Biometric Study, Condition Factor and Biochemical Composition of the Blue Crab *Callinectes sapidus* Rathbun, 1896

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ABSTRACT

Callinectes sapidus is one of the most important and valuable crabs worldwide, including the Egyptian fisheries. This study was carried out to provide baseline data, namely morphometric and weight relationships, condition factor, and biochemical composition of the blue crab population in Manzala Lake, Mediterranean Sea, Egypt. Samples were collected between March 2019 and February 2020, and data were analyzed seasonally. Male crabs were significantly more abundant and heavier than females. The majority of specimens (69 %) had carapace width in the range from 70 to 109.9 mm, while the 30-49.9 mm class represented only 1.12 %. The overall sex ratio of *C. sapidus* was in favor of males (1.41:1). The correlation between gonadosomatic index (GSI) and hepatosomatic index (HSI) was moderate to weak ($r^2 = 0.52$ in males and $r^2 = 0.32$ in females). Biometric analysis showed a tendency toward negative allometric growth. Males exhibited some isometric growth, but only in the CL-BW relationship (b = 3.02). Females exhibited significantly higher condition factor than males ($p<0.01$). However, the differences in biochemical composition of muscle between male and female blue crabs were statistically insignificant ($p>0.05$). A comparison of the present results with those from different localities is also presented.

Keywords: Biochemical composition, Condition factor, Growth pattern, Manzala Lake, Morphometric and weight relationships, Sex ratio

INTRODUCTION

The blue crab *Callinectes sapidus* Rathbun, 1896 (Crustacea: Decapoda: Brachyura: Portunidae) is native to the Atlantic coast of the Americas from Nova Scotia to Uruguay and Argentina (Millikin and Williams, 1984). Globally, it is one of the most invasive marine species worldwide, as it has been introduced to the European North East Atlantic, Mediterranean Sea, Baltic Sea, Black Sea, North Sea and Japan (Nehring *et al*., 2008; Garcia *et al*., 2018; Kampouris *et al*., 2019). It is thought that this alien species was transported into the Mediterranean Sea through ballast water of ships (Nehring, 2011).

Callinectes sapidus is a swimming crab characterized by a carapace width that is about twice its length. Individuals of this species are dioecious and exhibit apparent sexual dimorphism. The male crab is distinguished by a narrow T-shaped abdomen (Williams, 1974).

Callinectes sapidus is euryhaline and eurythermal, allowing it to adapt to a wide range of environments (Kampouris *et al*., 2020). Juvenile and adult crabs can tolerate changes in salinity and temperature to a similar degree. The strong swimming capacity, wide ecological tolerance as well as high fecundity of *C. sapidus* may help it to

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invade many seas (Streftaris and Zenetos, 2006). It inhibits estuaries, lagoons, seas and other coastal waters on sandy and muddy substrates from the intertidal zone to 90 m depth (Millikin and Williams, 1984).

This edible crab is considered an important source of popular, valuable and nutritious seafood for human consumption worldwide. This crab is beneficial for human health as its flesh is highly enriched with proteins, carbohydrates, minerals, vitamins and omega-3 fatty acids (Ayas, 2016). Protein is a vital dietary component as it plays important developmental, structural and metabolic roles in our bodies (Thalacker-Mercer and Drummond, 2014). Omega-3 fatty acids are considered as beneficial or healthy lipids that can control blood pressure, balance cholesterol levels in the blood, prevent atherosclerosis, and reduce the risk of cancers, brain disorders, cardiovascular disease and rheumatoid arthritis (Ayas and Özoğul, 2011).

The nutritional and economic benefits of crabs have prompted researchers worldwide to study and investigate their biology and ecology. Biological characteristics and population dynamics of blue crabs have previously been studied (Sumer *et al*., 2013; Abdel Razek *et al*., 2016). As *C. sapidus* is one of the most commercially important edible crabs in Egypt (Mehanna *et al*., 2019), information about its condition factor is useful to monitor the well-being of its populations. Condition factor is an important parameter to indicate the health of a species in its environment (Araújo and Lira, 2012). In addition, condition factor can provide crucial information about fat content of crabs and their degree of adaptation to the local environment (Le Cren, 1951; Pinheiro and Fiscarelli, 2009).

Despite the value of this information, only a few studies have been carried out in Egyptian waters. Abdel Razek *et al*. (2016) and Mehanna *et al*. (2019) studied biological parameters, population dynamics, and fisheries characteristics of this species in Bardawil Lake. However, there is no detailed information about the biology of *C. sapidus* in other lakes such as Manzala Lake. Manzala Lake, a shallow brackish lake, is the largest coastal lake in Egypt and also the most productive (Elmorsi *et al*., 2017; Mirdan, 2019). It produces more than 55 % of the total annual national fishery yield (Mirdan, 2019). Therefore, the aim of this study is to assess the biological state of the blue crab *C. sapidus* in this lake, as this information is essential for the development of fisheries, safe levels of exploitation, effective resource management and successful culture of this species. Moreover, the current study evaluates the nutritional value of this commercial crab and assesses its well-being in Manzala Lake using condition factor.

MATERIALS AND METHODS

Study area

Manzala Lake is located on the northeastern edge of the Nile Delta (between 31°00 and 31°35N; 31°45 and 32°15E). El-Gamil (the sampling area) is an outlet located along the northeast side of Lake Manzala, within the coastal sand bar 5 km west of Port Said on the Mediterranean Sea (Figure 1).

