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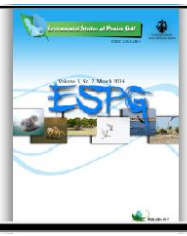

The Biology of the Blue Swimming Crab *Portunus segnis* (Forskal, 1775) along the Bushehr Coasts, Persian Gulf

Mehdi Hosseini*, Jamileh Pazooki, Mohsen Safaie, Fatemeh Tadi-Beni

Department of Marine Biology, Faculty of Biological Science, Shahid Beheshti University, Tehran, Iran

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ABSTRACT

The size composition, growth pattern, sex ratio and feeding habits of the blue swimming crab, *Portunus segnis* from Persian Gulf in south of Iran, was studied. Sampling was performed by trawl net during a one- year period (July 2011 to May 2012) as processed 864 crabs was collection. The crabs carapace width ranged were from 7.5-17.5 cm for males and 7.0-16.5 cm for females. The crab carapace length was from 4-8 cm for males and 3.5-8 cm for females. An analysis of covariance indicates that there is a significant difference between the two sexes with respect to the carapace width-weight relationship. The condition factor ranged between 3.78 and 5.46 with a mean of 4.85. The condition factor decreased with an increase in crab size. The analysis of dietary compositions showed that the main food items included crustaceans, mollusca and fish. The crustaceans included shrimp, barnacle and crab. The dominant molluscs were the bivalve *Cardita bicolor* and gastropod *Cerithium erythraeonense*. There were significant differences in the preference for food items in different seasons and size groups ($p<0.05$). Sex ratio during a year of study was M: F = 0.92: 1 which should be the relative frequency of females.

1 INTRODUCTION

The blue swimming crab *Portunus segnis* is distributed from the eastern Mediterranean to east Africa in the Indian Ocean, and to Pakistan, Red Sea and Persian Gulf (Joelle, 2010). It also lives in a wide range of inshore and continental shelf areas, including sandy, muddy or algal and sea grass habitats, from the intertidal zone to at least 50 m depth (Williams, 1982; Edgar, 1990). They are usually found in large numbers in shallow bays with sandy bottom (Dai and Yang, 1991) and are important commercial species in India and South East Asia (Prasad and Tampi, 1951). The blue swimmer crab *P. segnis* supports substantial commercial fishery in the Persian Gulf and is an important component of many recreational fisheries in Iran and other parts of the world. It is also the major species of crab caught in trawl nets. They have five paired legs (ten legs), some of the legs are pointed and others flat. The pointed ones are used for crawling and the flat ones are used like paddles for swimming. The first pair of legs, which are modified as claws, is called chelipeds. The cheliped are long, elongated ridged. They catch and hold food and bring it to the mouth by digging, cracking open shells and warning off would-be attackers. At

* *Corresponding author: mehdihosseini23@yahoo.com*

the same size, males are heavier than females in the coasts of Persian Gulf.

In crustaceans, as growth progresses, certain dimensions of the animal's body may grow much more than others, resulting in the phenomenon known as relative growth (Williams, 1982). Studies of relative growth are often used to determine changes in the form and size of the abdomen, pleopods, or chelipeds during ontogeny. Knowledge of these distinguishing characters and size relationships in sexually mature individuals is of particular importance in the study of commercially valuable crustaceans. Such knowledge can be useful for further studies on the life history of the species and in the development of its fishery, resource management, and culture. The mathematical length-weight relationship thus yields information on the general well-being of individuals, variation in growth according to sex, size at first maturity, gonadal development, and breeding season. Study of the length-weight relationship in aquatic animals has wide applications in delineating the growth patterns during their developmental pathways (Bagenal, 1978).

