
Food and feeding habits of *Pachygrapsus marmoratus* (Grapsidae) crab in the southern Mediterranean Sea (Eastern Libya)

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ABSTRACT: *The present study aimed to establish spatiotemporal food and feeding habits of the crab Pachygrapsus marmoratus inhabiting the rocky shores of the southern Mediterranean Sea coast, exemplified by Al-Haniyah, Al-Hamamah, and Susah sites in eastern Libya, and relate them to crab morphometric traits, and abundance of food organisms in the habitat. A total of 425 crabs collected during 2019 were used in the study. The minimum and maximum carapace length (CL), and total weight (TW) were: 8.5-35.1mm, and 0.4-31.0g in order, the means were 26.79mm and 12.37g. P. marmoratus is an omnivore facultative feeder, i.e. feeds on what is available in its habitat. Stomach fullness was established and discussed in terms of season, site, crab sex and growth, and availability of food in the habitat. The abundance of food in the stomach by taxa vary according to the site, and crab sex and size, but the overall trend was cnidaria and algae > crustacea > mollusca > seaweed, by season it was fall > spring > winter > summer. Cnidaria and mollusca were more abundant in stomachs of P. marmoratus of Al-Haniyah, Crustacea in Al-Hamamah, and mollusca and crustacea in Susah crab's stomachs.*

KEYWORDS: Food, feeding habits, *Pachygrapsus marmoratus*, Southern Mediterranean Sea, Eastern Libya

INTRODUCTION

Crabs are mostly small to medium-size decapod crustaceans, that are dorsoventrally flattened, protected with a waterproof exoskeleton of highly mineralized chitin (Boßelmann *et al.*, 2007; Chen *et al.*, 2008), and armed with a single pair of chelae (claws). Crabs are generally bottom dwellers in marine, brackish, and fresh water, some are semi-terrestrial (Sternberg and Cumberlidge, 2001). Most crabs are omnivores and detritus feeders; in their turn, crabs provide food for many co-inhabiting animals.

The marbled rocky crab, *Pachygrapsus marmoratus* of the Family Grapsidae is the most common crab species on the rocky shores of the southern Mediterranean Sea coast (Campbell, 1982; Eisay *et al.*, 2022). The present study aimed to establish the food and feeding habits of this crab in the eastern coast of Libya (Southern Mediterranean Sea).

METHODS

The study sites

Pachygrapsus marmoratus crabs used in the present study were collected from the rocky shores of Al-Haniyah (32° 50' 28" N, 21° 31' 15" E), Al-Hamamah (N 32° 55' 24" E 21° 38' 00"), and Susah (21° 58' 34" E 31° 53' 32" N) in eastern Libya (Fig. 1). The first two are small fish-landing inlets typical of those scattered along the southern Mediterranean Sea coast (Reynolds *et al.*, 1995; Suliman, 2018). Susah is a small fishing, commercial, and recreational harbor. The shores of these sites are characterized by alternating rocky and sandy tongues. The terrain on the rocky shores is very rough, being composed of rocks, cracks, and tidal pools, of various sizes; biodiversity is high.



Fig. 1. Al-Haniyah, Al-Hamamah, and Susah, from which the crabs were collected.

Collection of the study samples

Four hundred and twenty-five *P. marmoratus* crabs were collected randomly from the rocky shores of the three study sites from February to December 2019. Two methods were used for collecting the crabs:

- In the first method, buckets and pails baited with hen's guts were set at night in holes dug in soft bottoms adjoining the rocky shore such that only their rims protruded above the substratum. Falling crabs were collected in the morning. However, this method was abandoned as the offensive smell of decaying guts persisted on a large section of the shore the next day. Also, trapped crabs attacked and harmed each other. Furthermore, seabirds with their long necks picked up some of the crabs from the containers in the early morning. Therefore, crabs collected by this method were freed.
- In the second method, the adopted method, 425 *P. marmoratus* crabs were collected by hand from the rocky shore at night when they left their day-hiding crevices and tidal pools in search of food.

