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Food and feeding habits of the blue crab,*Callinectes sapidus* (Crustacea: Decapoda: Portunidae) with special reference to the gastric mill structure

Rady, A.[1]; Sallam, W. S.[2]; Abdou, N. E. I.[1] and El-Sayed, A. A. M.[3]

1-Biology and Geology Dept., Faculty of Education, Ain Shams University, Cairo, Egypt.
2-Marine Science Dept., Faculty of Science, Suez Canal University, Ismailia, Egypt.
3-Zoology Dept., Faculty of Science, Al-Azhar University, Cairo, Egypt

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ABSTRACT

Stomach contents of 161 specimens of *Callinectes sapidus*(Crustacea: Decapoda: Portunidae)from Bardawil Lagoon were examined from November 2016 to July 2017. The percentage point (% P) and percentage frequency of occurrence (% F) methods were used for stomach contents analysis. Out of the 161 individuals 75 (46.58 %) had empty stomach. Mollusca, Crustacea and Pisces dominated the diet of this species. According to points method Mollusca, Crustacea and Pisces scored 44.83%, 18.1% and 16.24% points in malesand 47.2%, 21.62% and 11.03% points in females, respectively. Consumed tissues of other benthic invertebrates were also present in verylow ratios, while algal fragments were occurred in low quantitiesin few stomachs. Sediments were also detected in considerable ratios. Results of the present study suggest that the blue crab *C. sapidus*is a carnivore. The remarkable seasonal fluctuations in the diet composition and stomach fullness of this species during the present studywere detected For understanding the mechanism of feeding, gastric mill structure was morphologically investigated and all its seven articulated ossicles were examined and photographically illustrated.

INTRODUCTION

Knowledge of the dietary habits of a species is essential for understanding its nutritional requirements and its interactions with other groups of animals (Santos and Borges, 2001). This information is also useful for its successful culture. Crabs occupy many different niches and inhabit many different habitats in a variety of geographical areas, and this is reflected in the variety of food consumed by them (Bryceson and Massinga, 2002). Primitively, crabs were probably opportunistic omnivores with a preference for animal food and with predatory tendencies (Warner, 1977). This feeding pattern is still followed by the majority of species and extreme specialization is relatively rare. However, most crab species retain the ability to deal with a variety of foods and the only specialization shown is by tendencies towards particular types of diet such as the grapsids which tend to be mainly herbivores, and portunids which are mainly carnivores (Bryceson and Massinga, 2002).

The energetics of individual organisms play an important role in ecological processes, determining where organisms can survive, the allocation of time to different activities, the rate at which organisms growand the timing of reproductive

performance (Mendo *et al*., 2016). Some store energy used in reproduction prior to the start of the reproductive process, termed capital breeders, while others finance reproduction using energy gained throughout the reproductive process, termed income breeders (Griffen, 2018).

The food and feeding habits of different crabs were treated in several studies. Jewett andFeder (1982) analyzed the food and feeding habits of the king crab, *Paralithodes camtschaticus* near Kodiak Island, Alaska. Moreoverfood habit ofcrab, *Chionoecetes bairdi*, was studied by Jewett and Feder (1983) near Kodiak Island, Alaska and of *C.opilio* examined by Wieczorekand and Hooper (1995) in Bonne Bay, Newfoundland. For portunids, Choy (1986) described the natural diet and feeding habits of two species of *Liocarcinus*, while foods of *Cancer* spp. and *Ovalipes ocellatus* were treated by Stehlik (1993). The natural diet and feeding habits of *Thalamita crenata* were investigated by Cannicci *et al*. (1996). On the other hand, the feeding habit of the blue crab, *Callinectes* spp., have been studied by several workers, such as Paul (1981) from Huizache-Caimanero lagoon system, Mexico, Laughlin (1982) from the Apalachicola estuary, Florida, Stoner and Buchanan (1990) from Laguna Joyuda, Puerto RicoandRosas *et al*. (1994) from a sub-tropical coastal lagoon of the Gulf of Mexico.

One of the essential organs for the nutrimental ingestion is the stomach which consists of cardiac, pyloric and gastric mill parts. The gastric mill possesses two types of teeth named medial and lateral teeth, and has been investigated in the crayfish, crabs, lobsters and shrimps (Nakamura and Takemoto, 1986). The secondary processing and the real trituration of the food, after manipulation of the mouthparts, occur by the action of the gastric mill (Ceccaldi, 2006). This structure varies between species, reaching its highest development (greater number of ossicles and calcification) in Brachyuran crabs (Icely and Nott, 1992), in which the gastric mill was described as a 'three-branched claw through which the food must pass in order to reach the pyloric region' (Ceccaldi, 2006). This 'claw' is made up of a pair of lateral teeth protruding from the side walls of the heart chamber, a medium tooth extending from the dorsal wall of the chamber and a number of supportive ossicles (Allardyce and Linton, 2010). On the other hand, in other groups of decapods the stomach can be very simple with just a few calcified ossicles or total absence of them (Icely and Nott, 1992). However, several studies suggest that the anatomy of the gastric mill varies according to the diet of species in different groups of decapods (Kunze and Anderson, 1979; Icely and Nott, 1992; Allardyce and Linton, 2010).

