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Morphology and age cohorts of *Pachygrapsus marmoratus* (Grapsidae) in the southern Mediterranean Sea

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ABSTRACT: *The aim of this work was to establish morphological traits of P. marmoratus inhabiting the rocky intertidal zone of the southern Mediterranean Sea coast. 457 P. marmoratus collected randomly from the AL-Haniyah, Al-Hamamah, and Susah sites, eastern Libya, during 2019 were used in the study. The largest carapace length (CL) and weight (WW) were 35.1cm and 31.0g, respectively, while the minimums were 8.50cm and 0.40g. The means were 24.5cm and 10.2g. The order of WW by season was: winter and spring > fall > summer; by site: Al-Haniyah > Susah > Al-Hamamah; males being heavier than females. The WW-CL relationship was* $WW=0.001*CL^{**2.817}$; R^2=0.909. *The condition factor of P. marmoratus was highest in spring and lowest in summer, highest in Al-Haniyah and Susah and lowest in Al-Hamamah, and similar for both sexes, it increased in a negative allometric manner as the crab grew. The morphometrical parameters of male P. marmoratus were higher than those of females. Most morphometrical parameters scored higher values in winter and spring, followed by fall, and summer, with Al-Haniyah and Susah parameters being higher than the Al-Hamamah ones. Temporal and spatial variations of the morphometric parameters were discussed in terms of the availability of food and prevailing environmental conditions. Regressions of females and males P. marmoratus morphometric parameters with CL were strong and positive. Bilateral dimorphism was not observed. Four-year age groups, +1 (11-12mm), +2 (16-18mm), +3 (25-26mm) and +4 (32-33mm), comprised the P. marmoratus population.*

KEYWORDS: morphology, morphometry, Pachygrapsus marmoratus, Mediterranean, Libya.

INTRODUCTION

Morphological, anatomical, physiological, biochemical, and behavioral traits enable living organisms to thrive and reproduce in their habitats. Morphology may be defined as the physical expression of part of the cumulative genetic makeup acquired by a living organism through its adaptive evolution. It is may subdivided into morphogenic (descriptive attributes such as body shape and color), morphometric (measurable traits, e.g. body weight and lengths of its different parts), and meristic (countable features, e.g. number of rays and spines in the fins of a fish) traits.

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Crabs are decapod crustaceans with four pairs of walking legs, and a pair of frontal chelipeds (pincers). Brachyurans, true crabs, have their abdomens and short tails tucked beneath their bodies, while Anomurans, false crabs, have their abdomens and relatively longer tails extending horizontally behind their thoraxes. Many crabs show sexual dimorphism. For example, males may be larger than females, or have larger claws (Claverie and Smith. 2007, 2009, 2010; Fazhan, 2021), and their abdomens are triangular, compared to more circular ones in females (FAO, 1998); the males' gonopods originate from the first 2 pairs of pleopods (Guillermo and Rotllant, 2009). Some have a heterogeneous left-right cheliped shape and size (Croll and McClintock, 2002). Sexual dimorphism and bilateral heterogeneity are usually explained on the basis of sexual attraction, and defensive/offensive adaptations.

The marbled crab, *Pachygrapsus marmoratus* (Fabricius, 1787), is common on the rocky shores of the eastern coast of Libya's Mediterranean Sea, where it participates in shaping the distribution of the mid and lower intertidal and the subtidal zones communities. It feeds on cnidarians, gastropods, crustaceans, microalgae, and seaweed; in its turn, it is prayed by marine birds (Yousef, 2020; Yousef *et al*., 2022).

The aim of the present work was to study the morphology of *P. marmoratus* in the Southern Mediterranean Sea using the eastern Libyan coast as an example.

PROCEDURES AND METHODS

The research locations

The *Pachygrapsus marmoratus* samples used in the present study were collected from AL-Haniyah, Al-Hamamah, and Susah on the eastern Libyan Mediterranean Sea coast (Fig. 1). AL-Haniyah (32° 50' 28" N, 21° 31' 15" E), and Al-Hamamah (N 32º 55' 24" E 21º 38' 00") are small inlets that are important artisanal fishing grounds, landing sites, and resorts, Susah (21º 58' 34" E 31º 53' 32" N) is a small commercial, fishing, and recreational harbor with many preserved ancient remains (Reynolds *et al*., 1995; Ekwella, 2008; Suliman, 2018). The supra littoral zones of these sites are rocky, with intermingled small sandy beaches. The intertidal zones are alternating tongues of rocky and sandy terrain. The rocky shores are very rough with rocks, crevices, cracks, and tidal pools of various sizes, and are exposed to winds; faunal assemblages appear in the mid-zone and become richer on moving downwards. Biodiversity, particularly of microalgae algae and benthic animals, is high. Mollusks, in particular, gastropod limpets and periwinkles, tubeworm polychaetes, and crabs prevail. Patches of *Posidonia oceanica* stands are present in the upper sublittoral. Environmentally, the shores are generally clean, but municipal waste is discharged directly into the sea in the eastern part of Al-Haniyah; a desalination plant is present in the western part of Susah.

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Fig. 1. The sites from which the study crab was collected: AL-Haniyah, Al-Hamamah, and Susah inlets (Source: Suliman, 2018).

Collection of the study samples

A total of 457 *P. marmoratus* were collected randomly at night by handpicking from the rocky intertidal of the three study sites during winter, spring, summer, and fall of 2019.

Measuring the morphometric parameters of *P. marmoratus*

The specimens were identified (according to Calvin and Valdes 2000) and sexed (abdomen triangular in males and circular in females, the first 2 pairs of pleopods modified to gonopods in males *Guillermo and Rotllant, 2009); their descriptive features, and 15 key morphometric parameters, were recorded (Table 1 and Fig. 2).