Identification of the collected specimens was ascertained according to Calvin and Valdes (2000); and WoRMS (2013).

Measuring the morphometric parameters of *P. marmoratus*

The collected crabs were sorted into males and females according to the shapes of their abdomens (triangular in males and circular in females) and the appearance of the first two pairs of pleopods (modified to gonopods in males). Total crab weight (TW) and carapace length (CL), were measured with a sensitive balance and a digital Vernier caliper to the nearest 0.1 g and millimeter.

Establishing food and feeding habits of the crab

The degree of stomach fullness of each crab was visually estimated according to Pillay (1952) as empty (nearly 0% full), trace (< 25% full), quarter full (about 25% full), half full (about 50% full), three-quarter full (about 75% full), and completely full (about 100% full).

Then, the alimentary tracts of individual crabs were removed, cut opened, and contained food scraped off into separate Petri dishes, each containing a small amount of water, and inspected with a hand lens and a binocular microscope. Food items were established qualitatively and quantitatively by the point and frequency of occurrence method of Hyslop (1980). Percent abundance of food by type in the stomachs was calculated.

Stomach fullness and diet composition were related to carapace length by regression equations to infer the dynamics of these parameters during growth of the crab.

The rocky shores of the three study sites were surveyed visually during the four seasons of the year 2019 to establish the availability and abundance of potential food items for *P. marmoratus*.

RESULTS

Carapace length and total weight of *P. marmoratus*

In the present study the minimum and maximum carapace length and weight of all collected crabs were: 8.5 – 35.1mm and 0.4 – 31.0g, the means were 26.79mm and 12.37g. Crabs collected during summer, and from Al-Hamamah, were smaller than those collected during the other seasons or from the other sites (Table 1). Sex had no effect on crab size.

Table 1. Means (\pm St E) of carapace length (black color) and total weight (red color) of *P. marmoratus* by season, area and gender. Means with different superscripts along rows are significantly different.

Season	Fall	Spring	Summer	Winter	
	27.22±2.2 ^b 13.3±1.06 ^b	27.02±2.2 ^b 13.7±1.09 ^b	23.2±1.8 ^a 11.2±0.9 ^a	25.8±2.1 ^b 11.3±0.9 ^a	
Area	Al-Hamamah	Al-Haniyah	Susah		
	23.5±1.93 ^a 11.2±0.9 ^a	26.31±2.6 ^b 13.6±1.1 ^c	27.51±2.3 ^b 12.3±12.3 ^b		
Gender	F	M			
	25.7±2.1 ^a 11.5±0.9 ^a	25.87±2.12 ^a 13.2±1.1 ^a			

Fullness of *P. marmoratus* stomach

In the present study, the indicator of stomach fullness was considered to range from 0 (completely empty stomach) to 100% (completely full stomach). The means of stomach fullness of *P. marmoratus* during fall, spring, and winter were not significantly different, but were significantly higher than the summer mean (Table 2).

The stomachs of Al-Haniyah *P. marmoratus* were significantly more full than those of Al-Hamamah and Susah crabs. Differences in fullness in Al-Hamamah and Susah were not significant (Table 2).

The effect of sex on the stomach fullness was insignificant (Table 2).

The stomach fullness increased as the crab increased in length (exemplified by carapace), i.e. as it grew (Table 3).

Table 2. Percent stomach fullness of *P. marmoratus* by season, site, and sex (±St E). Means with different superscripts are significantly different.