Sample collection

Random samples of blue crabs were collected using trammel nets from March 2019 to February 2020, at El-Gamil outlet of Manzala Lake. The crabs were transported in plastic tanks containing ice to the laboratory of the Faculty of Science, Port Said University for further investigation. Sexes were separated by external characteristics, particularly the shape and size of the abdomen flap. Only healthy crabs without missing legs or broken shells were used in this study, resulting in a total sample of 178 individuals of *C. sapidus* (104 males and 74 females).

Sample measurements

Total body weight (BW) of the crabs was measured to the nearest gram using a digital balance (IIAXIS model ATZ520). Carapace length (CL) was measured dorsally along the midline from the frontal teeth to the posterior edge of the carapace, and carapace width (CW) was taken from the tip of the right lateral spine to the tip of left one (Figure 2). CL and CW were measured to the nearest millimeter (mm) by a vernier caliper with an accuracy of 0.1 mm.

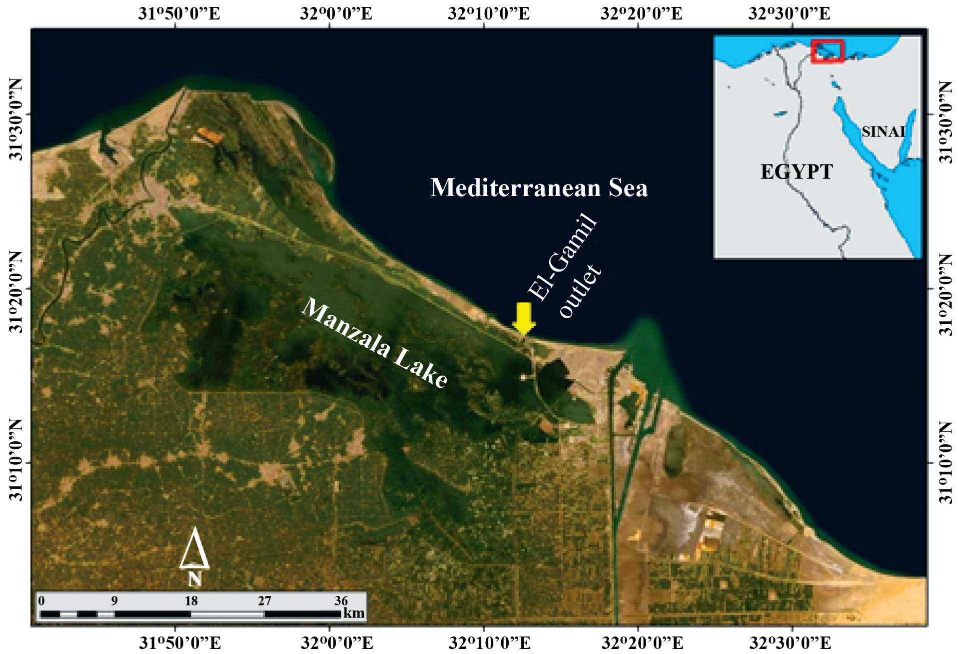

Figure 1. Map showing the location of El-Gamil outlet on Manzala Lake, Egypt.

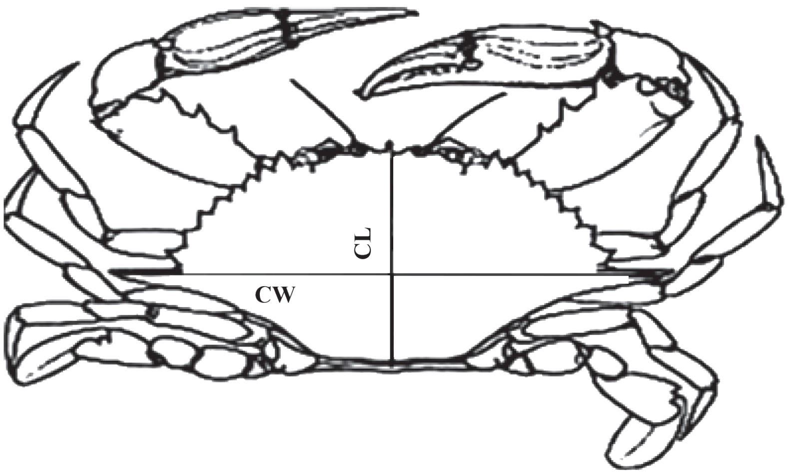

Figure 2. Schematic drawing highlighting the measured dimensions of the dorsal surface of *Callinectes sapidus*. CW: carapace width and CL: carapace length.

Biometric relationships

Carapace width-carapace length relationship

This relationship was determined for each sex separately according to the following equation:

$$CL = a \pm b\ CW \quad (1)$$

Where CL is the carapace length in mm, CW is the carapace width in mm, "a" is a constant and "b" is the slope.

Carapace width/length-body weight relationships

These relationships were estimated by the following equation (Hartnoll, 1978; Froese *et al*., 2014):

$$BW = a\ CW^{b} \quad (2)$$

$$BW = a\ CL^{b} \quad (3)$$

Where BW is the total weight in grams, CW is the carapace width and CL is the carapace length in mm, "a" is a constant or intercept and "b" is the slope.

The type of weight increase was defined as either isometric (b = 3), positively allometric (b>3), or negatively allometric (b<3).

Condition factor

Condition factor (K) of each sex was calculated by the following equation (Hile, 1936):

$$K = 100 \times (BW/CW^{b}) \quad (4)$$

Where BW is the total body weight in grams, CW is the carapace width in mm, and "b" is the power of the carapace width-body weight equation.

