fitted as: $Lt = L_{\infty}(1 - e^{-K(t-t_0)})$, Where

L_{∞} : Asymptotic length
K : Curvature parameter
t_0 : Theoretical age at length zero
t : Age

The parameters of the previous equation were fitted through least squares employing as objective function (Gallucci *et al.,* 1996).-

In order to overcome subjectivity in the identification of two distributions estimated over different times, as pertaining to the same cohort, only the modes between contiguous months were included, as the probability of error in cohort identification was found minor. Modes which were not obvious in the sample of the following month, were not considered, even if they were obvious in the second following month. In order to evaluate their reliability, the parameters estimated for *P. segnis* in the Gulf of Gabes were compared with those estimated for other species of the same genus, following the criteria of Pauly & Munro (1984) and Pauly (1983), who reported that a species-specific relation exists, at the genus level, between log(L∞) and log(K) such that the relation between these parameters remained constant, independently of their values and . This permits to estimate the pertinence of the values of the growth parameters (L∞) and (K), since φ' does not change independently of these values. In this way, the validity of the estimated two parameters could be evaluated, as they become more distant from the value of φ' reported for species of the same genus (Sparre &Venema, 1995), allowing inter-specific comparisons (Pauly, 1991).

Results

Morphometric relationships

In order to determine some morphometric characters, a total of 4198 crabs (2474 males and 1724 females) were analyzed. The crabs CW ranged from 45 to 168 mm (mean 105.586±0.865 mm) in males and 50 to 159 mm (mean 103.327±0.895 mm) in females. The mean CL was 53.451±0.448 mm for males, and 9.955±0.470 mm for females. Allometric equations with respect to males and females of *P. segnis* are indicated in Table 1. The allometric relations between the set of characters suggested that in most cases the relationship was positive and highly significant.

The CW/CL showed an isometric growth pattern in males and females. The comparison of the allometric equations separately for males, females and combined sexes showed no significant differences, neither in slope nor in position detected. The allometry lines were the same for the sexes.

Allometric equations between CW and Fr showed negative growth pattern in both males and females. Allometric CW/CH and CW/AE suggested that relationships followed negative growth pattern in males, while an isometric growth was found for the characters measured in females. Comparison of the equations between sexes showed that there were differences in slope and positions between males and females only for CW/Fr. For CW/CH only a difference in the slope was found between the two sexes. The CW/AE allometry lines were the same for the two sexes.

Carapace width-Total weight relationship and condition factor

This study analyzes BW data collected from 2944 *Portunus segnis*, 1392 females (47.3%) and 1552 males (52.7%). A statistical difference was found between the mean male CW (106.57 ± 1.13 mm) and the mean female CW (102.53 ± 2.63 mm; t_{2944} = 5.15, P = 0.021)

Table 1. Morphometric equations, determination factor (R^2) and t-test values in males (M), females (F) and combined sexes (CS) of *P. segnis*. N: sample size; *: significant.

Relationship	Sexes	N	Parabolic equation	Logarithmic equation	R^2	t-test value	P value
CW-CL	M	2767	$CL=0.4935CW^{1.0055}$	Log CL=-0.7062+1.0055Log CW	0.9655	1.52	0.064
	F	2094	$CL=0.4929CW^{1.0057}$	Log CL=-0.7075+1.0057Log CW	0.9610	1.29	0.099
	CS	4861	$CL=0.5029CW^{1.0014}$	Log CL=-0.6873+1.0014Log CW	0.9635	0.50	0.309
CW-Fr	M	2767	$Fr=0.5970CW^{0.8608}$	Log Fr=-0.5158+0.8608Log CW	0.9080	26.09*	$1.206\ 10^{-134}$
	F	2094	$Fr=0.6390CW^{0.8454}$	Log Fr=-0.4479+0.8454Log CW	0.9193	28.04*	$1.829\ 10^{-147}$
	CS	4861	$Fr=0.6254CW^{0.8498}$	Log Fr=-0.4694+0.8498Log CW	0.9009	37.15*	$1.930\ 10^{-266}$
CW-CH	M	2767	$CH=0.2970CW^{0.9848}$	Log CH=-1.2141+0.9848Log CW	0.9232	2.83*	0.002
	F	2094	$CH=0.2689CW^{1.0078}$	Log CH=-1.3136+1.0078Log CW	0.9237	1.26	0.104
	CS	4861	$CH=0.2903CW^{0.991}$	Log CH=-1.2369+0.9910Log CW	0.9197	2.14*	0.016
CW-AE	M	2767	$AE=0.2251CW^{0.977}$	Log AE=-1.4911+0.977Log CW	0.8119	2.57*	0.005
	F	2094	$AE=0.2014CW^{1.0049}$	Log AE=-1.6027+1.0049Log CW	0.8624	0.56	0.288
	CS	4861	$AE=0.2257CW^{0.9794}$	Log AE=-1.4884+0.9794Log CW	0.8150	3.08*	0.001