Table 1. The parameters measured on individual males and females of the crab *Pachygrapsus marmoratus*. Both right and left ChL, CHW, DL, and PL were measured. Weights and lengths were taken to the nearest 0.01g and mm.

No.	Measurements	Code
1	Wet weight	WW
2	Carapace length	CL
3	Carapace width	CW
4	Optical groove width	Op
5	Abdomen length	AL
6	Abdomen width	AW
7	Chela length	ChL

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8	**Chela width**	**ChW**
9	**Dactyl length**	**DL**
10	**Propod length**	**PL**
11	**Length of gonads channel**	**Lg**

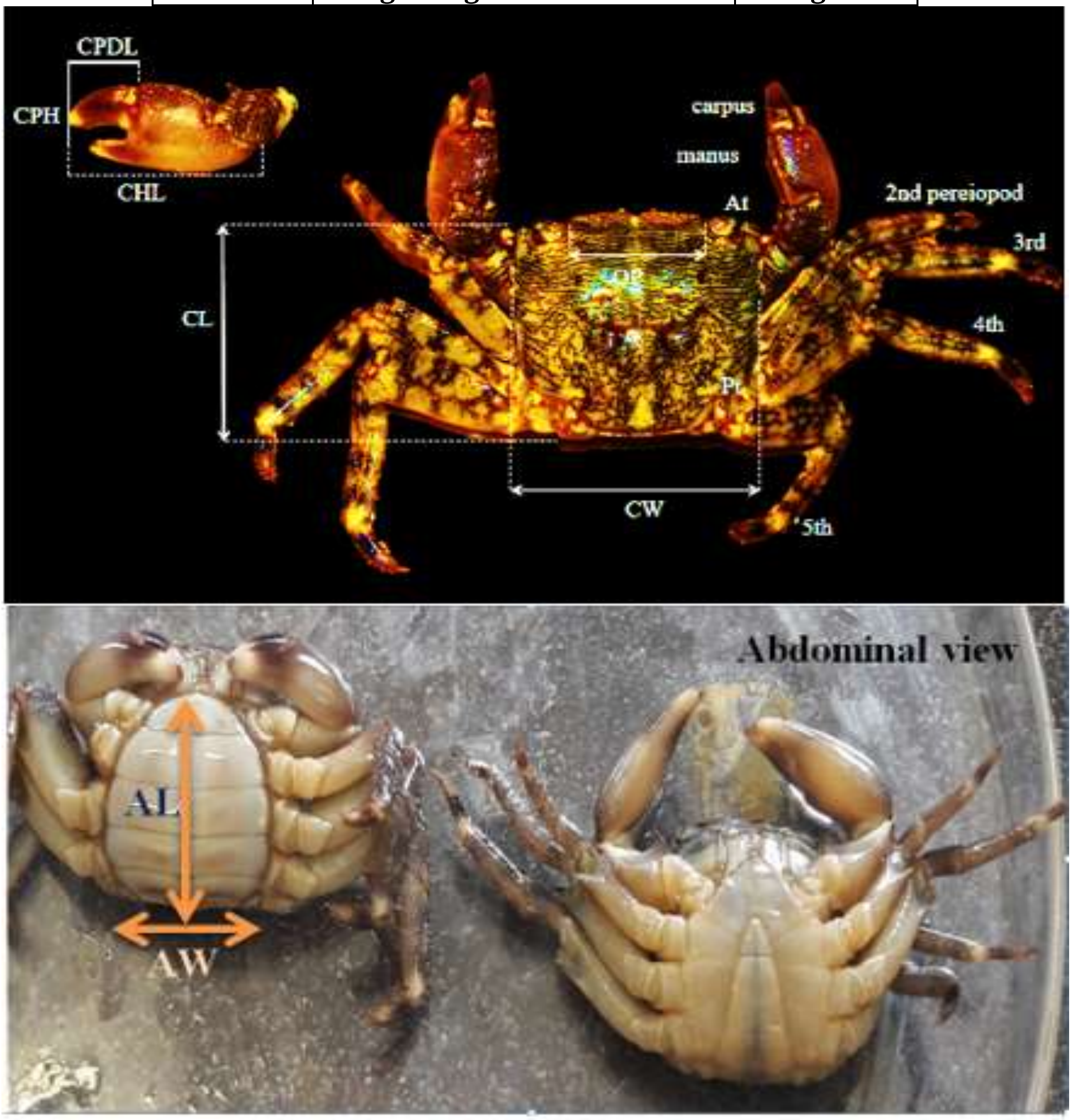

Fig. 2. Morphometrical parameters of female (left) and male (right) *Pachygrapsus marmoratus* measured in the present study (Top: Dorsal view. Bottom: Ventral view).

Assessing allometric changes occurring during the growth of the crab

The measured morphometric parameters were related to crab wet weight, carapace length, and carapace width (as indicators of body size, and hence, growth) to infer how these parameters change allometrically during the growth of the crab. In this context, Pearson's correlations, and linear and power regressions, were used.

Pachygrapsus marmoratus length-weight relationship

Linear (WW = a + b*x), power (WW = a*x^b), and logarithmic (WW = a + b*log(x)) relationships were estimated for both sexes according (Pauly, 1983), where x is the CL or CW in mm, WW in gm, and "a" and "b" are the regression constants.

Pachygrapsus marmoratus specific condition factor

The specific condition factor (weight per one centimeter of carapace length) was calculated as WW in g/CL in cm.