Contents in the cardiac stomach are usually identifiable where the digestion is less advanced (Ceccaldi, 2006). The analysis of stomach contents usually includes a quantitative and qualitative determination of the kinds and amounts of food consumed. There are several methods of analyzing and presenting the data of stomach contents. The best method of diet analysis and the relative importance of food items in Portunid crabs have been established by Williams (1981), who compared a sample size of 30 gastric mills and concluded that the sample size is appropriate in order to determine the description of a natural diet of these crabs. He chose the percentage occurrence method and the percentage points method as quantitative scoring methods for contents of gastric mills in these crabs. In the percentage occurrence method, the number of crab in which each food item occurs is recorded and expressed as a percentage of total number of crab examined. In the percentage points method, the food items in each stomach are allotted points on the basis of their quantity as judge by eye or rough counts.

For several years, Bardawil Lagoon has been an important fishing area for crabs in Egypt. Despite its importance, there is no information on the diet and preferred food items of its brachyuran inhabitants. The present study was undertaken to investigate the food and feeding habit of *C. sapidus* inhabiting Bardawil Lagoon to understand feeding requirements of this species which are crucial for its potential farming in Egypt.

MATERIALS AND METHODS

Study area:

Bardawil Lagoon is a hyper-saline shallow and oligotrophic coastal lake in Egypt, located at northern Sinai along the Mediterranean Sea coast (Touliabah *et al*., 2002). It is important source of commercially important fishes and invertebrates, and in particular of decapod crustacean fisheries and aquaculture (Mehanna, 2005). The bottom of the this lagoon is mainly muddy or sandy and is the habitat of a wide range of economically important taxa such as clams of the family Veneridae (Ibrahim and Abu El-Regal, 2014) and decapod crustaceans (Ibrahim and Amin, 2013).

Water exchange in the lagoon is regulated by the Mediterranean Sea's tides and has a mean tidal excursion of 25 cm during neap tides and about 35 cm during spring tides, while wind is responsible for internal circulation. Water temperature of the lagoon is low in winter and high in summer (17.3-20.2ºC) and (27.2-30.5ºC) respectively; salinity ranges from the lowest value of 38.3% in winter and the highest of 63% in summer (Emam, 2010).

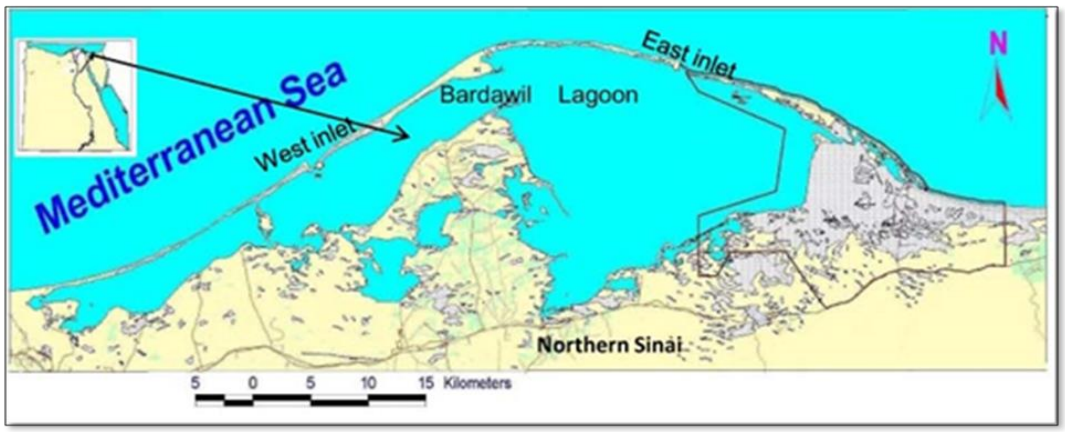

Fig.1. A Map shows location of Bardawil Lagoon at northern Sinai coast, Egypt.

Crab collection and stomach content analyses:

A total of 161 specimens of *Callinectes sapidus* were seasonally obtained from the commercial catch of the landing site (El-Telul) on Bardawil Lagoon during the period from November 2016 to July 2017.

At the laboratory, the obtained specimens were cleaned from adhering sediments and attached animals and plants, and then sexually separated. The external examination showed that, the majority of those specimens were sexually maturing. The stomach of this species lies underneath the gastric region of the hard carapace. To analyses its contents, the carapace was slit open and the stomach removed, it was opened and examined under a binocular microscope (Cambridge Model Galen TM III). The contents were relatively finely masticated, nevertheless, the different prey found were identified to the lowest taxonomic level possible.

Analysis of stomach contents:

The relative degree of fullness of the stomach was determined immediately after removal from the crabs and was assessed visually by the method of Wear and Haddon (1987). Each stomach was assigned to 1 of 6 ordered classes as follows: Class 5, 100% (100-90% full); Class 4, 75% (90-65% full); Class 3, 50% (65-35% full); Class 2, 25% (35-5% full); Class 1, <5% full or only a trace of food; and Class 0, empty stomachs. Visual assessment was made possible by the fact that the stomach of *C. sapidus* is a thin-walled translucent organ.

Observations on the contents of stomachs were made with a binocular dissecting microscope with the contents spread on 40 mm diameter Petri dishes. Stomach contents were identified and separated into major taxa.