and between the mean male BW and the mean female BW (males: 116.47 ± 3.62 g; females: 87.65 ± 2.53 g; t_{2944} =12.37, P<0.001). For females, the CW coefficient of variation (CV%) was 18.9%, slightly smaller than that for males (21.4%). These coefficients were about one-third smaller than the values found for the variable BW of females and males (55.1 and 62.5%, respectively).

The overall analysis of the BW-CW relationship of each sex showed a significant positive correlation between the variables, with the empirical points fit to the power function (R^2> 0.96) (Table 2). The 'b' value for the BW-CW relationship was distinct between the sexes with positive allometric growth pattern in weight for males (b = 3.19, t_{1552} = 20.46, P<0.001) and combined sexes (b=3.09, t_{2944} = 11.31, P<<0.001), and a negative allometric pattern was identified for females (b = 2.92, t_{1392} = -6.98, P<0.001). The comparison of the BW-CW equations related to the sexes showed a significant difference in slope and position in all cases (Table 3). The study also showed that males are slightly heavier than females at up

Table 2. Allometric BW-CW equations, Correlation cofficient (R^2) and t-test values in males (M), females (F) and combined sexes (CS) of *P. segnis*. N: sample size; *: significant.

Sexes	N	Parabolic equation	Logarithmic equation	R^2	t-test value	P value
M	1552	$BW=0.00003CW^{3.1870}$	Log BW=-10.287+3.1870Log CW	0.9797	20.46*	$6.2\ 10^{-79}$
F	1392	$BW=0.00010CW^{2.9198}$	Log BW=-9.1512+2.9198Log CW	0.9688	6.98*	$2.0\ 10^{-12}$
CS	2944	$BW=0.00005CW^{3.0931}$	Log BW=-9.8910+3.0931Log CW	0.9685	11.31*	$2.0\ 10^{-29}$

Table 3. Comparison of the slope (tpe) and the position (tpo) of the BW-CW linear regressions. *: significant.

tpo / tpe	Males	Females	Combined sexes (Males+Females)
Males		14.238* p = $7.778\ 10^{-45}$	5.361* p = $4.346\ 10^{-08}$
Females	14.787* p = $4.435\ 10^{-48}$		10.122* p = $4.053\ 10^{-24}$
Combined sexes (Males+Females)	4.947* p = $3.906\ 10^{-07}$	11.067* $2.151\ 10^{-28}$	

to 120 mm carapace width (mean BW is 75.05±2.29 for males and 69.55±1.69 for females; t_{2190} = 3.82, P<0.001). Afterwards, males grew heavier than females (mean BW is 203.58±3.93 for males and 167.17±4.02 for females; t_{750} = 11.57, P<<0.0001). The scatter diagram for males and females was obtained by plotting weight against carapace width of individual crabs. A distinct relationship between width and total weight was also found, as evidenced by the closeness of the scatter dots, as well as the parabolic nature of the plot.

The mean total Fluton's condition factor value of females (0.0074 ± 4.01 10^{-05}) differed significantly when compared to that of males (0.0082 ± 4.50 10^{-05}), with coefficients of variation of 10.32% and 10.98%, respectively. The mean CF differed significantly between the sexes, being higher in males (t_{2942} = 27.19, P<0.001). The condition factor fluctuated throughout the sampling period for both sexes (Fig. 3). In females, CF was highest during July-September and decreased sharply in December-January. Furthermore, males showed a small CF oscillation compared to females, the highest values were recorded in November and April and lowest in May and October.