Age groups (cohorts) within the *Pachygrapsus marmoratus* population

Age groups (in years) of male and female crabs within the population were estimated using the frequency distribution of pooled carapace lengths (males and females separate) according to Pauly (1983).

Statistics

Descriptive and inferential statistics, graphics, tabulation, and figures were performed with Excel and the "R" packages.

RESULTS

The morphogenic features of the crab are shown in Fig. 2. *P. marmoratus* collected from AL-Haniyah and Susah had short algae attached to its chela. This was not seen on Al-Hamamah crabs. In ventral view, female crabs had circular abdomens and males had triangular ones (Fig. 2). The number of anterior teeth was 3 in all crabs. There were no posterior teeth.

The minimum, mean (± St E), and maximum carapace lengths were 8.5, 24.5 ± 0.7, and 35.1cm, respectively, with wet weights of 0.40, 10.2 ± 0.8, and 31.0g. According to season, the order of carapace length was: winter and spring > fall > summer (Table 2). According to sites, it was: Al-Haniyah and Susah > Al-Hamamah. The carapace lengths of females and males were not significantly different. Interaction of carapace length by season and site was significant, that between season and sex, site and sex, and interaction by season, site and sex, was not significant (tables not shown). The distribution of carapace length by season, site, and sex is given in Fig. 3.

Table 2. *Pachygrapsus marmoratus* mean carapace length (± St E) by season, site, and sex. Means with different superscripts across columns are significantly different.

Season			Site			Sex		
Season	**Mean**	**St E**	**Site**	**Mean**	**St E**	**Sex**	**Mean**	**St E**
Winter	26.3[a]	0.39	**Al-Hamamah**	22.5[b]	0.36	**Female**	24.1[a]	0.30
Spring	26.0[a]	0.37	**Al-Haniyah**	25.8[a]	0.34	**Male**	25.0[a]	0.31
Summer	22.0[c]	0.34	**Susah**	25.4[a]	0.36			
Fall	24.0[b]	0.75						

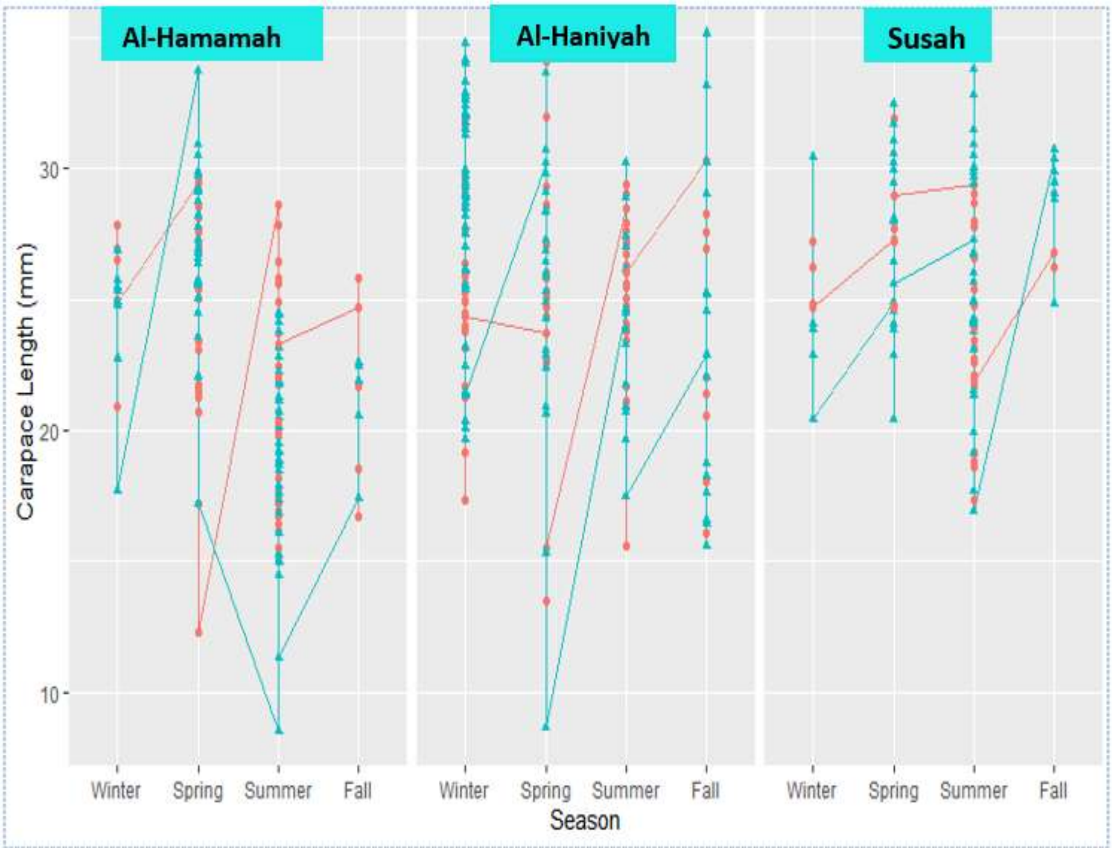

Fig. 3. *Pachygrapsus marmoratus* carapace length distribution by season, site, and sex (Males: turquoise dots/lines, Females: red dots/lines).

According to season, the order of wet weight was: winter > spring > fall > summer (Table 3 and Fig 4). According to sites: Al-Haniyah > Susah > Al-Hamamah. Males were significantly heavier than females. The interaction between weight and season and site was significant; that between season and sex and site and sex was not significant; but the interaction between season, site, and sex was significant (tables not shown).

Table 3. *Pachygrapsus marmoratus* mean wet weight (± St E) by season, site, and sex. Means with different superscripts across columns are significantly different.