The relative contribution of each prey category to the total volume of material in each stomach was subjectively assessed as follows: a category representing 90-100% of stomach contents was awarded 100 points; 65-90% = 75 points; 35-65% = 50 points; 5-35% = 25 points; 5% or less = 2.5 points; empty = 0 points. The number of points that each prey category received was then weighted by multiplying them by a value dependent on the degree of stomach fullness: full = 1; 75% = 0.75; 50% = 0.5; 25% = 0.25; trace = 0.02 (Wear and Haddon, 1987). The maximum weighed points possible for a single category in a single foregut are 100 (100 x 1), and the minimum weighed points possible are 0.05 (2.5 x 0.02).

Data analysis:

Both the percentage point method and the percentagefrequency of occurrence for each food item were calculated as follows (Williams, 1981).

Percentage points for i^{th} prey$= \sum_{j=1}^{n} aij \times 100/A$

Percentage occurrence for i^{th} prey = b_i X 100 / n

Where a_{ij} is the number of points of food taxa i in the stomach of j crabs; n is the number of crabs in the sample excluding crabs with empty stomach; A= total number of points for all crabs and all food categories in the sample; b_i is the number of crabs whose stomach contained food category i.

Statistical analyses for obtained data were carried out using ANOVA and Pairwise Multiple Comparison Procedures (Holm-Sidak method).

Gastric mill examination:

The gastric mills of 8 individuals representing different sizes were separated from the stomach tissues, washed with tap water, and examined. Each of the dorsal, lateral and ventral surfaces of the gastric mills and the lateral teeth as well as processes were counted and photographed using a binocular microscope Model Optika SZM-1 fitted by a Micro-Cam (PHD-5 MP). All used terminology were taken according to Warner (1977) and Creswell and Marsden (1990).

RESULTS

Stomach fullness:

A total of 161 stomachs (100 males and 61 females) of *C. sapidus* were examined and the obtained results showed that the stomach fullness was varied between examined individuals. The present results indicated that there are 5 specimens have full stomachs (class 5), 13 with 3/4 full (class 4), 35 have1/2 full (class 3), 19 with 1/4 full (class 2) and 14 with traces (class 1); while 75 specimens were recorded with empty stomachs represent 46.58 % of all examined individuals and belong to class 0.

Figure (2) shows the seasonal variations in the different categories of stomach fullness of males and females *C. sapidus.* The percentages of individuals have > 2.5

points in fullness (i.e. 1/4, 1/2, 3/4 andfull stomachs) reached the highest values during spring 2017 for both sexes. In contrast, males and females with 2.5 points were abundant during summer 2017.

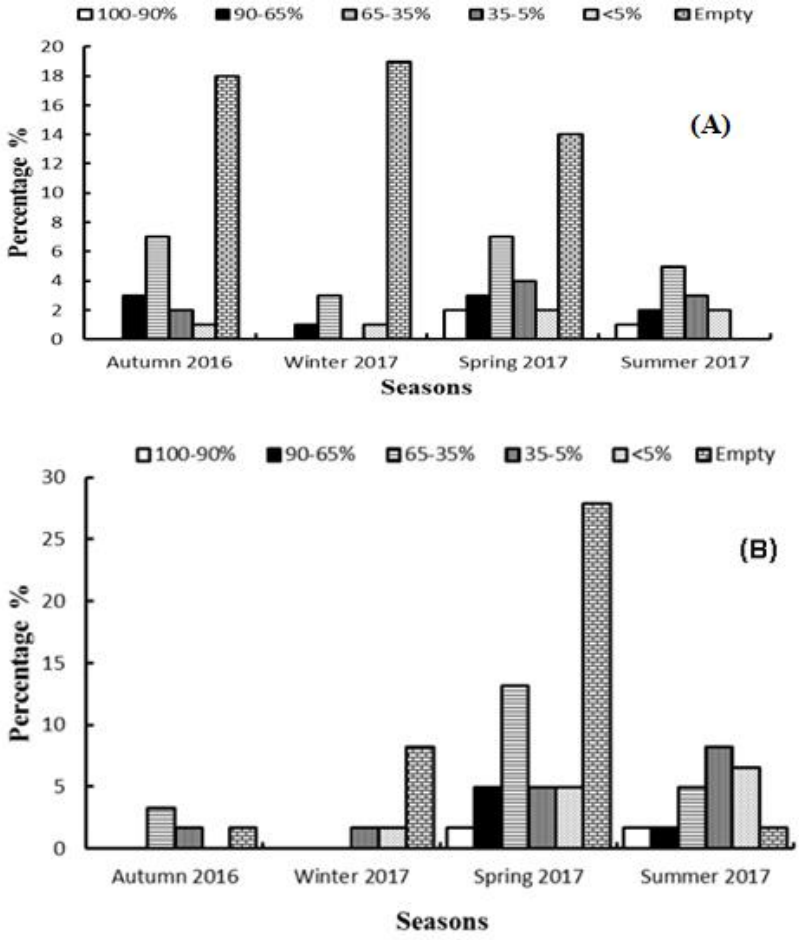

Fig. 2. Seasonal variations of stomach fullness of *C. sapidus* in Bardawil Lagoon during the study period (A= Males and B= Females).