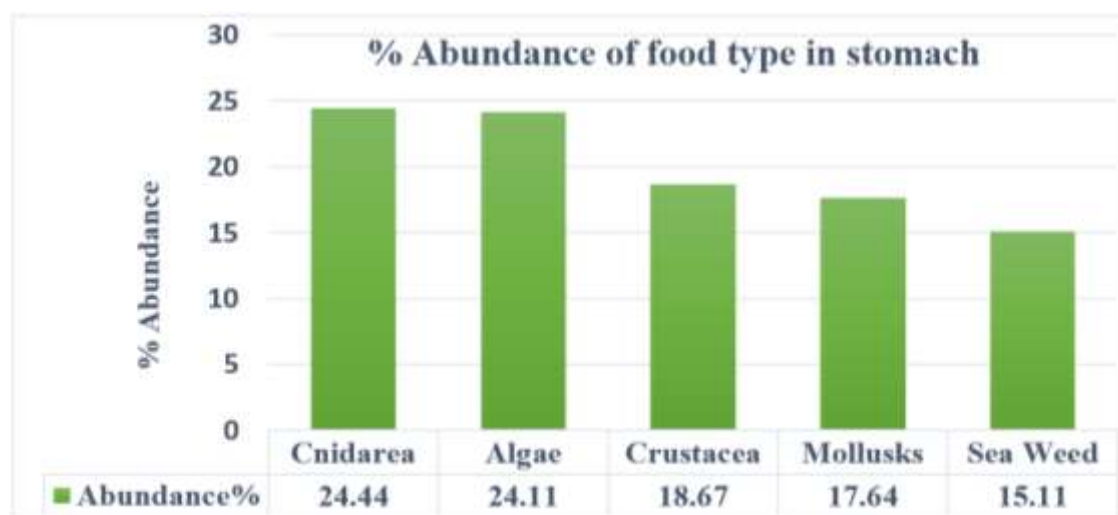
Season	Fall	Spring	Summer	Winter
	90 ^b ± 8	84 ^b ± 9	77 ^a ± 9	86 ^b ± 10
Site	Al-Hamamah	Al-Haniyah	Susah	
	81 ^a ± 9	90 ^b ± 10	82 ^a ± 9	
Sex	F	M		
	86 ^a ± 10	83 ^a ± 9		

Table 3. Frequency (%) of stomach fullness (%) at increasing carapace length.

Carapace length	Stomach fullness (%)				
	<25%	25%	50%	75%	100%
<15 mm	89%	11.00%	0.00%	0.00%	0.00%
15-20 mm	4.30%	87%	8.70%	0.00%	0.00%
20-25 mm	0.00%	37.00%	55.50%	7.40%	0.00%
25-30 mm	0.00%	0.00%	4.40%	66.20%	29.20%
30-35 mm	0.00%	0.00%	0.00%	4.3%	95.7%

Abundance of food by type in the stomach of *P. marmoratus*

The percent abundance of food by type in the stomachs of *P. marmoratus* (irrespective of season, site and sex) obtained by the point and frequency of occurrence method of Hyslop (1980) was of the order cnidaria and algae in the first place, followed by crustacea, mollusca and seaweed consecutively (Fig. 2). Cnidaria were represented mainly by sea anemones, algae by microalgae, mollusca mainly by bivalves but also gastropods, and seaweed mainly as filamentous algae.

**Fig. 2. Percent abundance of food type in the stomachs of *P. marmoratus* irrespective of season, site, or sex.**

Abundance of food in the stomach by type and season

Cnidaria was the most abundant food item in the stomachs of crabs in all seasons (Figs. 2 and 3). Algae came in second place, their order of abundance by season in the stomach was: fall > spring, summer, and winter. Crustacea and mollusks occupied the third place; the order of abundance of Crustacea was: spring > fall > winter > summer, that of Mollusca was: fall and spring > winter > summer. Seaweed was highest in the stomach in the fall, summer > spring and winter.