Gonadosomatic and hepatosomatic indices

After body measurements, crabs were dissected. Gonads and hepatopancreas were removed and weighed to the nearest gram. The gonadosomatic index (GSI) and hepatosomatic index (HSI) were determined according to the following equations:

$$GSI = 100 \times (GW/BW) \quad (5)$$

$$HSI = 100 \times (HW/BW) \quad (6)$$

Where GW is gonad weight, BW is body weight and HW is hepatopancreas weight.

Proximate composition of muscle

Muscles of the collected specimens of each sex were carefully removed. The biochemical composition of muscle tissue (total protein, carbohydrate, lipid and moisture) was estimated according to the methods of Lowry *et al*. (1951), Bligh and Dyer (1959) and Helrich (1990), Scherz and Bonn (1998), respectively. These analyses were carried out in the Research Center of the Zoology Department, Faculty of Science, Port Said, Egypt.

Statistical analyses

The data were pooled by seasons, which were defined as spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February). The data were then analyzed using student's t-test (for comparison between males and females) and one-way ANOVA followed by Tukey's test (to assess the differences between males, females and combined sexes). Statistically significant difference was reported when p-value<0.05. Statistical analyses were carried out using SPSS 22.0.

RESULTS

Size composition

Descriptive statistics of carapace width, carapace length and total body weight for male and female crabs are presented in Table 1. CW, CL and total BW of males and females fluctuated seasonally. Females ranged in CW from 35.6 to 154.8 mm, in CL from 21.2 to 68.8 mm, and in BW from 4.9 to 173.2 g. Males ranged in CW from 49 to 154.8 mm,

Table 1. Descriptive statistics of *Callinectes sapidus* during the study period.

Season	Sex	n	Carapace width (mm)			Carapace length (mm)			Total body weight (g)		
			Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
Spring	F	28	35.6	107.3	79.2±15.7	21.2	51.3	40.3±7.1	4.9	60.9	37.4±14.9
	M	58	64.7	121.2	87.5±11.7	35.8	60	45.8±5.3	23.2	128.1	50.9±22.3
Summer	F	19	65.1	143.7	90.7±21.5	36.1	67	46.6±7.9	25.2	145.1	53.7±30.5
	M	29	70.2	110.1	87.5±10.1	39.6	57.2	46.3±4.3	29.2	90.5	55.6±16.8
Autumn	F	19	103.1	154.8	126.1±13.7	49.1	68.8	57.2±6.3	74	173.2	115.4±25.9
	M	10	124.8	154.8	141±8.3	61.1	75.5	68.3±4.2	154.9	251.1	190.6±27.9
Winter	F	8	54	81.6	68.8±8.3	28.3	35.5	33.1±2.4	13.2	27.3	21.7±4.6
	M	7	49	78.8	66.8±8.7	26	40.7	34.2±4.2	10.1	34.5	24.7±7.7
All seasons	F	74	35.6	154.8	93.1±26.2	21.2	68.8	45.5±10.4	4.9	173.2	59.9±40.6
	M	104	49	154.8	91.2±20.2	26	75.5	47.3±8.9	10.1	251.1	63.9±46.9

Note: F = Female; M = Male; n = Count; Min = Minimum; Max = Maximum; SD = Standard deviation

in CL from 26 to 75.5 mm, and in BW from 10.1 to 251.1 g. The maximum values of these parameters were observed in autumn for both sexes, while the minimum values were observed during spring and winter for females and males, respectively.

Sex ratio

The overall sex ratio of sampled crabs was 1:1.41 (F: M), which significantly departed from an equal ratio ($p = 0.024$, $\chi^2 = 5.056$). Seasonal abundance of both sexes is shown in Figure 3. Male blue crabs were more abundant in the sample in spring and summer, while females outnumbered males in autumn and winter. The highest occurrence of females (65.5 %) and males (67.4 %) was recorded in autumn and spring, respectively. The lowest abundance of males (34.5 %) was observed in autumn, while the lowest abundance of females (32.6 %) was in spring. A highly significant difference ($p<0.001$) was found between males and females by season.

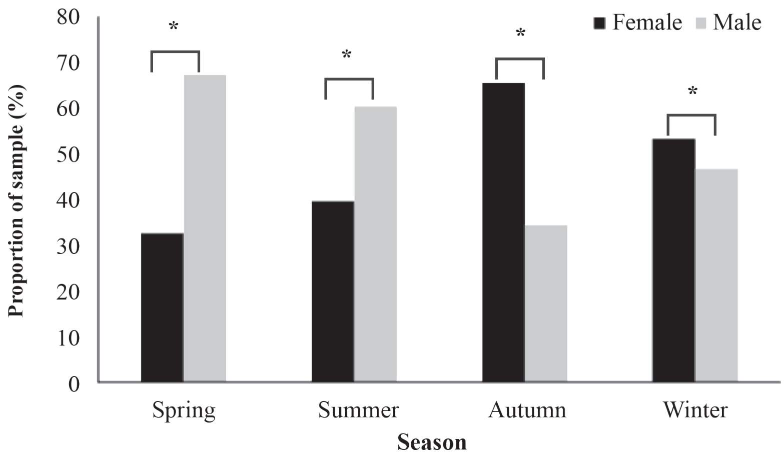

Figure 3. Proportion of male and female *Callinectes sapidus* sampled by season.
Note: * indicates significant difference ($p<0.05$) between males and females.