Diet composition:

The results of percentage points and percentage frequency of occurrence of the preys in the stomachs of the two sexes, males and females, of *C. sapidus* are shown in Tables (1 and 2). Mollusca was found to be the most commonly consumed food items for both sexes with a percentage of 44.83% and 47.20% for males and females, respectively (Table 1 and Figure 3). Crustaceans ranked the second highest food category with a percentage of 18.10% in males and 21.62% in female's stomachs. Pisces considered the third highest food category with a score of 16.24% and 11.03% in males and females, respectively. Tissues remains and other consumed animals were represented with little ratios, while plant materials were the least common food item consumed by *C. sapidus*, and varied between 2.2% in males and 1.31% in females. In spite of sediments not consider food items, but were represented with considerable ratios averaged 11.50% and 12.03% in males and females, respectively.

Table 1. Percentage points (%P) of majordiet categories in the stomachs of *C. sapidus* in Bardawil Lagoon.

Diet components / Seasons &sex		№.	Percentage points (%P)						
			Mollusca	**Crustacea**	**Pisces**	**Tissue remains**	**Others**	**Plants**	**Sediments**
Autumn 2016	♂	**13**	**47.40**	**7.32**	**34.0**	**4.68**	**1.70**	**0.50**	**4.40**
	♀	**3**	**55.45**	**19.73**	**6.12**	**2.28**	**1.50**	**0.20**	**14.72**
Winter 2017	♂	**5**	**36.43**	**17.71**	**14.14**	**4.70**	**1.30**	**4.29**	**21.43**
	♀	**2**	**42.7**	**21.32**	**10.48**	**5.17**	**2.28**	**1.30**	**16.75**
Spring 2017	♂	**18**	**49.43**	**19.54**	**9.63**	**6.71**	**3.85**	**3.13**	**7.71**
	♀	**18**	**32.24**	**28.59**	**23.66**	**7.88**	**2.17**	**1.52**	**3.94**
Summer 2017	♂	**13**	**46.08**	**27.65**	**7.26**	**3.13**	**2.49**	**0.87**	**12.52**
	♀	**14**	**58.42**	**16.83**	**3.88**	**5.40**	**0.60**	**2.16**	**12.71**
Mean	♂	**49**	**44.83**	**18.1**	**16.24**	**4.80**	**2.33**	**2.20**	**11.5**
	♀	**37**	**47.20**	**21.62**	**11.03**	**5.18**	**1.63**	**1.31**	**12.03**

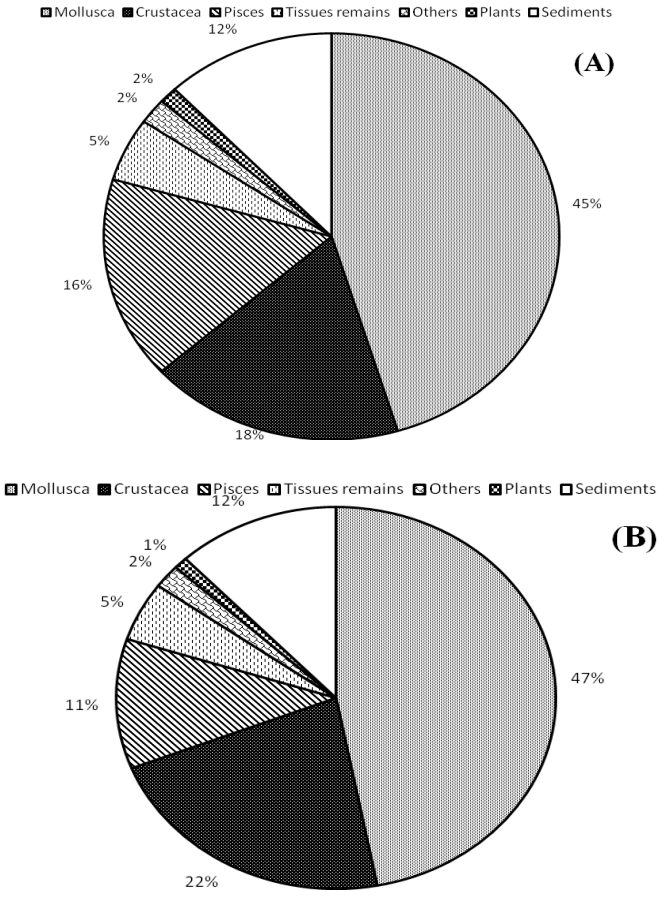

Fig. 3. Diet composition of *C. sapidus* from Bardawil Lagoon during the present study (A= Males and B= Females).

Data in Table (2) shows the percentage frequency of occurrence of the different food items consumed by both sexes of *C. sapidus*. Mollusca were also the most frequently occurring food item, being 93.4% in males and 94.1% in females. Crustacea came also in the second importance and were higher (90.5%) in female stomachs than males (70.2%). Pisces and tissues remains came in the third and fourth orders respectively and were represented with considerable high values while plants were recorded at considerable frequencies varied from 16.3% in males to 25.4% in females.

Table 2. Percentage frequency of occurrence (%F) of major diet types in the stomachs of *C. sapidus* in Bardawil lagoon.