The biology of feeding habitats of the Portunidae have been especially well studied (Prasad and Tampi, 1953; Eales, 1972; Patel et al., 1979; Williams, 1981; Wassenberg and Bill, 1987; Wear and Hadden, 1987; Razek, 1988; Edgar, 1990; Norman and Jones, 1992; Stehlik, 1993; Wu and Shin, 1998; Choy, 1998; Sukumaran, and Neelahantan, 1998; Mantelatto and Christofoletti, 2001;) probably because of their ecological importance in marine and freshwater habitats. The biology of this species in Persian Gulf has been studied (Kazemi et al., 2002; Jazayeri et al., 2008; Tadi et al., 2011). They are considered to be an opportunistic predator, and the diet of which depends on local availability of food items. The studies indicate that *P. segnis* is primarily a carnivore feeding on a wide variety of benthic animals, although lesser quantities of marine plants and seagrass are also consumed. It is an economically important crustacean for food, commerce, and biological research. Very little information is available on the biology of this species of Persian Gulf. Hence, the present study was conducted to investigate the size composition, growth pattern, food and feeding habits and sex ratio of *P. segnis* along Bushehr coasts. Probably, results of this study will be useful for developing successful farming techniques for this species in the future.

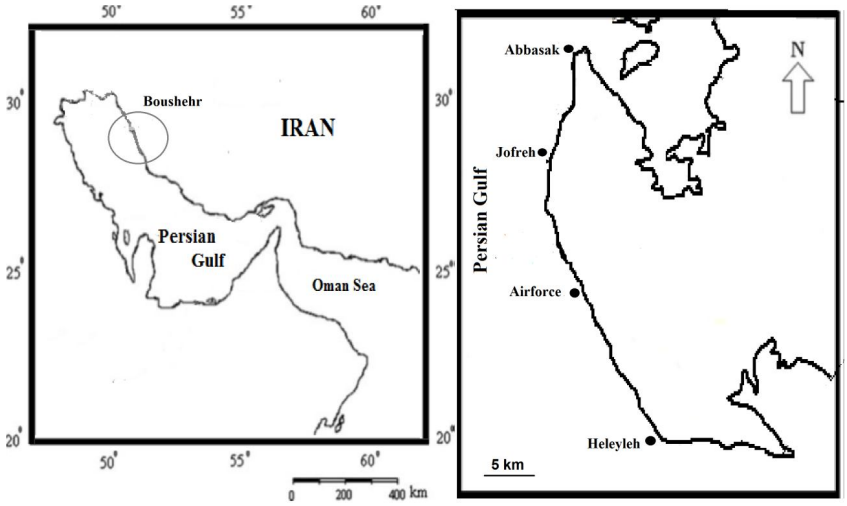

Fig. 1. Map of Persian Gulf coasts showing sampling stations and the site of study.

2 MATERIALS AND METHODS

The study was carried out along the Persian Gulf coasts (Bushehr province) in south of Iran (Fig. 1). The population of *P. segnis* were sampled seasonally from July 2011 to May 2012, at four stations (Heleyleh, Airforce, Jofreh, and Abbasak), using a 2 m beam trawl with a tickler chain and 5 mm mesh size in the cod end. Random samplings of several size ranges were obtained. Then, the crabs were washed for removing the mud and algae's and barnacles stuck to the external skeleton. After sampling, the samples were taken to the laboratory in a cooler and stored in a deep freezer for further analysis.

Male blue swimming crab has a V-shaped abdomen and female crab has a broad and round abdomen (Fig .2). Vernier callipers with an accuracy of 0.5 mm were used for length measurements, and the total weight of the crab was determined to the nearest gram using a digital balance (1 g). Crabs were counted, measured (carapace width (CW) and length (CL) and the total weight (TW)), and examined for sex, reproductive condition (occurrence of ovigerous females), and moulting stage. Carapace width (CW) was taken as the distance between the tips of the posterior most lateral carapace spines. Carapace length (CL) was measured dorsally along the midline, between the frontal notch and the posterior margin of the carapace. Right chelarpropodus length (Ch L) was measured from the tip of the propodus' fixed finger to the base of the propodus. When the right chela was missing or damaged, the left chelarpropodus length and height were taken, as in *P. segnis* both chelae are equally well-developed. Abdominal width was measured at the maximum width, i.e., across the fourth somite. Abdominal length was measured along the midline from the anterior margin of the first somite to the posterior margin of the telson.