Age and growth

In the 4971 collected samples, 2143 were females and 2828 were males. The size ranged from 50 to159 mm CW for females and from45 to168 mm CW for males. For both sexes, the CW size classes 90 to 125 mm were the highest in number and CW size classes 45 to 60 mm were the lowest. The carapace width showed a unimodal distribution where most crabs (65%) were in the medium size group (Fig. 4).

Bhattacharya's and Normsep's methods were used to distinguish the size frequencies for the determination of the mean CW crab cohort. A modal progression analysis was used to trace the mean cohort lengths throughout monthly growth progression (Sparre & Venema, 1998).

Out of the 91 modes (40 for females and 51 for males) determined by the sample analysis, only 71 modes (34 for females and 37 for males) were included for growth parameters estimation. The mean female cohort length ranged between 57.50 and 147.40 mm CW (Table 5) for Bhattacharya method and between 57.20 and 141.87 mm CW for Normsep's method while the mean male modes ranged between 59.57 mm and 152.65 mm CW for Bhattacharya method (Table 5) and between 45.82 and 155.64 mm CW for Normsep method. In both sexes, the relationship between size and monthly increase in length was inverse, though with high variability (Fig. 5).

For the blue swimming crab *P. segnis* in the Gulf of Gabes, the Von Bertalanffy growth equation parameters obtained by the two methods are presented in Table 4. Analysis of the growth curves showed higher value for K and lower value for L∞ in females, which is consistent with the larger male sizes observed in the catches (Fig. 6). The growth performance index (φ') values were quite close, 4.546 for females and 4.774 for males by Bhattacharya method and, 4.681 and 4.757, respectively for the two sexes, by Normsep method.

Discussions

Sizes in the present study ranged between 50 and 159 mm CW for females and between 45 and 168 mm for males. Comparatively, the largest males and females observed in the Persian Gulf were 149 mm and 164 mm CW, respectively (Noori *et al*., 2015) and between 39.3-156 mm CW for males and 34-149 mm for females in the Gulf of Gabes (Hajjej *et al*., 2016). The maximum carapace width in *P. segnis* varies substantially from one population to another. There is solid evidence in the literature that abiotic variables, namely the climate, have the strongest influence on this parameter (Wenner *et al.,* 1974; Annala *et al.,* 1980; Araújo *et al.,* 2012).

The total body weight-carapace width relationship and the condition factor was previously evaluated for some Portunids such as *Callinectes bocourti* (Costa *et al*., 1980), *Callinectes danae* (Branco &Thives, 1991; Branco *et al*., 1992) and *Callinectes sapidus* (Atar & Secer, 2003; Summer *et al.,* 2013). In the Gulf of Gabes, the exponent 'b' value for body weight-carapace width relationship of *P. segnis* was distinct between the sexes, indicating a sexual dimorphism in the corresponding rela-

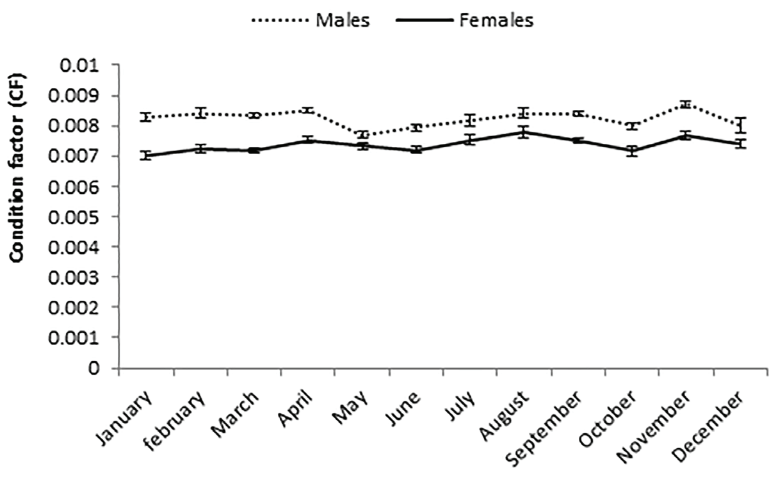

Fig. 3: Monthly means of the Fluton's condition factor for females and males of *Portunus segnis* in the Gulf of Gabes.