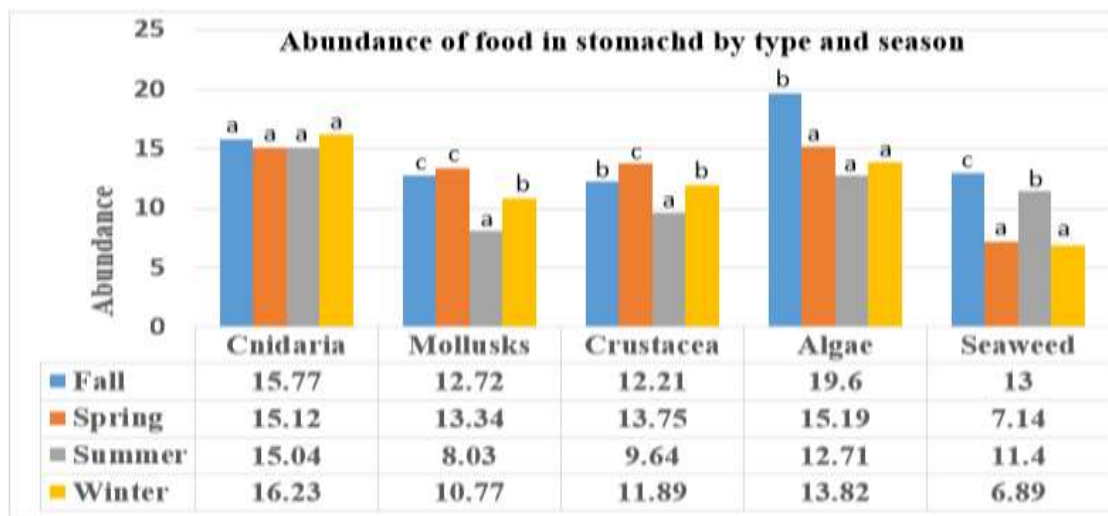


Fig. 3. Percent abundance of food in stomachs of *P. marmoratus* by type and season.

Abundance of food in stomach by type and site

Cnidaria and mollusca were more abundant in stomachs of *P. marmoratus* of Al-Haniyah than in the stomachs of Al-Hamamah and Susah crabs (Fig. 4). Crustacea were more abundant in the stomachs of Al-Hamamah *P. marmoratus* than in stomachs of Al-Haniyah crabs. Mollusca and crustacea were absent from the stomachs of Susah crabs. In contrast, algae and seaweed were present only in the stomachs of Susah crabs and were absent from the stomachs of Al-Haniyah and Al-Hamamah crabs.