Regression equations were calculated assuming an allometric growth equation ($Y = a + bx$), to determine any relations between different morpho metric characters in males and females. The values of the correlation coefficient (r) were calculated to know the pattern of associations between propodus/ abdomen and carapace dimensions (Snedecor and Cochran, 1967), with the objective of establishing a mathematical relationship between the variables, so that if one variable is known, the other could be computed approximately.

The carapace width-weight relationship was estimated using the log form of the allometric growth equation W = aLb

Fig. 2. The ventral view of male (a) and female (b) of blue swimming crab *P. segnis*

(Rickter, 1973), where W = expected weight, L = total carapace width, 'a' = *y*-intercept or the initial growth coefficient, and 'b' = the slope or growth coefficient. The values of constants of 'a' and 'b' were calculated by the least squares method. The differences in the carapace width-weight relationship between sexes were tested by ANOVA (MS Excel).

Studies on food and feeding were carried out following the method adapted from Williams (1981). Stomachs were removed and the contents were preserved in 70 % buffered formalin for a week, prior to being cut open and their contents were transferred into petri dishes with distilled water later identification. The fullness of the stomach was visually examined and assessed as 0, 25, 50, 75, or 100%. The food components of the gut contents were separated and identified under a compound microscope. Diet characterization was based on these stomach contents. The stomach contents of 837 crabs (442 males and 395 females) were examined. Each prey item was identified to the lowest taxonomic level possible. Next, they were counted, and weighed (wet weight).

3 RESULTS AND DISCUSSION

The crab carapace width ranged from 7.5-17.5 cm for males and 7.0-16.5 cm for females. The crab carapace length was from 4-8 cm for males and 3.5- 8 cm for females. The total weight ranged from 40.0 to 275.0 g for males and 32.50 to 242.2 g for females (Table 1). The size classes 11 to 13 cm were the highest in number for both sexes. The least number was recorded for size classes 13 to 15 cm. The carapace width and length frequency distribution showed a unimodal distribution of which most crabs (70 %) were in the medium size group and were of the same year class.

Similar results were obtained for *Callinectes latimanus* by Kwei (1978), *C. amnicola* by Lawal-Are and Kusemiju (2000), *Portunus pelagicus by* Jazayeri et al. (2011) and *Portunus pelagicus*by Hosseini et al. (2012).The results of this study show that at the same size, BW and the parameters of CL and CW of male *P. segnis* are higher than females in Persian Gulf coasts. Allometric equations with respect to males and females of *Portunus segnis* have been indicated in Tables 2 and 3.

Table 1
The morphological characteristics of *P. segnis.*

characteristics	Male		Female	
	Min	Max	Min	Max
Carapace width (cm)	7.5	17.5	7	16.5
Carapace Length (cm)	4	8	3.5	8
Total Weight (gr)	40.0	275.0	32.50	242.2

Table 2
Allometric equations and correlation coefficient (r) values between different variables in females of *P. segnis.*

Independent variable (*x*)	Dependent variable (*y*)	Allometric growth equation ($y = a + bx$)	'r^2' value
Carapace width	Abdomen width	AW = −18.228 + 0.4563 CW	0.5567[a]
Carapace width	Abdomen length	AL = −16.442 + 0.7664 CW	0.3343[a]
Carapace Length	Abdomen width	AW = −15.232 + 0.6673 CL	0.7675[a]
Carapace Length	Abdomen length	AL = −6.664 + 0.5579 CL	0.4454[a]
Abdomen width	Abdomen length	AL = −7.886 + 0.7764 AW	0.7677[a]
Carapace width	Chelarpropodus length	CPL = −69.334 + 1.4676 CW	0.6777[a]
Carapace length	Chelarpropodus length	CPL = −58.665 + 1.7655 CL	0.3343[a]

[a] Indicates highly positive allometry, significant at 1% level

Table 3
Allometric equations and correlation coefficient (r) values between different variables in females of *P. segnis*