Diet components / Seasons &sex		№.	Percentage frequency of occurrence (%F)						
			Mollusca	Crustacea	Pisces	Tissue remains	Others	Plants	Sediments
Autumn 2016	♂	13	92.3	46.2	61.5	38.5	15.4	7.7	53.8
	♀	3	100	100	66.7	100	33.3	33.3	100
Winter 2017	♂	5	100	80	80	60	20	20	60
	♀	2	100	100	100	100	50	50	100
Spring 2017	♂	18	88.9	77.8	61.1	66.7	27.8	22.2	72.2
	♀	18	83.3	83.3	77.8	61.1	16.7	11.1	44.4
Summer 2017	♂	13	92.3	76.9	69.2	53.8	23	15.4	61.5
	♀	14	92.9	78.6	28.6	42.9	14.3	7.1	57.1
Mean	♂	49	93.4	70.2	67.9	54.8	21.55	16.3	61.9
	♀	37	94.1	90.5	68.3	76	28.6	25.4	75.4

The food consumed by *C. sapidus* was fragmented due to mastication; the remains of animals with hard parts were readily identified. The presence of shell and opercula help in the identification of some molluscan species (gastropods, bivalves). Crustacea (shrimps and crabs) were identified by the carapace remains and fragments of certain particular appendages. Pisces were recognized from scales, soft rays and bones. Annelida (polychaetes) were recognized from jaws, setae, and intact portions of the head and body. Echinoderms were identified from ossicles and body wall. Algae were recognized from small pieces. All unrecognizable tissue and animal fragments are assigned to a category entitled "tissues remains."

Occurrence of the different diet components:

Tables 1 and 2 show that Mollusca was abundant in all seasons for both males and females. The highest values was recorded during spring and the minimum was observed in winter for males while the maximum points recorded was occurred during summer and the lowest value was in spring for females. Crustacea occurred at a high abundance during summer and spring for males and females, respectively. It was less abundant during autumn in males and summer in females. Males had the highest abundance of Pisces in their stomachs during autumn and the minimum value

was observed during summer. Females had the highest abundance of pisces items during spring and the lowest was recorded during summer.

The statistical analyses using ANOVA showed significant differences between different categories of food items (F= 40.658, P <0.001), but no significant differences were detected between seasons (F= 8.064, P >0.001). All Pairwise Multiple Comparison Procedures (Holm-Sidak method) showed that, there are significant differences between Mollusca and all other food items, and between crustaceans and both of plants, other animals and tissue remains only, as well as between pisces and both plants and others (Overall significance level = 0.05).

Gastric mill structure:

C. sapidus has relatively large stomach, distinctly divided into an anterior large portion called "cardiac stomach" and a small posterior one called "pyloric stomach" (Figure 4). No structural differences were noticed between the two sexes of this species.

Cardiac stomach:

The cardiac stomach (Figure 4) is a large, spherical, dorsoventrally flattened sac-like structure. Certain parts of the membranous wall of the stomach are thick and calcified, forming hard structures on dorsal, lateral and postero-lateral sides of cardiac stomach called ossicles or gastric mills. Fine examination for these ossicles indicating that there are 7 types of ossicles can recognize (Figure 4), they are arranged as following:

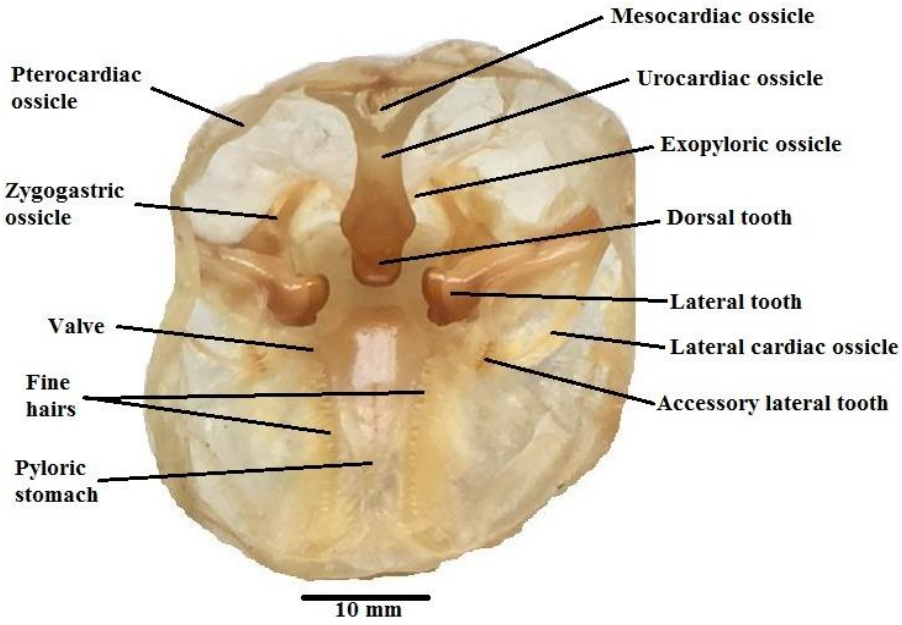

Fig. 4: Sagittal view shows the cardiac and pyloric stomachs of *C. sapidus* with different ossicles of the gastric mill.