Size frequency distribution

Carapace width frequency distribution

Carapace width frequency distributions of male and female crabs are shown in Figure 4. The highest carapace width frequencies of females (40.5 %) and males (54.8 %) were observed within the 70-89.9 mm size class. Meanwhile, about 1.4 % of female crabs were recorded within the smallest (30-49.9 mm) and largest (150-169.9 mm) CW size classes, while the lowest frequency of male crabs (0.96 %) was found in the 30-49.9 mm class.

Carapace length frequency distribution

Figure 5 shows the carapace length frequency distributions for male and female crabs. Only 4.1 % of females were recorded within the 20-29.9 mm size class, while the highest frequency (32.4 %) was within the 30-39.9 mm class. No female crabs were recorded within the 70-79.9 mm size class. On the other hand, the maximum (58.7 %) and minimum (0.96 %) CL frequencies of male crabs were observed in the 40-49.9 mm and 20-29.9 mm classes, respectively.

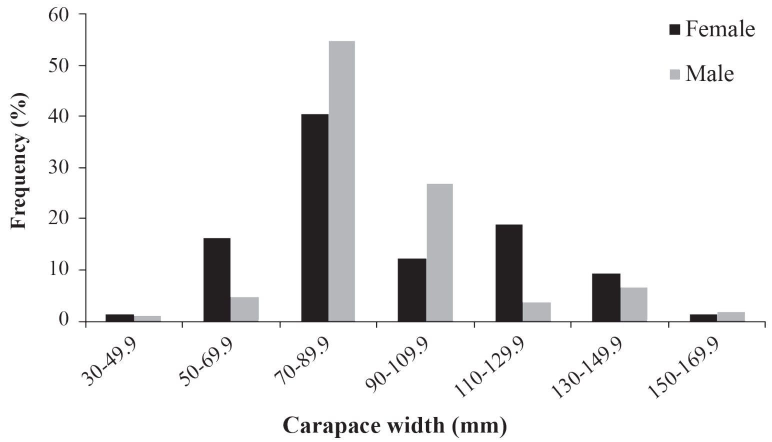

Figure 4. Frequency distribution of carapace width for male and female *Callinectes sapidus* during the study period. Frequencies calculated separately for male and female.

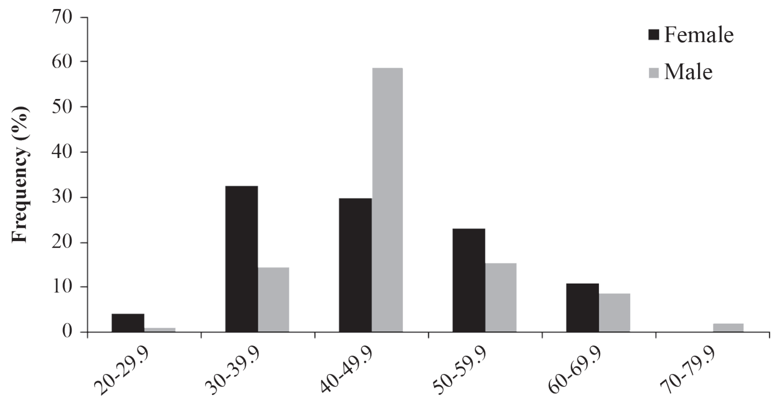

Figure 5. Frequency distribution of carapace length for male and female *Callinectes sapidus* collected during the study period. Frequencies calculated separately for male and female.

Carapace width/length-weight relationships

The relationships between CW-CL, CW-BW and CL-BW are presented in Figure 6. Very strong correlations (>0.9) were found between each pair of parameters for each sex (Table 2). Also, a negative allometric growth pattern was dominant except for CL-BW in male crabs (b = 3.02).