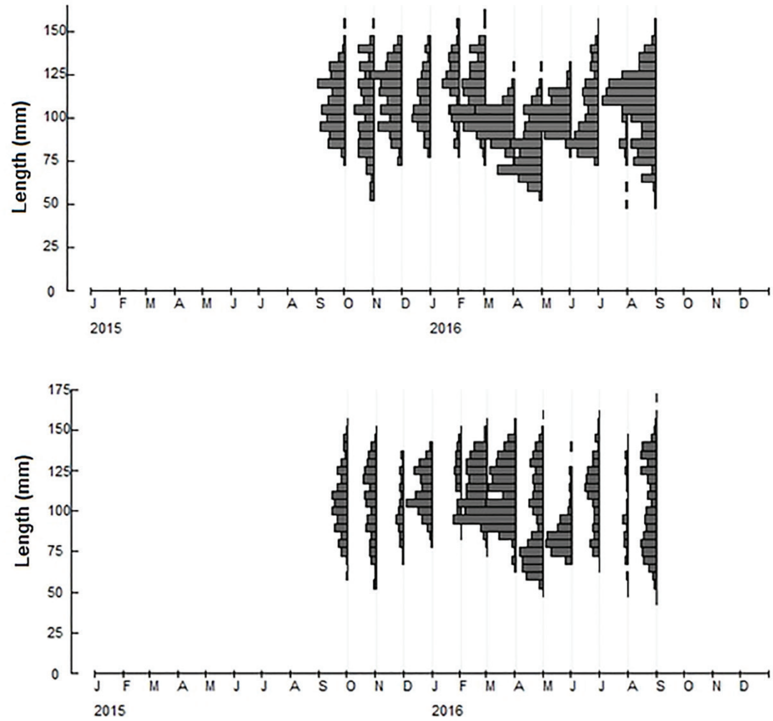

Fig. 4: Length frequency distributions in males (up) and females (down) of *Portunus segnis* in the Gulf of Gabes.

Table 4. Parameters of the Von Bertalanffy growth model estimated for *Portunus segnis* in the gulf of Gabes. M: Males, F: Females, CS: combined sexes.

Methods	Sexes	CW∞		K		t_0
		value	SE	value	SE	value
	F	183.79	7.434	1.04	0.105	-0.175
Bhattacharya	M	206.09	4.201	1.40	0.085	-0.124
	CS	192.16	5.839	0.92	0.089	-0.196
	F	183.89	7.815	1.42	0.195	-0.127
Normsep	M	206.48	3.555	1.34	0.147	-0.130
	CS	190.60	5.686	1.02	0.072	-0.177

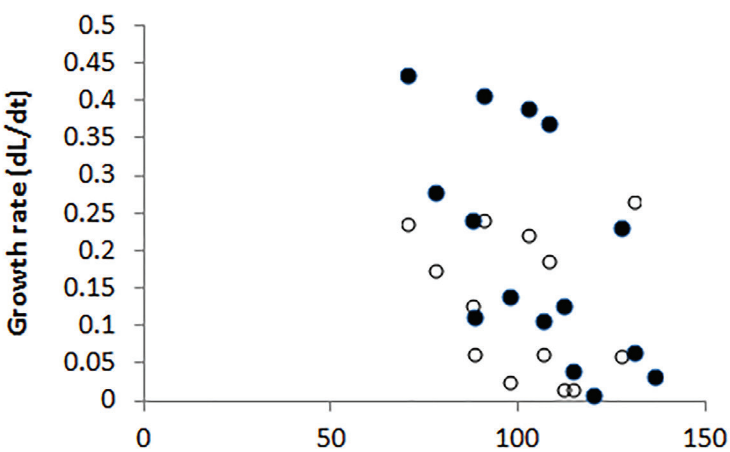

Fig. 5: Monthly CW increase as a function of size in males and females of *Portunus segnis* in the Gulf of Gabes.

tionship. Females showed negative while males positive allometric growth considering the length-weight relationship. While Hajjej *et al.* (2016) found similar results, Rabaoui et *al*. 2015, reported a positive allometric growth in females in the Gulf of Gabes. Noori *et al*. (2015) noted that the body weight-carapace width relationship indicated positive allometric growth in males and isometric growth in females. In some studies, in other Portunids

Table 5. Identified age groups from *Portunus segnis* LFD's in the Gulf of Gabes. SI: Separation index, N = number of individuals.