Season			Site			Sex		
	Mean	**St E**		**Mean**	**St E**		**Mean**	**St E**
Winter	11.90^{a}	0.55	**Al-Hamamah**	8.18^{c}	0.38	**Male**	11.0^{a}	0.37
Spring	11.85^{a}	0.43	**Al- Haniyah**	11.68^{a}	0.41	**Female**	9.2^{b}	0.28
Summer	8.06^{c}	0.32	**Susah**	10.64^{b}	0.43			
Fall	10.07^{b}	0.85						

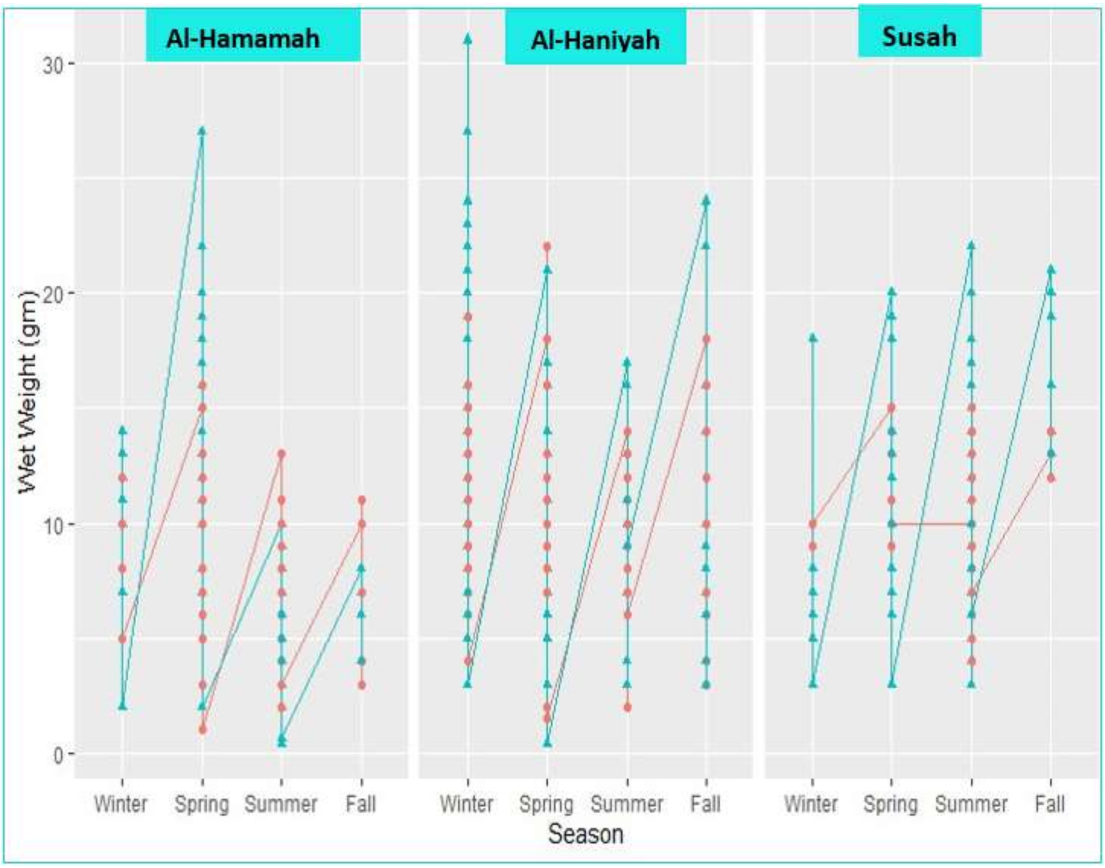

Fig. 4. *Pachygrapsus marmoratus* wet weight by season, site, and sex (Males: turquoise dots/lines, Females: red dots/lines).

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Carapace length-wet weight relationships
The linear, power, and logarithmic regressions of carapace length-wet weight generated in the present study predicted the relationship for females (Fig. 5) and males (Fig. 6) *P. marmoratus* very well.

This was deduced from their high R^2 values, which ranged from 0.846 to 0.909 for males, and 0.846 to 0.916 for females. However, the power regression was more powerful as it is the one that has the highest R^2 among the three regressions. The regression constants "a" and "b" were significant in most cases. The b values of the power regression, 2.41 for females, and 2.817 for males, were less than 3 (the theoretical value for isometric growth), indicating negative allometric growth, especially for females.