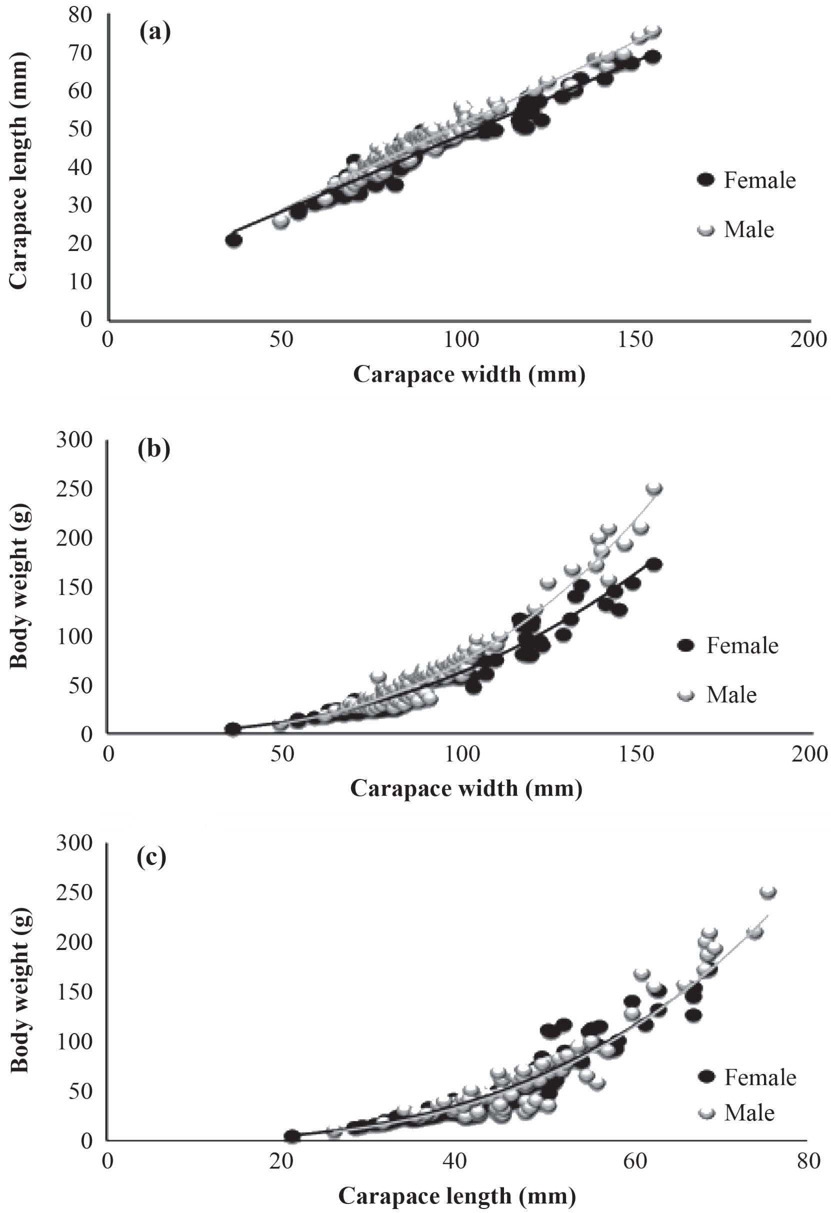

Figure 6. Relationships between carapace width (CW), carapace length (CL) and total body weight (BW) in male and female *Callinectes sapidus*: (a) CW-CL; (b) CW-BW; (c) CL-BW.

Table 2. Coefficients of regression and correlation for relationships between carapace measurements and weight of *Callinectes sapidus*.

Sex	Relationship	Regression coefficient			r	r^2
		b value	95 % C.I.	Growth pattern		
Females	CW-CL	0.39	0.37-0.41	-ve	0.98	0.95
	CW-BW	2.4	2.39-2.59	-ve	0.98	0.96
	CL-BW	2.89	2.33-2.98	-ve	0.97	0.94
Males	CW-CL	0.43	0.42-0.45	-ve	0.98	0.96
	CW-BW	2.21	2.08-2.34	-ve	0.96	0.92
	CL-BW	3.02	2.57-3.27	iso	0.92	0.85

Note: CW = carapace width; CL = carapace length; BW = body weight; -ve = negative allometry; iso = isometry; r = correlation coefficient; r^2 = coefficient of determination

Condition factor

The condition factor (K) was significantly higher ($p<0.01$) for female crabs than for males in each of the four sampling seasons (Figure 7). Maximum and minimum K values were recorded in autumn and spring, respectively. The maximum K values were 1.92 and 1.42 for females and males, respectively. Condition factor (K) was also calculated according to crab size (Figure 8). This view of the data also showed females to have higher K than males. For both sexes, maximum K was in the 30-49.9 mm CW class; the K value gradually declined as CW increased. Males and females within the largest size class (150-169.9 mm CW) exhibited the lowest K values.

Gonadosomatic index

Seasonal variation in the gonadosomatic index of female and male blue crabs is shown in Figure 9. The maximum GSI for females (6.9±2.6 %) was recorded in summer and for males in summer (5.5±1.0 %) and autumn (5.6±0.7 %). GSI values gradually declined to their minimum values (~ 1.7 %) in winter for both sexes. Significant difference was recorded between the two sexes only in the summer season ($p<0.01$).

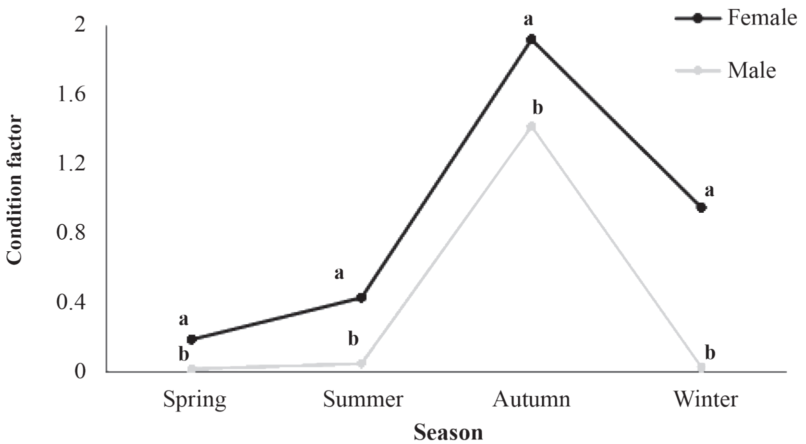

Figure 7. Condition factor (K) for male and female *Callinectes sapidus*, by season. Different lowercase letters within the same season denote significant difference ($p<0.05$).