Year	Month	Mode	S.I.	N	Year	Month	Mode	S.I.	N
		Males					**Females**		
		82.03		54			88.54		46.93
	October	109.33	2.56	160		October	105.42	2.10	62.34
		141.77	3.06	17			126.75	2.13	66.05
		78.51		49			57.50		12.61
2015	November	108.16	4.12	63	2015		82.53	2.35	45.44
		125.28	2.06	92		November	95.82	2.07	27.58
		83.32		19			122.26	2.14	96.56
	December	96.43	2.65	29			93.39		62.74
		115.77	2.81	31		December	122.98	2.20	129.56
	January	104.12		156			87.50		19.91
		128.87	2.90	73		January	102.87	2.06	54.13
	February	102.50		12			120.04	2.09	33.99
		127.55	3.56	56			140.39	2.16	11.72
		105.06		197			86.30		7.49
	March	128.91	2.56	137		February	104.63	2.25	17.05
		147.50	3.05	5			120.90	2.14	39.59
		69.46		11			136.17	2.05	26.54
	April	96.98	5.33	341			103.47		119.46
		126.91	3.59	199		March	120.87	2.01	32.78
		66.34		120			147.40	2.06	51.31
		80.93	2.25	74		April	104.09		215.50
	May	105.25	3.38	79	2016		69.59		112.90
		130.35	3.04	91		May	90.09	2.16	81.81
2016	June	83.88		176			116.23	2.08	31.86
		131.31	2.37	31		June	101.64		184.84
		87.21		151			122.50	2.15	3.62
	July	115.81	3.64	184			85.53		79.60
		135.97	2.88	28		July	112.36	2.31	60.32
		152.65	3.94	10			137.95	2.20	21.13
		62.50		7		August	84.52		12.73
	August	87.92	3.09	34			110.18	2.30	34.67
		127.17	4.46	17			65.27		21.05
		59.57		15		September	84.39	2.31	61.92
		76.90	2.14	106			117.59	2.32	275.15
	September	96.30	2.08	66					
		124.31	2.24	77					
		138.20	2.03	59					

like *P. pelagicus* (Josileen, 2011) and *Callinectes danae* (Araújo & Lira, 2012), a positive allometry was demonstrated in both sexes. However, an isometric growth was found in male and female *P. sanguinoletus* (Sukumaran & Neelakantan, 1997). This inter-specific variation may be the result of species-specific characteristics and/or abiotic factors (e.g. water salinity, pH, dissolved oxygen and especially temperature) which can influence growth (Wambold *et al.*, 2011).

On the other hand, the exponent 'b' in the present study demonstrated that *P. segnis* males are heavier than females at a given size. This sexual dimorphism in weight is a typical pattern for many Brachyuran crabs (Pinheiro &Fiscarelli, 2009; Araújo & Lira, 2012). The tendency of males to be heavier than females is also consistent with previous studies on Portunids such as *P. pelagicus* (Sukumaran & Neelakantan, 1997), *P. sanguinoletus* (Sukumaran & Neelakantan, 1997) and *Scylla serrata* (Prasad *et al.*, 1989). This sexual dimorphism can be explained by a reproductive behavior that differs from one crab family to another. In Portunids, males are heavy and strong enough to protect females before and after reproduction and to compete for them (Pinheiro &Fransozo, 2002). In contrast, gonad development and oocyte production take most female energy (Kotiaho & Simmons, 2003).

This study found higher male condition factor which echoes the findings of Hajjej *et al.* (2016). Still, estimated condition factor of *P. segnis* females (0.074) and males

Fig. 6: Growth curves fitted for males and females of *Portunus segnis* in the Gulf of Gabes.