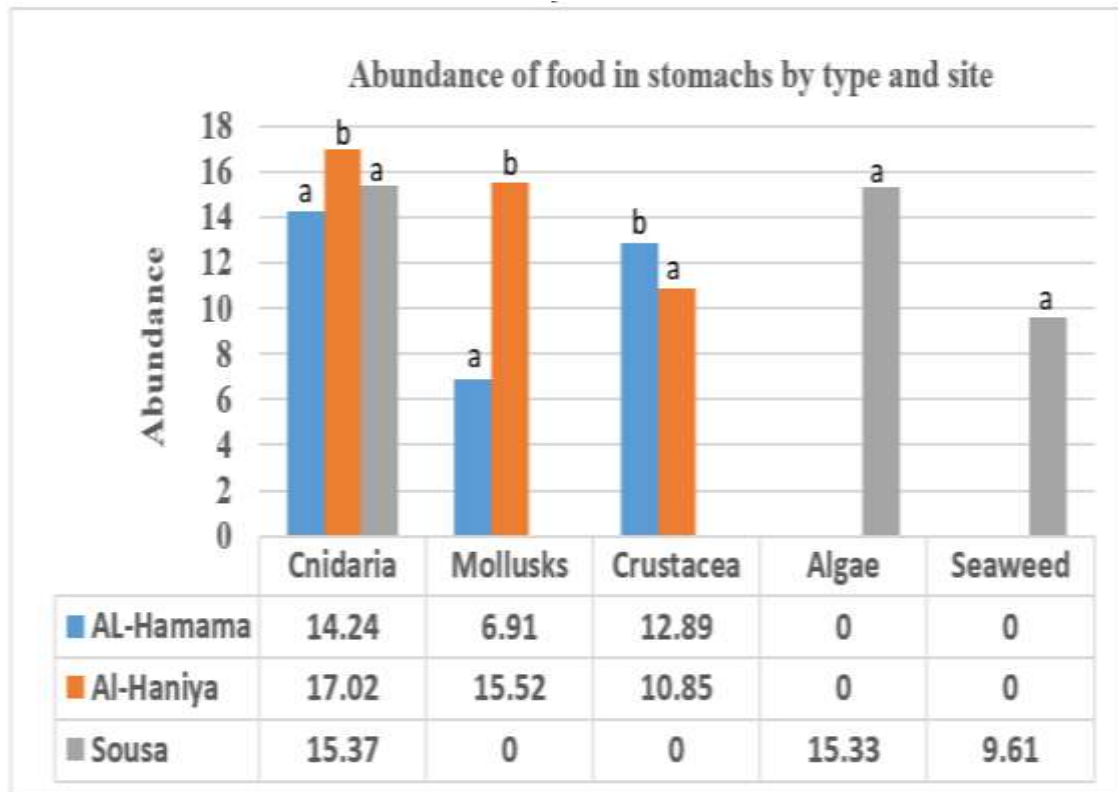


Fig. 4. Percent abundance of food in the stomach of *P. marmoratus* by type and site.

The abundance of food in the stomach by type and sex

The effect of sex on the abundance of cnidaria in the stomachs of *P. marmoratus* was not significant (Fig. 5). Mollusca and crustacea were more abundant in the stomachs of female crabs, but seaweed was more abundant in the stomachs of male crabs.