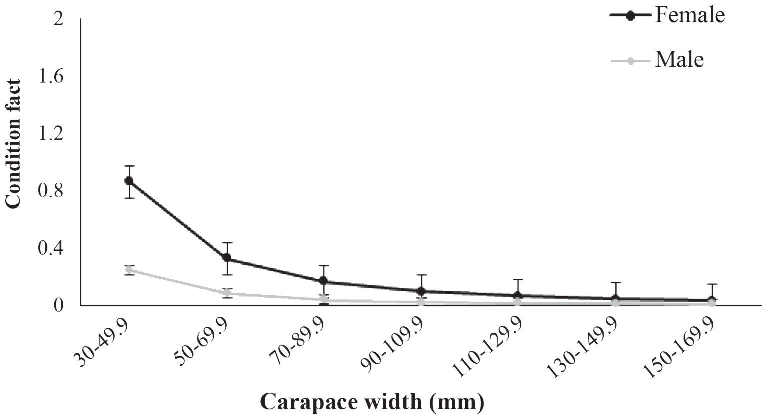

Figure 8. Condition factor (K) of male and female *Callinectes sapidus* by carapace width class.

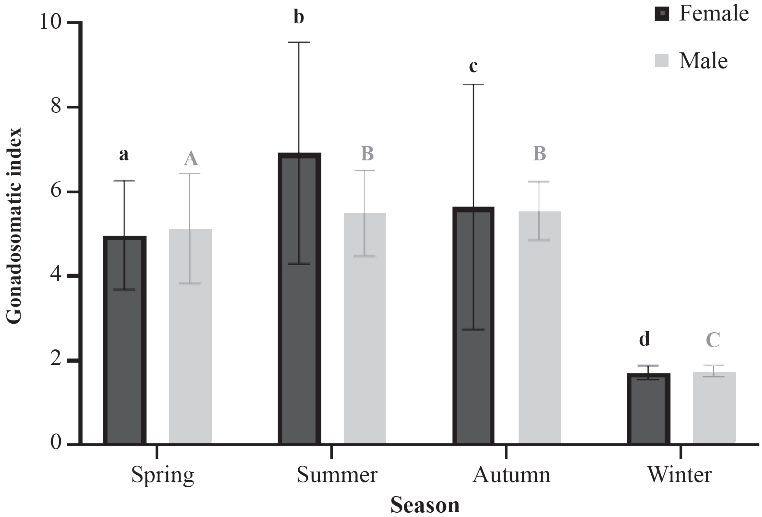

Figure 9. Seasonal variation in gonadosomatic index for male and female *Callinectes sapidus*.
Note: Different lowercase letters denote significant difference ($p<0.05$) in GSI between seasons for females; different uppercase letters show seasonal differences for males.

Hepatosomatic index

The hepatosomatic indices for females and males are shown in Figure 10. For females, the maximum (3.5±0.9 %) and minimum (0.7±0.2 %) values were found in summer and winter, respectively. In contrast, males showed highest HSI in spring and summer (3.0±0.9 % for both seasons), while the lowest HSI (0.8±0.2 %) was recorded in winter. HSI values of males were significantly different from those of females during all seasons ($p<0.01$).

GSI and HSI relationship

The relationship between GSI and HSI is shown in Figure 11. This relationship was weak ($r^2 = 0.32$) in females and moderate ($r^2 = 0.52$) in males. Regression coefficients (b) for female and male blue crabs were 1.4 and 1.1, respectively.

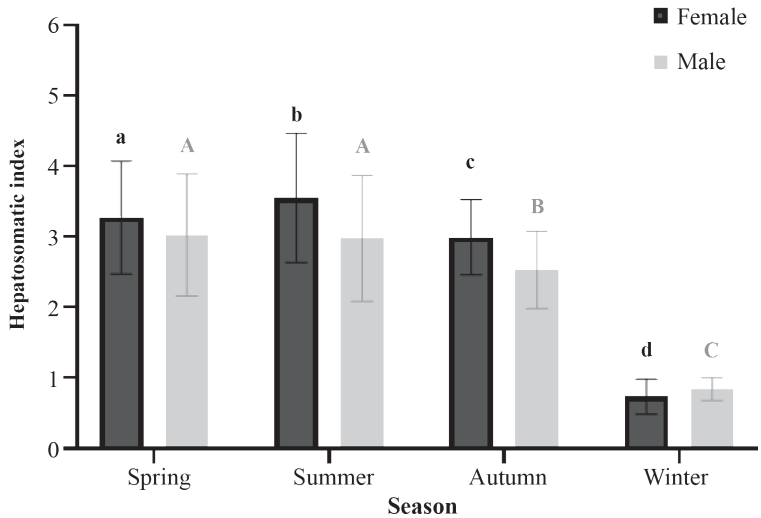

Figure 10. Seasonal variation in hepatosomatic index for male and female *Callinectes sapidus*.
Note: Different lowercase letters denote significant difference ($p<0.05$) in HSI between seasons for females; different uppercase letters show seasonal differences for males.

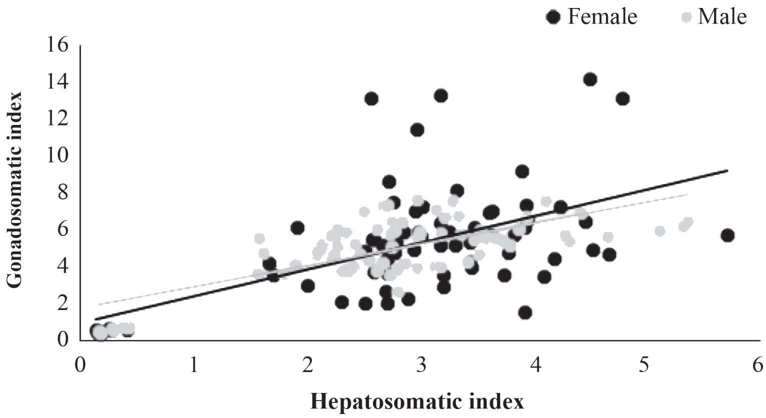

Figure 11. Relationships between hepatosomatic index and gonadosomatic index for male and female *Callinectes sapidus*.