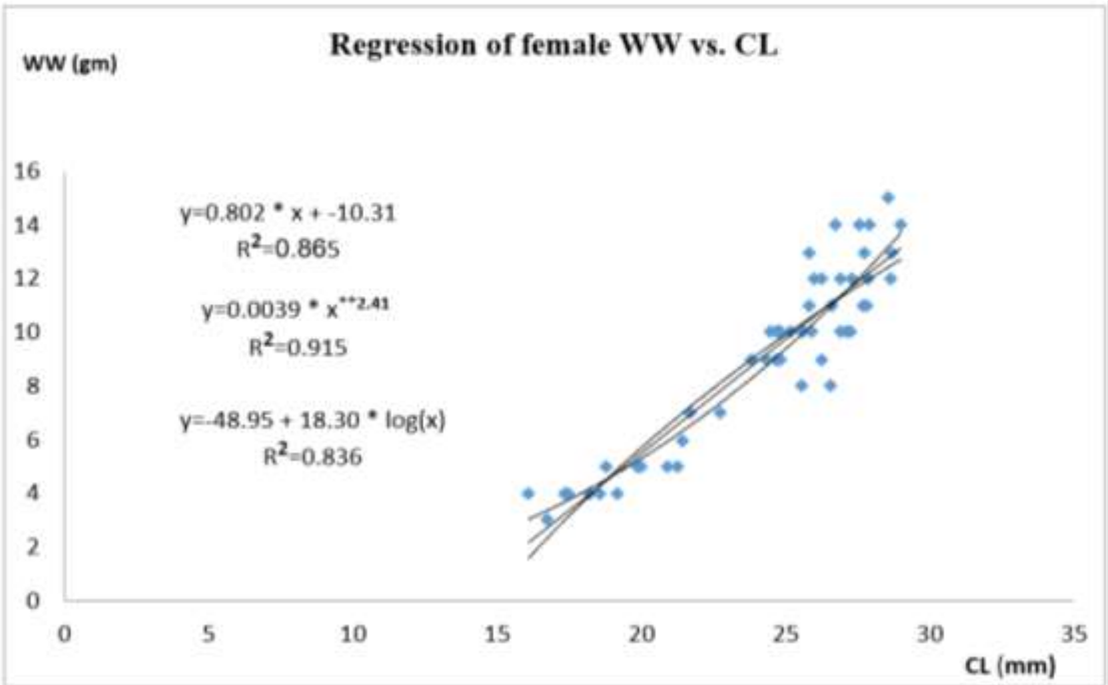

Fig. 5. Female *Pachygrapsus* regression of wet weight (WW) vs. carapace length (CL).

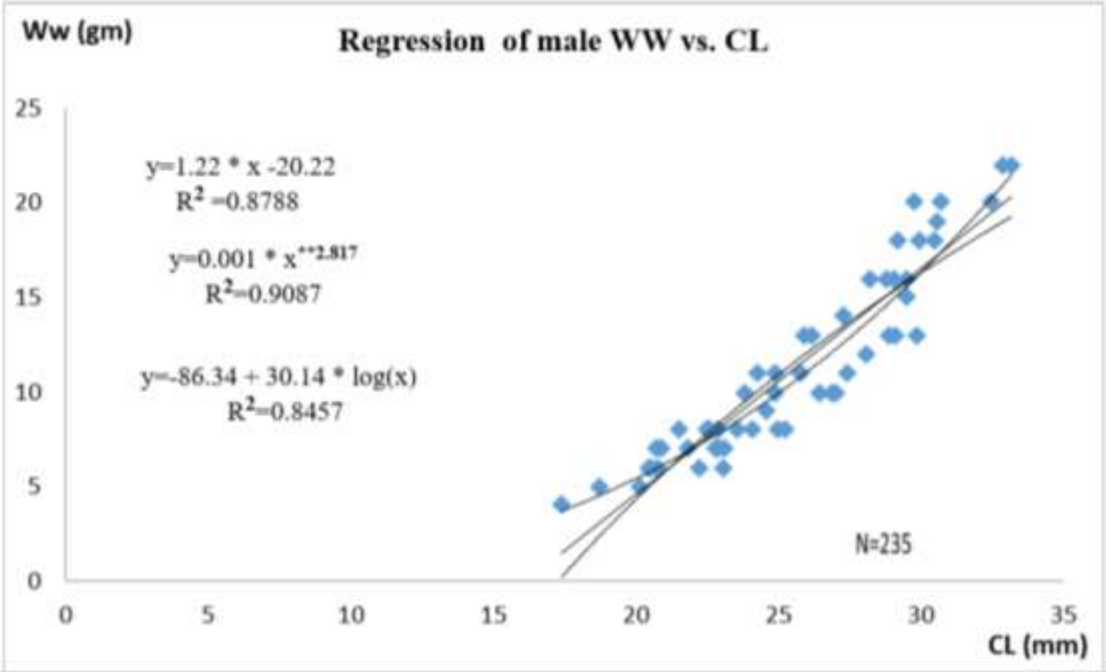

Fig. 6. Male *Pachygrapsus marmoratus* regression of wet weight (WW) vs. carapace length (CL).

The condition factor of *Pachygrapsus marmoratus*

The condition factor was significantly highest in spring and lowest in summer (Table 4), highest in Al-Haniyah and lowest in Al-Hamamah, and was not affected by sex.

Regressions of the condition factor with carapace length (Fig. 7) shows that the condition of the crab improved with growth at a negative allometric trend, the "b" value of the power regression was 2.76 (R^2: 0.92), which was less than 3, the theoretical value for isometric growth.

Table 4. *Pachygrapsus marmoratus* mean condition factor (± St E) by season, site, and sex. Means with different superscripts along rows are significantly different.

Season	**Winter**	**Spring**	**Summer**	**Fall**
	$3.9±0.78^{b}$	$4.5±0.9^{c}$	$3.4±0.6^{a}$	$4.3±0.86^{bc}$
Site	**Al-Haniyah**	**AL-Hamamah**	**Susah**	
	$4.4±0.88^{b}$	$3.5±0.70^{a}$	$4.2±0.84^{b}$	
Sex	**F**	**M**		
	$3.7±0.75^{a}$	$4.3±0.86^{a}$		