Urocardiac ossicle:

This is a single massive ossicle, extends on the mid dorsal wall of the cardiac stomach and bears only a single dorso-ventral flattened tooth lies on the posterior end. No ridges of sharp processes were detected.

Mesocardiac ossicle:

This is a bifurcate- like structure ossicle, beings fragile without teeth or ridges. It lies at the anterior limit of the urocardiac ossicle articulates between both of urocardiac and pterocardiac ossicles.

Pterocardiac ossicles:

These ossicles are fine; consist of left and right transverse ossicles, articulate with both of the mesocardiac and zygocradiac ossciles.

Zygogastric ossicles:

These ossicles lie on the dorso-lateral gastric wall, and are articulating with both pterocardiac anteriorly and expyloric ossicle posteriorly. The posterior portion of each zygocardiac ossicle is massive, nearly triangular in shape, forming a lateral tooth, equipped with well-developed transverse ridges (12- 16) posteriorly, two or three of them are enlarged and forming blunt teeth or molar-like structures on the lower anterior end and it has two processes at the upper end articulated with each other (Figure 5).

Propyrolic ossicle:

It is a fine transverse structure that lies posteriorly between the left and right exopyloric ossicles.

Exopyloric ossicles:

It consists of left and right ossicles, articulating with the zygocardiac ossicle and propyloric ossicles.

Lateral cardiac ossicles:

These ossicles are a paired structure lie on the postero-lateral side of the stomach facing the dorsal tooth of urocardiac ossicle. They articulate with the exopyloric ossicle dorsally and attached to the wall of the cardiac stomach posteriorly. A pair of prominent processes appear attached to the lateral cardiac ossicle anteriorly, each carry 5 unequal spinules, and lie in front of the lateral tooth, are called accessory ossicles. Setae are observed on the anterior surface.

The beginning of lateral teeth is exactly facing the beginning of first ridge on the urocardiac ossicle. Also ridges were noticed on the posterior portion of the lateral tooth, at the articulation with exopyloric ossicles (Figure 5).

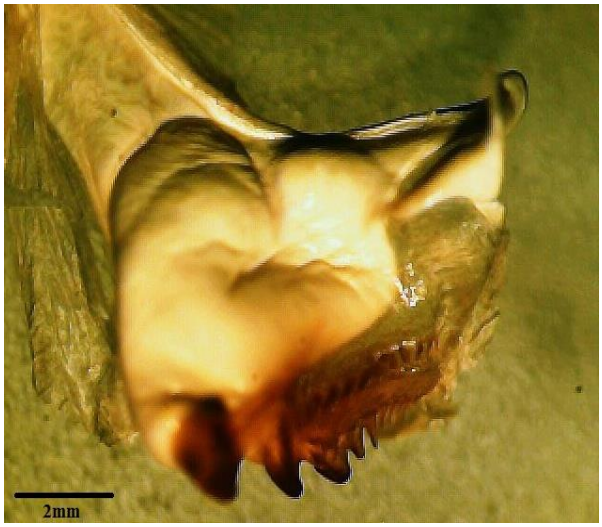

Fig. 5. Internal view of the left lateral tooth of *C. sapidus*.

The pyloric stomach:

The pyloric region of the stomach is separated from the cardiac region by a distinct valve. It isremarkably narrower than the cardiac stomach. Its latero-ventral part and the cuticular lining is thrown into longitudinal ridges, equipped with more than 4 longitudinal rows of setae or fine hairs (Figure 6).

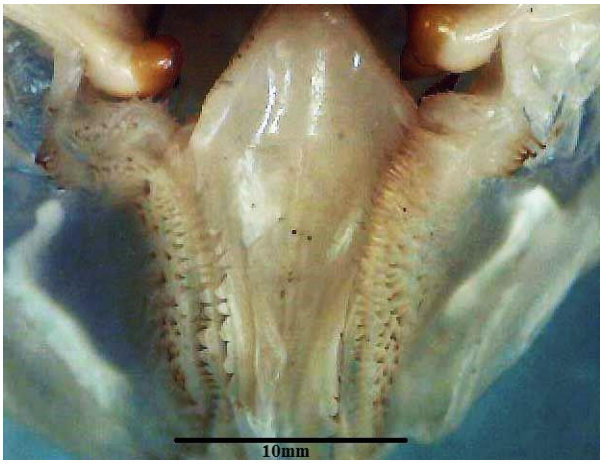

Fig. 6. Top view for internal structure of pyloric stomach of *C. sapidus*.

DISCUSSION

Stomach fullness:

Results of stomach contents of *Callinectes sapidus* exhibited the general food habits of this species. Approximately 60% of the individuals captured have stomachs with 1/2 full and 1/4 full of food (class 3 and 2). The differences of stomach fullness between different seasons may be related to the energy required for development and reproductive cycles, where the highest spawning period of *C. sapidus* extends through spring and summer in Bardawil Lagoon. The high percentage of stomach fullness was recorded during spring and summer, therefore, these results are in consistent with highest spawningof this species during spring and summer seasons. Similarly,the results obtained by Griffen (2018) provided clear evidence that some brachyuran crabs, *Callinectes maenas* and *C. sapidus* from U.S.A, use an income breeding strategy. The present data showed asimilarity with those obtained from the analysis of the natural diets of *Callinectes ornatus* in Ubatuba Bay, São Paulo, Brazil (Mantelatto and Christofoletti, 2001).