Proximate composition of muscle

Proximate composition of the muscle tissue of *C. sapidus* specimens was evaluated as shown in Table 3. None of the measured parameters were significantly different between males and females ($p = 0.28$-0.76).

Table 3. Proximate composition of muscle of male and female *Callinectes sapidus*.

Component	Females	Males	p value
Moisture ($g{\cdot}100\ g^{-1}$)	75.14±2.22	74.38±1.01	0.56
Protein ($g{\cdot}100\ g^{-1}$)	9.38±2.79	11.51±2.14	0.76
Lipid ($g{\cdot}100\ g^{-1}$)	3.75±0.68	4.77±0.55	0.28
Carbohydrate ($g{\cdot}100\ g^{-1}$)	0.34±0.14	0.51±0.11	0.36

DISCUSSION

The blue crab *Callinectes sapidus* is one of the most economically important and commercially valuable crabs worldwide, especially in Egypt (Mehanna *et al*., 2019). The overall sex ratio of *C. sapidus* in the current study was in favor of males (1.41:1) and was in agreement with Abdel Razek *et al*. (2016) and Kampouris *et al*. (2020), who found similar sex ratios of 1.55:1 and 1.28:1, respectively. The migration of gravid females toward saline waters for spawning may be the main reason for the low abundance of females in the current study. This explanation is supported by the total disappearance of gravid female crabs in winter and the appearance of the juveniles in summer, making the variation between sexes highly significant ($p<0.001$). Sumer *et al*. (2013) attributed variation in the sex ratio to many factors such as migration patterns in the lagoon system. In contrast, females were found in higher abundance than males in other studies. Sumer *et al*. (2013) found that the sex ratio of *C. sapidus* in Turkey was in favor of females (1:0.65). Additionally, female *Charybdis natator* outnumbered males with a sex ratio of 1.1:1 in Egypt (Sallam and Gab-Alla, 2010). Akin-Oriola *et al*. (2005) reported that the mean sex ratio was also in favor of females (1.16:1) in a *C. pallidus* population in Nigeria.

Generally, males were found to be significantly heavier than females ($p<0.001$) in the present study. This is common among portunid crabs (Hosseini *et al*., 2014). Similar results were reported for the Atlantic blue crab *C. sapidus* along the southern coast of Portugal (Vasconcelos *et al*., 2019) and in Bardawil Lake, Egypt (Abdel Razek *et al*., 2016). This can be explained by the difference in reproductive effort between sexes. In most portunids, females spend a large amount of their energy on gonad development and egg production. On the other hand, males become larger, heavier and stronger in order to compete with other males and to protect them before and after copulation (Pinheiro and Fransozo, 2002).

In the current study, all of the specimens were found with a carapace width between 35.6 and 154.8 mm. The majority of crabs (69.7 %) were found in the size classes of 70-89.9 mm and 90-109.9 mm, while the 30-49.9 mm class contained the fewest crabs (1.12 %). Similar results were reported for the same species (Pereira *et al*., 2009) as well as other species such as Charybdis natator (Sallam and Gab-Alla, 2010). However, the distribution pattern was found to differ seasonally. This difference may be related to environmental factors such as temperature, depth and resource availability. Such factors influence the reproductive state, growth, age and mortality rates of crabs, which in turn affect the abundance and size distribution (Sallam and Gab-Alla, 2010; Kampouris *et al*., 2020).

Carapace width and carapace length are the most significant body dimensions used in the study of crustaceans, especially crabs (Sukumaran and Neelakantan, 1997). The relationship between carapace width and carapace length in this study indicated negative allometric growth for both sexes. The same growth pattern was observed for this species in Bardawil Lake, as reported by Abdel Razek *et al*. (2016) and Mehanna *et al*. (2019) (Table 4). On the other hand, isometric growth was observed for male and female blue swimming crab *Portunus segnis* in the Gulf of Gabes, Southeastern Tunisia (Hamida *et al*., 2019). Therefore, it may be concluded that growth of crabs in length or width may differ by genera as well as by locality.

The relationship between carapace width and body weight can give important insight about the increase in weight of a population, and this can be useful for comparative studies between populations. In the present investigation, the regression coefficients (b values) were less than 3 for both sexes, indicating negative allometric growth. Similar results were reported by Atar and Seçer (2003) and Sumer *et al*. (2013) for the same species in Beymelek Lagoon, Turkey. Abdel Razek *et al*. (2016) also revealed negative allometric growth for both sexes of *C. sapidus*. Meanwhile, Mehanna *et al.* (2019) and Kampouris *et al*. (2020) found negative allometry for females and positive allometric growth in male *C. sapidus* populations in Egypt and Greece, respectively.

Table 4. Growth patterns of crab species from various localities.