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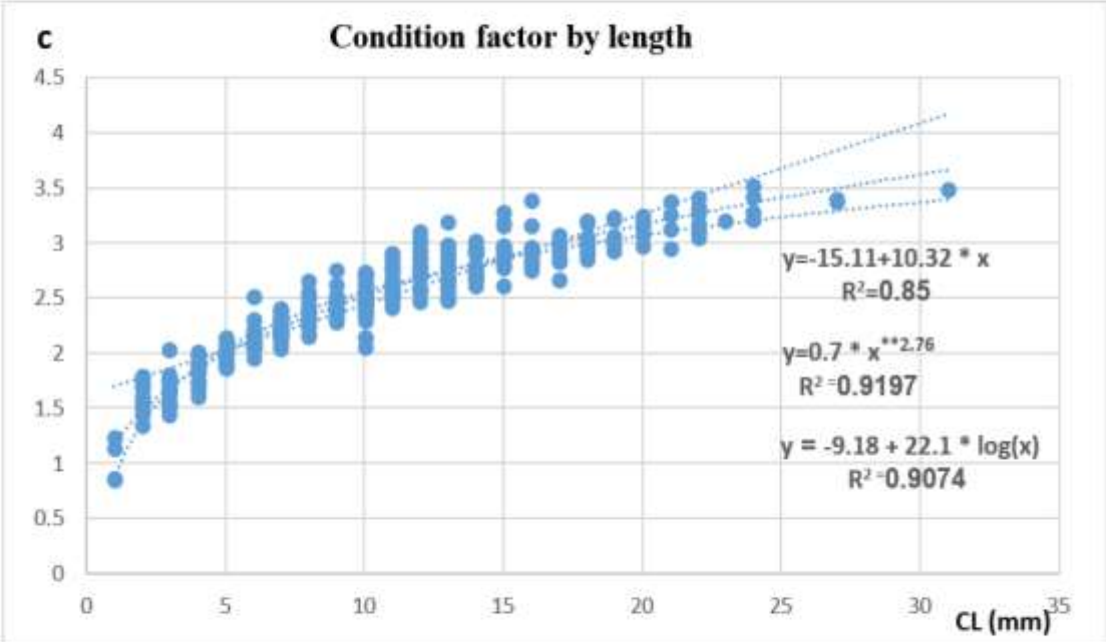

Fig. 7. *Pachygrapsus marmoratus* condition factor (C) vs. carapace length (pooled data: irrespective of season, site, or sex).

Morphometric parameters of *P. marmoratus*

Morphometric parameters of *P. marmoratus* (other than wet weight and carapace length which were presented earlier) by season are shown in Table 5. These parameters generally scored higher values in winter, followed by spring, but the differences between the two seasons were not significant for most parameters. Fall, then summer, values followed after, but differences were not significant for many parameters.

Values of all the parameters of *P. marmoratus* from Al-Haniyah and Susah were significantly higher than those of *P. marmoratus* from Al-Hamamah, however, they were not significantly different from each other (Table 6).

All males *P. marmoratus* parameters were significantly higher than those of the females (Table 7).

Table 5. Mean (±St E) morphometric parameters of *P. marmoratus* (weight or length) by Season.

Parameter	Winter	Spring	Summer	Fall
CW	28.0^{a}±0.434	27.7^{a}±0.404	24.3^{c}±0.365	25.7^{b}±0.762
Op	16.4^{a}±0.232;	16.0^{a}±0.222	14.1^{b}±0.208	14.7^{b}±0.471
AL	15.9^{a}±0.277	16.1^{a}±0.309	14.1^{b}±0.256	14.3^{b}±0.525
AW	14.7^{ab}±0.451	15.5^{a}±0.458	14.2^{bc}±0.389	13.6^{c}±0.722
Right ChL	20.0^{a}±0.436	18.7^{b}±0.383	15.5^{d}±0.285	17.3^{c}±0.819
Right ChW	10.22^{a}±0.233	9.89^{a}±0.248	7.88^{c}±0.158	8.85^{b}±0.451
Right DL	11.53^{a}±0.279	10.85^{a}±0.218	8.93^{c}±0.166	9.96^{b}±0.531
Right PL	19.8^{a}±0.428	18.5^{b}±0.378	15.4^{d}±0.284	16.7^{c}±0.797
Left ChL	20.1^{a}±0.461	18.9^{b}±0.389	15.5^{d}±0.287	17.3^{c}±0.811
Left ChW	10.18^{a}±0.235	9.65^{a}±0.221	7.84^{c}±0.168	8.97^{b}±0.451
Left DL	11.89^{a}±0.288	11.04^{b}±0.237	9.02^{d}±0.178	10.23^{c}±0.538
Left PL	20.0^{a}±0.475	18.8^{b}±0.388	15.4^{d}±0.287	17.0^{c}±0.757
Lg	11.1^{a}±0.383	11.5^{a}±0.391	10.0^{b}±0.301	10.6^{ab}±0.606

Table 6. Mean (± St E) morphometric parameters weight or length of *P. marmoratus* by site (Al-Hamamah, Al-Haniyah and Susah).

Parameter	Al-Haniyah	Al-Hamamah	Susah
CW	27.6^{a}±0.367	24.0^{b}±0.379	27.2^{a}±0.396
Op	15.9^{a}±0.203	14.0^{b}±0.215	15.8^{a}±0.239
AL	15.9^{a}±0.247	13.8^{b}±0.283	15.5^{a}±0.268
AW	15.2^{a}±0.372	13.5^{b}±0.388	15.1^{a}±0.473
Right ChL	18.7^{a}±0.365	15.8^{b}±0.348	18.4^{a}±0.354
Right ChW	9.77^{a}±0.214	8.08^{b}±0.198	9.37^{a}±0.193
Right DL	10.88^{a}±0.231	9.11^{b}±0.203	10.53^{a}±0.199
Right PL	18.5^{a}±0.361	15.6^{b}±0.342	18.3^{a}±0.350
Left ChL	18.7^{a}±0.378	15.9^{b}±0.350	18.6^{a}±0.373
Left ChW	9.59^{a}±0.206	8.00^{b}±0.188	9.45^{a}±0.211
Left DL	11.04^{a}±0.240	9.22^{b}±0.205	10.94^{a}±0.239
Left PL	18.6^{a}±0.376	15.8^{b}±0.349	18.5^{a}±0.374
Lg	11.08^{a}±0.307	9.99^{b}±0.326	11.21^{a}±0.382

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Table 7. Mean (± St E) morphometric parameters weight or length of *P. marmoratus* by sex (female and male).