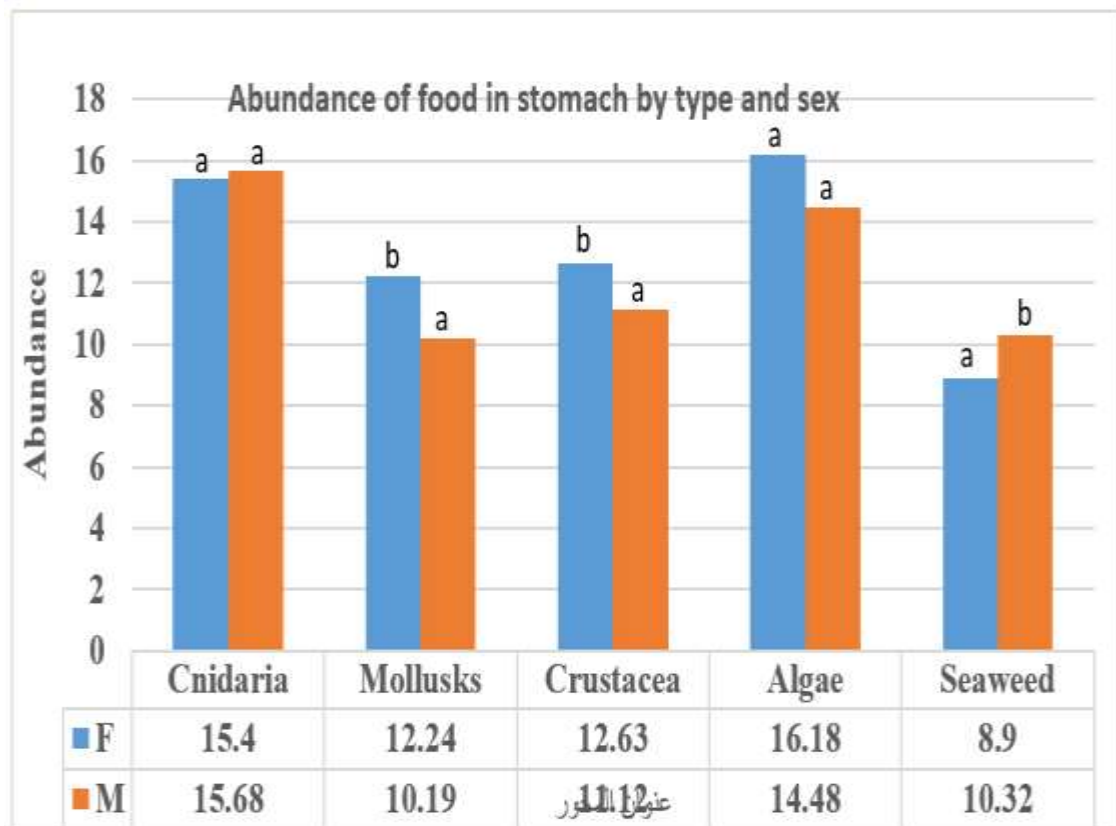


Fig. 5. Percent abundance of food in stomachs of *P. marmoratus* by type and sex.

The abundance of food in the stomach relative to the size of the crab - as indicated by carapace length

Cnidaria was the most abundant type of food in the stomachs of *P. marmoratus* during all seasons, at all the study sites, and irrespective of the crab sex and size (Fig. 6). The class interval 20-30mm was more dependent on cnidaria than the other classes (95.7-98.1%). Consumption of mollusks increased with increasing crab size; mollusks and crustacea were absent in the stomachs of young crabs (crabs up to 20mm carapace length). Consumption of mollusks increased with increasing crab size; that of crustacea was maximum at the class interval of 20-30mm. Large crabs (with a carapace length of > 30mm) did not consume algae. Sand and detritus were not observed in any of the investigated stomachs.