Crab species	CW-CL		CW-BW		CL-BW		Country	Reference
	F	M	F	M	F	M		
Callinectes sapidus			-ve	-ve	-ve	-ve	Turkey	Atar and Seçer (2003)
Callinectes sapidus			-ve	-ve			Turkey	Sumer *et al*. (2013)
Callinectes sapidus	-ve	-ve	-ve	-ve	-ve	+ve	Egypt	Abdel Razek *et al*. (2016)
Portunus pelagicus					+ve	+ve	Indonesia	Rohmayani *et al*. (2018)
Portunus segnis	Iso	Iso	+ve	-ve			Tunisia	Hamida *et al*. (2019)
Callinectes sapidus	-ve	-ve	-ve	+ve	-ve	+ve	Egypt	Mehanna *et al*. (2019)
Callinectes sapidus			-ve	+ve	-ve	+ve	Greece	Kampouris *et a*l. (2020)
Callinectes sapidus	-ve	-ve	-ve	-ve	-ve	Iso	Egypt	The present study

Note: CW = carapace width; CL = carapace length; BW = body weight; -ve = negative allometry; +ve = positive allometry; Iso = isometric growth

The carapace length-weight relationship is very important and suitable for assessing populations. The regression coefficient for males in the present study showed isometric growth, however females exhibited a negative growth pattern with very strong correlation between body weight and carapace length (r>0.9). This result was in agreement with findings of Abdel Razek *et al*. (2016) and Mehanna *et al*. (2019) for the same species. On the other hand, male and female crabs both showed negative allometry in a study by Atar and Seçer (2003) on *C. sapidus* in Turkey. However, both sexes of *Portunus pelagicus* exhibited positive allometric growth in a population studied by Rohmayani *et al*. (2018) in Indonesia. Therefore, it may be suggested that the difference in growth pattern among crabs can be influenced by many factors such as locality, environmental conditions, time, sex, maturity stage and age (Bagenal and Tesch, 1978; Pauly, 1984; Noori *et al*., 2015)

Condition factor is a useful index for indicating the condition, heaviness or well-being of marine creatures from similar or contrasting habitats. It can be also used as an indicator to evaluate the condition of the aquatic ecosystem where the organisms live (Anene, 2005). Bagenal and Tesch (1978) stated that the value of K is based on the hypothesis that heavier individuals of a given length are in a preferable physiological condition. In the present study, the condition factor of female blue crabs was always significantly higher than males. This may be explained by higher productivity in females, as their gonads are heavier than males. This result was similar to those of Araújo and Lira (2012), who demonstrated higher condition factor in female *Callinectes danae* than in males from the Santa Cruz Channel, Brazil. In contrast, K values of blue crabs *C. sapidus* in Beymelek Lagoon, Turkey, were higher in males than females (Atar and Seçer, 2003; Sumer *et al*., 2013). Hamida *et al*. (2019) also reported that mean K of the blue swimming crab *Portunus segnis* in the Gulf of Gabes, Tunisia, differed significantly between the sexes, being higher in males. The condition factor of male *P. pelagicus* was also higher than that of females in a population from Java Sea, Indonesia (Rohmayani *et al*., 2018). In the current study, K values were highest for both sexes during autumn. As its value was greater than one, it indicated good health for both sexes during this season (Moslen and Miebaka, 2018). Various factors such as fatness, gonad development, environmental conditions, food supply and degree of parasitization can affect the state of crabs and influence the condition factor (Le Cren, 1951). Generally, the condition factor of *C. sapidus* in the current study declined as size increased. This means that K value was negatively correlated with the crab body size. Zhang *et al*. (2017) reported a similar result for the Japanese mitten crab *Eriocheir japonica* in the Banda River, eastern Japan.

In the present study, GSI reached its peak during summer for both sexes, while male GSI continued its peak until autumn. Then, GSI of both sexes declined and reached their minimum values in winter. These results suggest that this population of *C. sapidus* may spawn in summer, which agrees with the July-September spawning period (late summer to early autumn) reported by Sumer *et al*. (2013) for a population in Turkey. In addition, HSI was measured, as the hepatopancreas is an important organ having antioxidant and antiproliferative activities (Zakzok *et al*., 2021). The results show that the highest values of HSI correspond to summer for females, and spring and summer for males. The lowest values of HSI were recorded during winter for both sexes.

Biochemical composition of muscle can differ from one species to another and from one individual to another. This difference can be related to season, age, environmental conditions and migratory swimming, sex and sexual changes in connection with spawning (Tzikas *et al*., 2007; Kuley *et al*., 2008; Ayas, 2016). In the current study, the biochemical composition of muscle of both sexes was the same (p>0.05). Kuley *et al*. (2008) reported similar results for the same species in Turkey. In contrast, mature female *P. pelagicus* possessed higher protein and lower water and lipid contents than males (Ayas and Özoğul, 2011). Ayas (2016) revealed that both sexes of *C. sapidus* had similar levels of protein, fat and moisture. Küçükgülmez *et al*. (2006) studied the nutritional composition of *C. sapidus* (combining sexes) in Turkey and reported protein levels (18.81±0.13 $g{\cdot}100\ g^{-1}$) that were higher than our results.

CONCLUSION

The current study showed that male blue crabs sampled from Manzala Lake, Egypt, tended to outnumber females, with a sex ratio of 1.41:1 (M:F). Both sexes exhibited negative allometric growth, while isometric growth was also shown for males, but only in the CL-BW relationship. The GSI of males and females suggested that summer may be the spawning season of this *Callinectes sapidus* population. No significant differences in biochemical composition of muscle were found between sexes. The findings of the present study can serve as a baseline for future monitoring of *C. sapidus* stocks in Manzala Lake, and for comparison with studies in different localities. Further investigations can be conducted to benefit the development of crab aquaculture.

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