Parameter	Female	Male
CW	25.8[a] ±0.315	26.6[b]±0.336
Op	14.9[a] ±0.178	15.5[b]±0.190
AL	16.3[a] ±0.236	14.1[b]±0.198
AW	18.5[a] ±0.296	11.5[b]±0.192
Right ChL	15.7[a] ±0.217	19.2[b]±0.322
Right ChW	7.95[a] ±0.126	10.00[b]±0.183
Right DL	9.03[a] ±0.133	11.10[b]±0.194
Right PL	15.5[a] ±0.217	19.0[b]±0.317
Left ChL	15.7[a] ±0.217	19.3[b]±0.334
Left ChW	7.91[a] ±0.119	9.88[b]±0.182
Left DL	9.16[a] ±0.135	11.37[b]±0.208
Left PL	15.6 a ±0.216	19.2[b]±0.333
Lg	13.45[a] ±0.274	8.57[b]±0.181

Components of right and left chelipeds of *Pachygrapsus marmoratus*

The lengths of individual components of the right and left chelipeds (ChL, DL, and PL) were not significantly different (Table 8). Means of fall, spring, and winter were not different but differed significantly from the summer ones (Table 9a). The means of Al-Haniyah and Susah were not significantly different but were significantly higher than those of Al-Hamamah (Table 9b). The effect of sex on chelipeds components was not significant (Table 9c).

Table 8. The mean length of *Pachygrapsus marmoratus'* right and left chelipeds components: means are not significant (Ns)**.**

	Code	No.	Mean	St E	Sig.
ChL	**Right**	425	17.20	0.21	**Ns**
	left	425	17.27	20.2	
ChW	**Right**	425	8.88	0.12	**Ns**
	left	425	8.78	0.12	
DL	**Right**	425	9.92	0.12	**Ns**
	left	425	10.44	0.27	
PL	**Right**	425	17.01	0.21	**Ns**
	left	425	17.24	0.23	

Table 9a. The effect of season on chelipeds' components of *Pachygrapsus marmoratus*.

Effect of season on chelipeds components (mean ± St E)				
Parameter	**Fall**	**Spring**	**Summer**	**Winter**
ChL	18.67±2.05^b	19.63±2.15^b	16.06±1.76^a	18.65±0.93^b
ChW	9.31±0.931^b	10.2±1.02^c	8.19±0.81^a	9.52±0.95b^c
DL	10.58±1.03^b	11.34±1.11^b	9.36±0.91^a	10.84±1.06^b
PL	18.8±1.99^b	19.54±2.14^b	15.93±1.75^a	18.5±2.03^b

Table 9b. The effect of site on chelipeds' components of *Pachygrapsus marmoratus*.

Effect of site on chelipeds components (mean ± St E)			
Parameter	**Al-Hamamah**	**Al-Haniyah**	**Susah**
ChL	16.77±1.84^a	18.76±2.06^b	19.23±2.11^b
ChW	8.5±0.85^a	9.64±0.96^b	9.78 ±0.97^b
DL	9.66±0.94^a	11.01±1.07^b	10.93±1.07^b
PL	16.49±1.81^a	18.49±2.03^b	19.14±2.10^b

Table 9c. The effect of sex on chelipeds' components of *Pachygrapsus marmoratus.*

Effect of sex on chelipeds components (mean ± St E)		
Parameter	**F**	**M**
ChL	16.4±1.80^a	20.11±2.21^a
ChW	8.22±0.82^a	10.39±1.03^a
DL	9.42±0.94^a	11.65±1.14^a
PL	16.27±1.78^a	19.81±2.17^a

Regressions of the morphometric parameters with CL (carapace length)

The linear, power and logarithm regressions of the morphometric parameters of females and males *P. marmoratus* with CL represented the relationship with equal strength {Table 10). This was deduced from their comparable high R^2 and the strong significance of the intercept "a" and the slope "b" of their regression lines. However, in general, the power regressions were more significant than the linear and logarithmic ones.

Table 10. Regression of morphometric parameters weight or length of *P. marmoratus* with carapace length (CL).

Parameter	Regression	Female			Male		
		a	b	R^2	a	b	R^2
CW	Liner	0.95	1.02*	0.968	1.06*	0.01*	0.96
	power	1.25*	0.94**	0.9662	1.11*	0.98**	0.96
	log	-48.1	23.2*	0.9522	58.7	26.6*	0.95
Op	Liner	1.2	0.57*	0.8974	1.09	0.58*	0.94
	power	0.8*	0.9**	0.9019	0.79*	0.94**	0.95
	log	-25.1	12.6*	0.8825	-25.01	12.7*	0.87
AL	Liner	-17.1	0.75*	0.8783	0.097	0.56*	0.88
	power	0.42*	1.15**	0.8912	0.52*	1.02**	0.91
	log	-36.8	16.8*	0.8773	-25.5	12.4*	0.86
AW	Liner	-3.15	0.93*	0.8773	0.77	0.41*	0.93
	power	0.31*	1.29	0.8623	0.51*	0.95**	0.93
	log	-47.3	20.9*	0.8826	-18.14	9.14*	0.91
ChL	Liner	360	0.50*	0.7814	-2.89	0.88*	0.77
	power	1.39*	0.76**	0.8218	0.51*	1.12**	0.75
	log	-20.56	11.47*	0.7886	-51.3	22.01*	0.75
ChW	Liner	2.20	0.23*	0.6065	-1.40	0.45*	0.72
	power	0.83*	0.70**	0.6746	0.29*	1.08**	0.69
	log	-10.8	6.2*	0.6277	-26.16	11.26*	0.69
DL	Liner	2.3	0.28*	0.7068	-1.19	0.49*	0.71
	power	0.98*	0.69**	0.7572	0.38*	1.04**	0.72
	log	-10.8	6.2*	0.712	-28.0	12.2*	0.72
PL	Liner	3.07	0.52*	0.7758	-0.84	0.79*	0.74
	power	1.24*	0.79**	0.7961	0.65*	1.04**	0.73
	log	-21.9	11.83*	0.7758	-44.8	19.8*	0.73
Lg	Liner	-0.68	0.63*	0.6308	0.48	0.29*	0.81
	power	0.49*	1.06**	0.6262	0.27*	1.04**	0.81
	log	-32.5	14.8*	0.6422	-13.6	6.69*	0.81