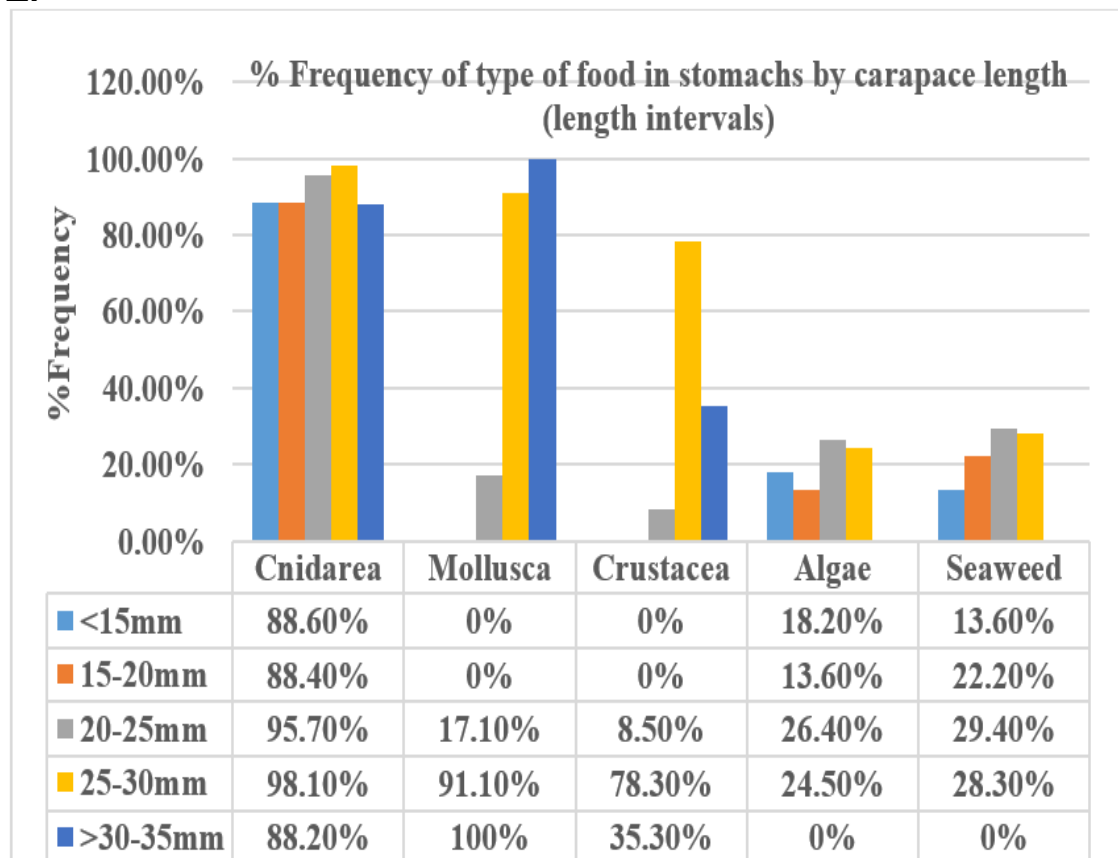


Fig. 6. % frequency of occurrence of food in the stomachs of *P. marmoratus* by type and by crab size (carapace length intervals) irrespective of season, site, or sex.

DISCUSSION

The means of carapace length (CL) and total weight (TW) of *Pachygrapsus marmoratus* of the present study were 26.79mm and 12.37g; differences based on sex were not significant. More or less similar results were reported by Cannicci *et al.* (2002); Cannicci *et al.* (2007); Katsanevakis *et al.* (2007); and Aydın (2018).

In the present study, food abundance by type in the stomach of *P. marmoratus* irrespective of season, site, sex, or size, was of the order of cnidaria and algae in the first place, followed by crustacea, mollusca and seaweed consecutively. Cnidaria was represented mainly by sea anemones, algae by microalgae, mollusca mainly by bivalves but also gastropods, and seaweed mainly as filamentous algae. Surveys of the shallow-sublittoral and intertidal zones of the study sites showed that cnidaria was abundant in all three study sites at all seasons. Algae and seaweed were abundant in Susah but to a lesser extent in the other two sites. Mollusks were more abundant in Al-Haniyah than in the other two sites. Crustaceans were abundant in Al-Hamamah but were fewer in Al-Haniyah and Susah. The exact causes of this spatial disparity are not clear, bearing in mind that the three regions are not much far from each other. However, it is well

established from previous studies that the diversity of coastal and intertidal biota depends in part on the nature of the terrain, the ambient physicochemical traits, such as temperature, tides, winds, pH, salinity, and nutrients, in addition to grazing and predation, and anthropogenic activity and consequent pollution and irrational exploitation of resources. These parameters change spatiotemporally. Intertidal animals, such as *P. marmoratus* of the present study, derive their food from their habitat. Many of these animals are facultative feeders, i.e. feed on what is available. Cannicci *et al.* (2007) concluded that the Italian *P. marmoratus* is an omnivore that relies on many trophic sources according to temporal availability. Cannicci *et al.* (2002) showed that *P. marmoratus* in southwestern Europe is omnivorous. Fouda *et al.* (2015) found that the stomach of *P. marmoratus* from Alexandria coast, Egypt, contained benthic algae and animals, and sediments. In contrast, the present study did not reveal the presence of any sediments in the stomachs of *P. marmoratus* of the three study sites at all seasons.

In the present study, it appears that the degree of stomach-fullness of the crab was mainly affected by the availability of food; the more food available, the more the crab ate and filled its stomach, and the faster it grew. Stomach fullness was greatest in the fall, winter, and spring, and least in the summer. Crabs were larger at these seasons, and smaller at summer. Fall, winter, and spring are the rainy seasons in eastern Libya; runoff from land fertilizes adjacent coastal waters; summer is the dry season, the season of the least marine productivity. Fouda *et al.* (2015) reported marked temporal variations in the diet and stomach fullness of *P. marmoratus*. In the present study, the stomach fullness of *P. marmoratus* was maximum in Al-Haniyah and minimum in Al-Hamamah and Susah, Al-Haniyah and Susah crabs were larger than Al-Hamamah crabs. Again, it appears that the availability of food at the site determined the stomach's fullness, which in turn affected the growth rate of the crab.