Independent variable (*x*)	Dependent variable (*y*)	Allometric growth equation ($y = a + bx$)	'r^2' value
Carapace width	Abdomen width	AW = −17.008 + 0.7656 CW	0.6754[a]
Carapace width	Abdomen length	AL = −15.332 + 0.7334 CW	0.6884[a]
Carapace Length	Abdomen width	AW = −12.552 + 0.8873 CL	0.7332[a]
Carapace Length	Abdomen length	AL = −6.7764 + 0.8979 CL	0.6112[a]
Abdomen width	Abdomen length	AL = −5.6554 + 0.9884 AW	0.6442[a]
Carapace width	Chelarpropodus length	CPL = −59.556 + 1.5556CW	0.5221[a]
Carapace length	Chelarpropodus length	CPL = −51.225 + 1.4443CL	0.5546[a]

[a] Indicates highly positive allometry, significant at 1% level

The allometric relation between the set of characters studied suggested that in most cases the relationship was positive and highly significant. The study has shown that males are heavier than females up to 120- 125 mm carapace width, and thereafter males are heavier than females. The results are displayed in Table 2.

The scatter diagram for males and females was obtained by plotting weight against carapace width/length of individual crabs. From the data presented, a distinct relationship was found between width and total weight, as judged from the closeness of the scatter dots, as well as from the parabolic nature of the plot.

The exponential values (b) for the carapace width-weight relationship in males and females (2.334 and 2.554, respectively) show that there is a marked deviation from the isometric growth pattern. The '*t*' test confirmed that 'b' significantly differs from 3, in both sexes. The exponential values (b) for carapace length-weight in males and females (2.112 and 3.443, respectively) indicate that the significant departure from isometric growth is only evident in females. In males, the curve follows an isometric growth pattern. The '*t*' values are given in Table 4. The results of the analyses of covariance (Tables 5 and 6) show that the difference between slopes ($F = 18.32$; $P < 0.01$) and the difference between elevations ($F = 11.43$; $P < 0.01$) were both highly significant, indicating that there is a significant difference between the sexes with respect to this carapace width-weight relationship. Likewise, also in the case of the carapace length-weight relationship a significant difference was found both between slopes ($F = 10.22$; $P < 0.01$) and also between elevations ($F = 5.87$; $P < 0.05$). Knowledge of the distinguishing characteristics and size relations of sexually mature individuals is of particular importance in the study of commercially valuable crustaceans.

Table 4
Carapace width/length-total weight relationship in males and females of *P. segnis*

Measurements	Sex	Logarithmic equation	Parabolic equation
Carapace Width-Total Weight	Male	Log = −16.532 + 2.334 log L	$W = 0.00006469L^{3.552}$
	Female	Log = −15.278 + 2.554 log L	$W = 0.00002233L^{2.443}$
Carapace Length-Total Weight	Male	Log = −6.551 + 2.112 log L	$W = 0.00005445L^{3.033}$
	Female	Log = −5.720 + 3.443 log L	$W = 0.00003442L^{2.332}$

Table 5
The '*t*' values for the carapace width/length and total weight relationship in males and females of *P. segnis*

Relationship	Sex	'*t*' value	Remarks
Carapace Width-Total Weight	Male	18.22	Significant at 1% level
	Female	5.45	Not significant
Carapace Width-Total Weight	Male	2.33	Significant at 1% level
	female	6.51	Significant at 1% level

Table 6
ANOVA for testing the equality of regression lines in the carapace width and total weight relationship among males and females of *P. segnis*

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F
Deviation from individual regression (within sexes)	885	19.331	0.04443	
Difference between regressions	1	0.481	0.77	18.32[a]
Deviation from average regression	889	23.814	0.0997	
Differences between corrected means	1	18.886	0.2144	11.43[a]

[a] Significant at 1% level.

Crabs of the Portunidae family are distinguished by having the dactylus of their fifth pereiopods enlarged and flattened, which facilitates swimming.

In the Indo-Pacific region, the genus *segnis* is represented by a member that has nine antero-lateral spines at each side of the carapace, the posteriormost one of which is enlarged. All these characters are in agreement with the descriptions of *P. segnis*. In addition, in this species sexes are easily differentiated by the colour pattern of their exoskeleton. Males are brilliantly coloured with bright blue, and females have a dull brown colour. This unique feature is not seen in other common portunids.