Diet composition:

Stomach contents of portunid crabs were generally consisting of animal foods with plants occurring rarely (Wu and Shin, 1998). The diet of *C. sapidus* was found to be similar in several respects to the diet of other portunid crabs. *C. sapidus* of Bardawil Lagoon is predominantly carnivorous, feeds mainly on molluscs, crustaceans and Pisces. Similar results were reported by Al-Behbehani (2007) where molluscs and crustaceans were the dominant food items in the stomachs of *Portunus pelagicus* from Kuwait waters, and by Chande and Mgaya (2004) for the same species fromKunduchi (Tanzania). In the present study, the blue crab *C. sapidus* fed on benthic invertebrates, which were either sessile or slow moving, as also reported by Patel *et al*. (1979) in India, Williams (1982) in Moreton Bay, and Sukumaran and Neelakantan (1997) in southwest India. The quantitative analysis of the stomach contents of *C. sapidus* in Bardawil Lagoon revealed that Mollusca constituted over 44% for males and 47% for females of the diet composition and were mainly represented by bivalves and gastropods, followed by Crustacea and Pisces. In contrast, the diet of both*Portunus sanguinolentus* and *P. pelagicus*is consisted mainly of crustaceans, fish remains and molluscs respectively along the southwest coast of India (Sukumaran and Neelakantan, 1997). The preference for animal matter was also in agreement with previous works carried out by Batoy *et al*. (1988); De Lestang *et al*. (2000) and Chande and Mgaya(2004).

Although *C. sapidus* feeds on macroscopic food, identification of the various food items as well as a reliable estimate of their (relative) quantity, are both very difficult (Icely and Nott, 1992). In addition Williams (1981) stated that, the portunid crabs use their mouthparts to chop the food into small pieces and then the gastric mill ossicles further reduce the food to unidentifiable fragments. However, he mentioned that, the majority of researchers use the foregut contents to study the quantity and nature of the different food items that the crab has consumed.

The presence of sediments among stomach contents of the examined specimens was common. Sediments may enter accidentally with food items as a result of the benthicnature of *C. sapidus*. In addition, Mantelatto and Fransozo (1999) proposed that the frequent occurrence of calcareous sediment items in the diet may reflect the utilization of calcium in the exoskeleton due to frequent molting process occurring in *C. sapidus* from the Ubatuba region, São Paulo, Brazil.

The occurrence of sediments among food items of brachyurans has been reported in several brachyurans by by Warner (1997) and El-Sayed (2004).

Unidentified plants and algae appeared frequently in the diet of *C. sapidus*. These materials could be consumed by individuals but in small amounts as reported in *Liocarcinus puber* and *L. holsatus* by Choy (1986) in Wales, United Kingdom and Branco and Verani (1997) in *Callinectes danae*in Santa Catarina, Brazil. McClintock *et al*. (1991) stated that, young *C. sapidus* individuals are able to process plant materials which use vegetated areas as refuge and may have limited abilities to capture and consume live an imalprey.

Occurrence of the different diet components:

The frequency occurrence method demonstrates the general food habit for the examined specimens during the present study. However, this method overestimates the small-sized items over other larger sized ones (Mantelatto and Christofoletti, 2001). On the other hand, the percentage point method was more convenient, therefore its values were used for statistically analyses and calculations. The congruence of results from the two methods of scoring may be attributed to the fact that those food items which are ingested most often by crabs are also eaten in the greatest quantities.

During the present study, there were differences observed in the items of the food consumed by males and females. This is in agreement with the previous studies reported earlier by Williams (1981), Jewett and Feder (1982), Sumpton and Smith (1990) and Wieczorek and Hooper (1995). The present results reported that there remarkable seasonal variations in feeding of this species. Feeding increases during spring and decreases in winter which agrees with that reported by Jewett and Feder (1982) on the king crab, *Paralithodes camtschaticus* near Kodiak Island, the south coast of Alaska, U.S.

Thus, the present study, as earlier related studies, suggests that, despite the diversity in crab diets and feeding habits, *C. sapidus* of Bardawil Lagoon is an opportunistic carnivore with a preference for molluscs, crustaceans and pisces items.

Gastric mill structure:

The stomach of decapods is a very complicated masticatory (gastric mill), sorting and filtering structures, whose morphology varies with the type of food eaten (Powell, 1974). Amongst decapods, the most complex gastric mills are found in Brachyura and Anomura (Zainal, 2013). The structure of *C. sapidus* gastric mill is very complicated consisting of 7 articulated ossicles. The main function of these ossicles is collectively concerned with chewing, grinding and trituration of consumed food as previously reported for different crabs (Warner, 1977; Holdish and Reeve,

1988; El-Sayed *et al*., 1998). However, there is a specific specialization in the function of each ossicle alone. The present results indicated that, the pterocardiac, mesocardiac, propyloric, exopyloric and lateral cardiac ossicles are simple, without teeth, denticles, or ridges and are used only for the articulation between two massive and well modified ossicles and gastric muscles. However, the urocardiac, and zygocardiac ossicles are strong and have well developed teeth and ridges. The lateral tooth has, in addition to strong accessory spines, many ridges and palps, provided with various hairs either simple or with associated setules. Overall, the ossicles of this species follow the complex system as proposed by Brosing (2010). Apparently, this structure enables *C. sapidus* to deal with different types of food. This structure is in full agreement with that mentionedon several true crabs by Warner (1977); Creswell and Marsden (1990) and El-Sayed *et al*. (1998).