Previous studies showed that the feeding habits and strategies of *P. marmoratus* were not only dependent on the availability of food by type and quantity in the habitat, but also on the environmental factors that affect the rate of food uptake. Choy (1986), El-Sayed, (2004), Sumpton and Greenwood, (1990) and Shentu *et al.* (2015) mentioned that food and feeding habits of marine organisms can be modulated by environmental factors such as temperature and salinity, food intake decreases at low temperatures and low salinities. Contrary to this, in the present study, food intake was lowest in summer, the season with higher temperature.

In the present study, the effect of sex on stomach fullness was insignificant. Possibly this explains Eisay (2022) finding that the effect of sex on *P. marmoratus* size and length of individual components of the right and left chelipeds of the crab was insignificant. Protopapas *et al.* (2007) found no difference in allometric growth between right and left chelar propods in either sex of *P. marmoratus* of the Saronikos Gulf, Greece.

In the present study, cnidaria was the major type of food for *P. marmoratus* of all sizes, both sexes, at all seasons and sites. The degree of stomach fullness increased as the crab grew in size (increased in CL). Smaller crabs (15 to 20 mm CL) consumed cnidaria in addition to plant food (algae and seaweed), but did not consume mollusks or crustacea. It is possible that their smaller sizes prevented them from handling mollusks and

crustaceans, relatively sizable animals; however, as they grew (20 to 39 mm CL), they were able to consume mollusks and crustaceans, and thus more food became available to them. Crabs, > 30mm in size stopped consuming algae and seaweed completely, possibly because they were now capable of consuming the more nutritious mollusks and crustaceans. Eisa (2022) found that the regression of the condition factor of *P. marmoratus* vs. carapace length was positive, indicating that the crab got relatively “fatter” as it grew. Algae and seaweed were more abundant in Susah rocky intertidal, particularly during the fall, than in the other two sites. Thus, they were significantly more abundant in the stomachs of *P. marmoratus* of Susah during the fall, but were completely absent from the stomachs of Al-Hamamah and Al-Haniyah *P. marmoratus*. Fall is the season when runoff from land fertilizes the sea, causing algae and seaweed to flourish. Why algae were completely absent from the stomach of *P. marmoratus* in Al-Hamamah and Al-Haniyah is not clear.

Conclusions

- ❖ The present work provides baseline information on the food and feeding habits of the marbled crab *P. marmoratus* in the southern Mediterranean Sea exemplified by eastern Libya.
- ❖ Sex had no effect on stomach fullness, but season and site had. Stomach fullness increased as the crab grew.
- ❖ Food abundance by type in the stomach of the crab was in the following order: cnidaria and algae > crustacea > mollusca > seaweed. The abundance of food by season was: fall > spring > winter > summer.
- ❖ Mollusca and crustacea were absent from the stomachs of Susah crabs, algae and seaweed were absent from the stomachs of Al-Hannah and Al-Hamamah crabs.
- ❖ Younger crabs were more dependent on cnidaria. Consumption of mollusks and crustacea increased as the crab grew. Large crabs did not consume algae. Sand and detritus were not observed in any of the stomachs.
- ❖ The qualitative and quantitative spatiotemporal availability of food items in the rocky intertidal and its relation to the feeding habits, and growth, of the crab were discussed. Across all sites and seasons, cnidarians were the most abundant food item in the crab habitat.

Recommendations

Pachygrapsus marmoratus is a common crab in the rocky littoral zone of eastern Libya where it is an omnivore on algae and seaweed (the main primary producers of the intertidal and shallow sub-tidal regions), and cnidarians, crustaceans and mollusks, (the most common animals of tropical rocky shores). Therefore, we recommend the execution of studies on the specific and integrative roles that this crab, the co-inhabiting animals, and the prevailing environmental factors, play in shaping the rocky shore community.

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