Gross morphological differences in external anatomy between sexes are similar to those of other portunids crabs (Ryan, 1967; Johnson, 1980; Sumpton, 1990; Ghorbani et al., 2002; Hitoshi, 2007; Hosseini et al., 2011).

The allometric regression found describes changes in soft tissue content (or total animal weight for crustaceans) relative to carapace width/length. This result is consistent with general trends of scaling with body size in animals (Sumpton, 1990; Johnson, 1980). In the present study, we did not examine any potential seasonal changes in carapace allometry and body weight, since a uniform climate (typical tropical-dry) prevailed in the area throughout the period of study (Ghorbani et al., 2002; Hosseini et al., 2011).

The results of the length-weight relationship analysis in *P. segnis* indicate that in juveniles and pre-adult crabs, weight gain is almost uniform; however males are slightly heavier than females until they attain 10-12 cm carapace width. Thereafter males are heavier than females at any given length. Sukumaran and Neelakantan (1997) found that a weight increase was evident above a carapace width of 115 mm in *P. pelagicus*. The tendency of males to be heavier than females in portunids is in accordance with the observations of Potter et al. (1983) in *P. pelagicus*, of Thomas (1984) in *P. pelagicus* and *P. sanguinolentus* (Herbst, 1783), from Cochin, of Sukumaran et al. (1986) in *P. sanguinolentus* from Mangalore, of Prasad et al.

(1989) in *P. sanguinolentus*, *P. pelagicus*, and *Scylla serrate* (Forskal, 1775) from Karwar and of Sukumaran, and of Neelakantan (1997) in *P. pelagicus* and *P. sanguinolentus* from Mangalore. However, from the reports of these workers it is understood that there are marked variations in the results of carapace width-weight relationship in portunids from different places, and also within various regions of the same coast. In contrast to the result and reports of the above workers, Dhawan et al. (1976) found that females of *P. pelagicus* are heavier than males at a given length in Goan waters. There have been a large number of studies on morphometric in marine crabs along the coasts of Persian Gulf (Ghorbani et al., 2002; Jazayeri et al., 2008; Tadi et al., 2012).

Ghorbani et al. (2002) reported that males of *P. pelagicus* are heavier than females in coasts of Persian Gulf (Bushehr Province), but Jazayeri et al. (2008) found that females of *P. pelagicus* are heavier than males in the coasts of Persian Gulf (Khuzestan Province). Tadi et al. (2012) reported that males of *P. segnis* are heavier than females in the coasts of Persian Gulf (Hormozgan Province).

Some studies showed different sizes with carapace width ranging from 8 to15.9 cm for female and 7.8 to13.7 cm for males and mean weight of males was considerably more than females from Moreton Bay, Eastern Australia (Gaddes and Sumpton, 2004). Also Razek (2006) showed carapace width ranging from 4.5 to 16.5 cm, carapace length from 1.9 to 7 cm for the same species from Bardawil lagoon, Northern Egypt.

The exponential values (b) of the carapace width-weight relationship for males and females showed marked variation from the cube law, a marked departure from the isometric pattern of growth. In the case of carapace length-weight relationship, males followed an isometric growth pattern, while a significant deviation from isometric growth was evident among females. The results of the analysis of covariance indicated a significant difference between the two sexes with respect to carapace width/length-weight. The present findings are in accordance with those of Sukumaran and Neelakantan (1997) in *P. pelagicus*. same author observed isometric growth in males and females of *P. sanguinolentus*. Ghorbani et al. (2002) reported isometric growth in males and females of *P. pelagicus*. Hitoshi (2007) reported that males had steeper slopes (i.e., larger *b* values) than females in two crab species, *Helicetridens* and *Chasmagnathus convexus*, in Japan. Other studies showed isometric growth in males and females of *P. pelagicus* (Jazayri et al., 2002; Gaddes and Sumpton, 2004; Razek, 2006; Hitoshi, 2007; Tadi et al., 2012). Consequently, the results of the length/width-weight relationships presented here will enable crab biologists to derive length estimates for blue crabs that are weighed but not measured. Hence, the results of the study will make useful information, needed for the effective management and utilization of this resource in this area, where the blue swimmer crab occurs, such to make a good fishery possible.