The morphology of the gastric mill confirms the previous result that *C. sapidus* is a carnivore. The strongly developed urocardiac and zygocardiac ossicles with variable sided ridges are similar to those found in *Cancer novaezelandiae* described by Creswell and Marsden (1990). The lateral tooth has heavily dentate ridges which interlock with those on the dorsal tooth. In addition, a number of curved spines that meet together over the dorsal tooth are visible on the lateral tooth which possibly could be used for keeping food in place. The accessory lateral tooth probably helps to gather material between the lateral teeth prior to chewing. The chewing mechanism was previously described in crabs (Nakamura and Takemoto, 1986; Creswell and Marsden, 1990). It involves the contraction and subsequent relaxation of the anterior and posterior gastric muscles (extrinsic muscles) as well as the intrinsic gastric muscles and by elasticity of the gastric cuticle as well demonstrated by Nakamura and Takemoto (1986). This mechanism leads to elongate the cardiac stomach, moving the dorsal tooth downwards and forwards in an arc between the lateral teeth. This helps grinding and crushing any food between them, while food moves within stomach from place to place with the help of intrinsic muscle contraction and relaxation as well described by Nakamura and Takemoto (1986).

Despite the information given herein, the biology of food and feeding of *C. sapidus* in Bardawil Lagoon still requires further investigation using a large number of specimens, particularly females, smaller individuals of both sexes and juveniles. This investigation is essential for the evaluation of the impact of this carnivorous species on the structure of the macrofauna of the lagoon.

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ARABIC SUMMARY

طبيعة الغذاء والتغذي فى سرطان البحر الأزرق *Callinectes sapidus* (القشريات : عشرية الأرجل : السرطانات السبّاحة) مع الإشارة إلى بنية تركيب طاحنة المعدة

أحمد راضى[1]، وفاء سعيد سلام[2]، ناهد السيد عبده [1]، عواد عبده محمد السيد[3]

1- قسم العلوم البيولوجية و الجيولوجية، كلية التربية، جامعة عين شمس، القاهرة، مصر،
2- قسم علوم البحار، كلية العلوم، جامعة قناة السويس، الإسماعلية، مصر،
3- قسم علم الحيوان، كلية العلوم، جامعة الأزهر، القاهرة، مصر.

تم خلال هذه الدراسة فحص محتويات المعدة (الجزء الفؤادي) لعدد 161 عينة من *Callinectes sapidus* (القشريات : عشرية الأرجل:Portunidae) جمّعت موسميا من بحيرة البردويل من نوفمبر 2016 (موسم الخريف) إلى يوليو(موسم الصيف) 2017. ولقد تم تقدير نسب المكونات الغذائية باستخدام طريقتى نسب النقاط المئوية (P%) و نسب التكرار المئوي لكل عنصر غذائي (F%) لتحليل المحتوي المعدي للجزء الفؤادي لجميع العينات التي تم تجميعها. كما تم تقدير نسب امتلاء المعدة بالعناصر الغذائية للعينات المجمعة واسفرت النتائج عن تسجيل 75 عينة (46.58٪) تحتوي على معدة فارغة تماما من المحتويات الغذائية. واوضحت النتائج أن الرخويات خاصة المصرعيات والحلزونيات بطنية القدم و القشريات (السرطانات والروبيان) و الأسماك هى المكونات الأساسية لغذاء هذاالنوع. ووفقا لطريقة نسب النقاط، أتت الرخويات في المرتبة الأولى بنسة 44.83٪، تلتها القشريات في المرتبة الثانية (18.1٪) فالأسماك في المرتبة الثالثة (16.24٪) فى الذكور، كما سجلت تلك المحتويات نفس الترتيب في الإناث مع وجود ارتفاع طفيف في نسب الرخويات (47.2٪) والقشريات(21.62٪) بينما انخفضت نسبة الأسماك إلى 11.03٪. أما بقايا الأنسجة المستهلكة من اللافقاريات القاعية الأخرى فقد سجلت أيضا ولكن بنسب منخفضة مقارنة بالنسب السابقة للرخويات والقشريات والأسماك، في حين سجلت فتات الطحالب كميات قليلة في عدد قليل من معي هذا النوع. كما تم تسجيل نسب عالية من رواسبيات القاع. وتشير نتائج هذه الدراسة إلى أن هذا النوع يعد من السرطانات المفترسة (آكلات اللحوم). كما تشير الدراسة إلى ارتباط التغير في نسب هذه المكونات إلى التغيرات الموسمية ومدي توافر الغذاء المناسب ودرجة امتلاء المعدة بالغذاء. ولفهم آلية التغذي تم فحص مكونات طاحنة المعدة شكليًا وكذلك فحص العظيمات المتمفصلة السبعة وتصويرها فوتوغرافيا.