(0.082) were found higher than those reported in a previous study (Hajjej *et al.*, 2016). However, other studies on other species of brachyuran, such as *Ocypode macrocera* (Dubey et *al.*, 2014), *C. danae* (Araújo & Lira, 2012) and *Ucides cordatus* (Pinheiro & Fiscarelli, 2009), demonstrated higher condition factor's values in females than males. The condition factor is highly influenced by exogenous (e.g. environmental factors) and endogenous parameters (e.g. feeding rate, growth rate, sexual cycle, etc.) and may vary over the time and across populations (Froese, 2006; Pinheiro & Fiscarelli, 2009). In this study, CF reached its peak during the reproduction period of *P. segnis* (May-October).

In general, short-lived species such as crabs reach asymptotic length in their first or second year and are characterized by a high K-value (Garcia & Le Reste, 1981). In this study, *P. segnis* had differential growth rates between sexes. Males and females have at least two cohorts in most months of the year, which is consistent with the results of Safaie *et al.* (2013). The K-value was higher in males for Bhattacharya method and in females for Normsep method. Safaie *et al*. (2013) also found higher K-value for females of *P. segnis* of Persian Gulf and Gulf of Oman (Iran). These authors estimated higher K-values compared to this study (Table 6). Studies on *P. pelagicus* in Thailand (Sawusdee &Songrak, 2009), India (Josileen & Menon, 2007; Sukumaran &Neelakantan, 1997) and Iran (Kamrani et *al*., 2010) have also reported differential growth between sexes.

In India, Safaie *et al*. (2013) estimated highest CW∞ value for females (185 mm) and lowest one for males (191 mm), but higher K-values for both sexes (1.7 $year^{-1}$ for males and 1.6 $year^{-1}$ for females). In comparison with *P. pelagicus*, Josileen & Menon (2007) and Sukumaran & Neelakantan (1997) estimated higher CW∞ values for females. However, the CW∞ values estimated for *P. pelagicus* males were lower in Thai waters (Sawusdee & Songrak, 2009) and Indian waters (Sukumaran & Neelakantan, 1997). Growth performance indexes estimated for *P. segnis* in the present study were similar to those of Safaie *et al.* (2013) in the Persian waters (φ' = 4.793 for males and 4.738 for females). On the other hand, the mean φ' values in *P. pelagicus* studies in Thailand and India were 4.530-4.528 for both sexes and were also quite similar to our findings. The present φ' values suggested that the estimates of Von Bertalanffy growth

Table 6. Comparison of growth parameters and Ø' of *Portunus segnis* from the gulf of Gabes *P. pelagicus* from other study areas.

Area	Authors	Species	Sex	K ($year^{-1}$)	CW∞ (mm)	φ'
Trang province (Thailand)	Sawusdee and Songrak (2009)	*P. pelagicus*	M	1.5	179	4.682
			F	1.6	171	4.670
Mandapam coast (India)	Josileen & Menon (2007)		M	0.95-1.68	191.9-199.4	4.544-4.825
			F	1-1.42	190.4-196.9	4.559-4.741
South-West coast of India	Sukumaran & Neelakantan (1997)		M	1.14	211	4.705
			F	0.97	204	4.606
Persian Gulf (Iran)	Kamrani *et al.* (2010)		M	1.2	168	4.530
			F	1.1	177.9	4.542
Gulf of Gabes (Tunisia)	Present study	*P. segnis*	M	1.34	206.5	4.681
			F	1.42	183.9	4.757

parameters are reliable. The results of Normsep and Bhattacharya methods lead to almost similar estimations of growth parameters, as evidenced by the similar growth curves. Nevertheless, growth parameters in Normsep method are more reliable because (i) they are consistent with the parameters calculated in several studies, and (ii) they are just a refined version of the results of Bhattacharya method.

The maximum *P. segnis* mode in the present study was 155.64 mm. It corresponds to 14 months for females and 11 months for males. The maximum age or longevity (tmax≈3/K; Pauly, 1983) estimated is 25 months for females and 27 months for males. Safaie *et al*. (2013) estimated lower longevity (19 months for females and 18 months for males).

Most results of this study give new information on this new species in Tunisian coasts. The documented age, growth and morphometric information, which is also among the rare carried out in the Mediterranean, might be usable for future comparative studies on other swimming crab species, ecological and stock assessment studies of the species in Tunisian waters, and comparative purposes with studies conducted in other regions.

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