3.1 Sex ratio

The sex ratio obtained for *P. segnis* was M: F = 0.92:1 (male/female) which showed a significantly more abundant female population. Similar results were reported for *Portunus pelagicus* by White (1999) and Sumner and Malseed (2004), *Portunus pelagicus* by Jazayeri et al. (2011) and *Portunus segnis* by Tadi et al. (2012).

3.2 Food habits

The identifiable food items included crustaceans (44.38%), molluscs (22.8%), fishes (21.2%), plants (1.68%), benthos (1.62%) and debris (8.3%). The details according to the size of the crabs are given in Table 1. Through

analysis, it was found that the percentage frequency of occurrence of different items comprised 87.43% of all cases. In percentage of points, crustacean as the most apparent food group was found in 57.5% of the stomachs with food items. This fraction consisted primarily of decapods (parts of shrimps, parts of exoskeleton, appendages; and crab exoskeleton, appendages), and another contained the remains of copepods and barnacles, by followed molluscs (bivalves and gastropods) and fishes (bone, scale, fin and eye lens). The dominant molluscs were the bivalve *Cardita bicolor* and the gastropod *Cerithium erythraeonense*. Other molluscs were *Marcia hiantina*, *Circenita callipyga* and *Tellinasp* (Table 7).

Juvenile crabs (<90 mm CW) appeared to prefer crustaceans (48.6%) followed by molluscan (21.5%), Fish (17.5 %) and different items (12.4 %). In the sub-adult group (91- 110 mm CW), crustaceans (43.2%) were the major food item followed by molluscan (25.3%), Fish (20.6%) and different items (10.9%). In adults (111-150 mm), crustaceans were the principal food item (40.5%), followed by fish (26.7%) molluscan (24.5%) and different items (8.3%). In the larger size group of adults (151-170 mm) crustaceans (37.5%) followed by fish (29.4%), mollusca (21.6%) material constituted the main food items and different items (11.5%) (Fig .3). We observed a significant reduced consumption of crustacean, molluscan and benthos as the animals increased by size, accompanied by a significant elevation in the consumption of fish. The results showed that the blue crab *P. segnis* is a carnivorous with a preference for animal prey, but within that framework only rarely feed on more mobile preys such as fish and prawns (Williams, 1981; Sukumaran and Neelahantan, 1998). Warner (1977) was also of the opinion that crabs are opportunistic omnivores with a preference for animal food in conjunction with a definite predatory propensity. Our results are similar to those on the diets of other Portunidae crabs (Patel et al., 1979; Williams, 1981a 1982b; Wassenberg and Bill, 1987; Wear and Hadden, 1987; Razek, 1988; Edgar, 1990; Norman and Jones, 1992; Stehlik, 1993; Sukumaran, and Neelahantan, 1998; Mantelatto and Christofoletti, 2001; Kazemi et al., 2002; Tadi et al., 2011).

In the present study, it is observed that crustaceans constitute the most favored item in this species' diet, followed by molluscs and fish. While this confirms the findings of Patel et al. (1979), Sukumaran and Neelakantan (1997) also reported that *P. pelagicus* from the Mangalore coast preferred crustaceans, but in that location followed by fishes and molluscs, respectively.

Table 7
ANOVA for testing the equality of regression lines in the carapace length and total weight relationship among males and females of *P. segnis*

Source of variation	Degrees of freedom	Sum of squares	Mean square	Observed F
Deviation from individual regression (within sexes)	885	25.554	0.22	
Difference between regressions	1	0.499	0.6652	10.22[a]
Deviation from average regression	889	23.814	0.0023	
Differences between corrected means	1	0.221	0.4410	5.87[a]

[a] Significant at 1% level

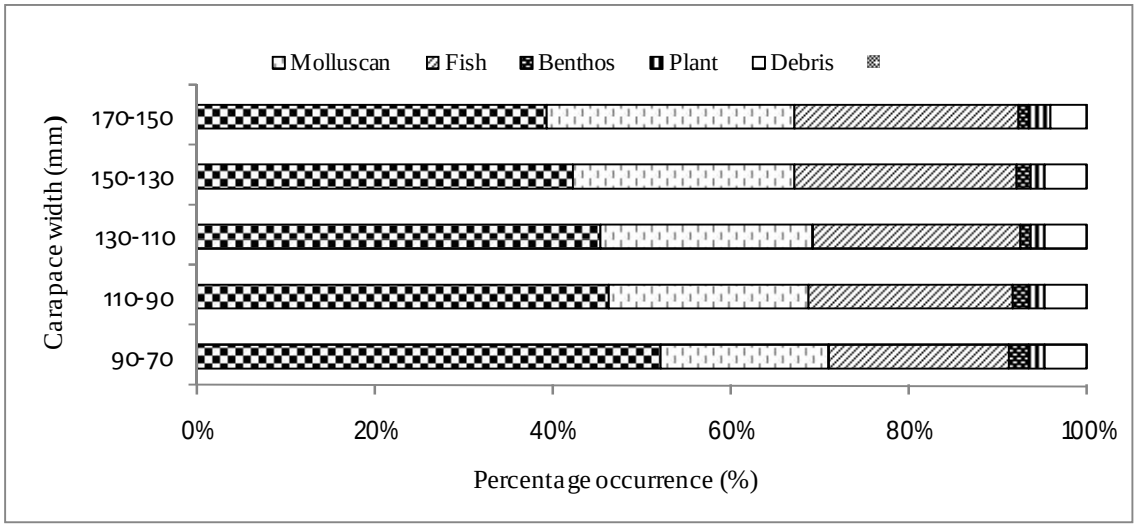

Fig 3. Points of major food groups in various size group of *P. segnis.*

Chande and Mgaya (2004) reported that molluscs, particularly the bivalve *Arcuatula arcuatula* (Hanley, 1843), were the most important food items in the stomachs of *P. pelagicus* along the coast of Dar es Salaam, Tanzania. Tadi et al. (2012) also reported that *P. segnis* from the Persian Gulf coasts (Hormozgan coast) preferred crustaceans, followed by fish and molluscs, respectively. The differences in diet composition could be related to changes in, (a) space and time in the benthic fauna composition, (b) the habitats available for foraging, (c) shifts due to life-history patterns of prey, and (d) the feeding activities of predator.

The changes in the dominant and occasional prey in the diet of crab have already been

Table 8
Percentage of points and frequency of occurrence of major food groups in *P. segnis*

Items		P	%P	% O
	Shrimp	5589	57.5	75.6
Crustacean	Crab	2234	22	34.2
	Barnacle	883	11	27.5
	Copepod	1223	9.5	23
	Bivalve *Cardita bicolor*	5463	55	79.5
Mollusca	bivalve *Marcia hiantina*	4560	43	71.3
	Bivalve *Circenita callipyga*	2544	21	44.3
	gastropod*Cerithium erythraeonense*	4771	38.6	50
	Vertebrae	1660	17.3	18.5
Fish	Bones	2675	21	31.3
	scales	3362	19.6	22.5
	Fins	1930	10.5	15
Plants	Algal filaments	521	4.9	18.4
Benthos	Foraminiferans	1652	6.8	28.3
Debris	Sand and Mud	1540	9.5	23.4

P: Points, %P: Percentage Points, %O: of Percentage of Occurrence

reported (Williams, 1981; Mantelatto and Christofoletti, 2001; Prasad and Neelakantan, 1988).

Finally, the results of present study and other similar studies cited above strongly suggest that crustaceans, molluscs and fishes were the most commonly ingested items throughout the one year period of sampling. Thus, the present study, as earlier related studies, suggests that, despite the diversity in crab diets and feeding habits, portunids crabs are carnivores with a preference for animal food and the behaviour of active predators of sessile and slow-moving macro-invertebrates. This study also shows that blue swimming crab *Portunus segnis* consumes a variety of food items. It is suggested that a major reduction in availability of one prey group would not have a major effect on the crab population.

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