Aging of *P. marmoratus*

Length and weight frequency distribution of pooled individual carapace lengths and weights (of all the studied 457 *p. marmoratus* irrespective of season, site or gender)

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suggested four-year age groups for the crab population: +1, +2, +3 and +4 (Fig. 8). Mean carapace length of these groups are given in Table 11.

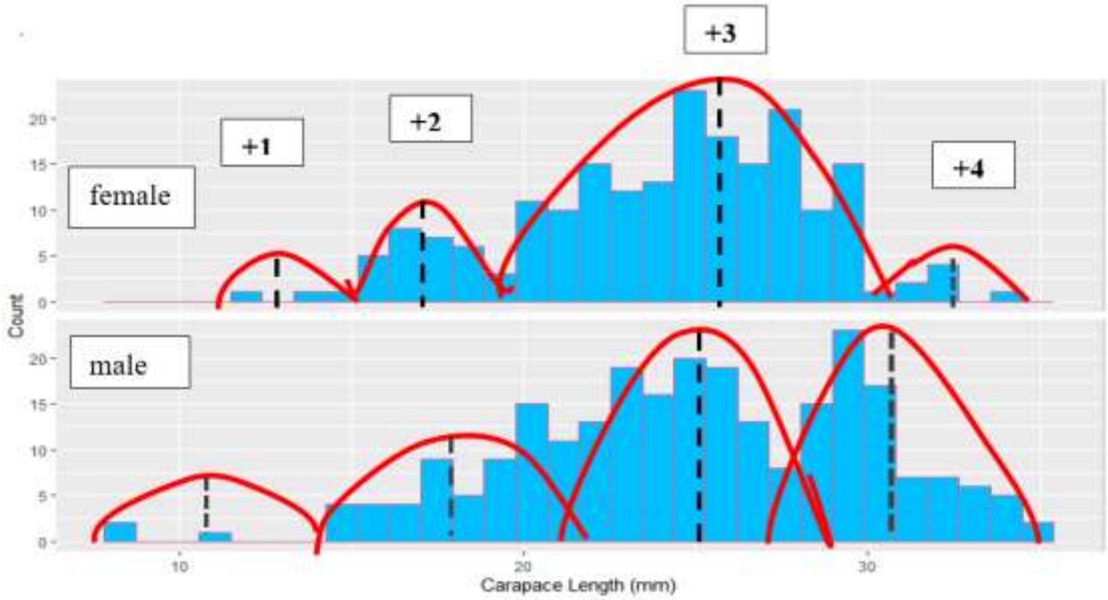

Fig. 8. Frequency distribution of carapace length and cohort groups.

Table 11. Age groups of males and females of *P. marmoratus* and corresponding carapace length (mm).

Age group (years)	female	male
+1	12	11
+2	16	18
+3	26	25
+4	33	31

DISCUSSION

The carapace length (CL), and wet weight (TW), of *Pachygrapsus marmoratus* of the present study ranged from: 8.5 to 35.1mm, and 0.4 to 31.0g, respectively. The corresponding means were 24.5mm and 10.2g; 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; Aydın 2018; and Yousef, 2022.

The CL-TW relationship in the present study was established by means of three regressions: linear, logarithmic, and power. The three regressions predicted the relationship on equal levels, though the power was slightly better than the others. The b value of the power regression, 2.817, indicated negative allometric growth (CL increased at a faster rate than TW as the animal increased in size) since it was less than 3, the theoretical value for isometric growth where CL and TW increase at similar rates. Most previous studies on *P. marmoratus* reported negative allometric growth (Sümer *et al*., 2016; Sümer *et al*., 2016; Selimolu, 1997; and Aydn, 2018). Aydın *et al*. (2014), however, reported "b" values of CW and W for male and female crabs as 3.1 and 3.06, respectively, indicating isometric growth.

In the present study, the condition factors (C) of males and females were not significantly different. The level of C was significantly higher in spring and lower in summer, possibly because more food was available in spring (spring-blooming) than in summer, and it was highest in Al-Haniyah and Susah, and lowest in Al-Hamamah; the reason for this contrast is not clear. Sümer *et al*. (2016) established that the C of *P. marmoratus* in the southern Black Sea (Sinop, Turkey) was highest in March and lowest in August. In the present study, regression of the C with CL indicated a slight improvement of condition with growth (but at negative allometric increase). Possibly, this reflected the increased ability of the crab to obtain food as it grew. Yousef *et al*., (2022) found that *P. marmoratus* depends more on animal food as it grows.

In the present study, values of all morphometric parameters of males *P. marmoratus*, other than CL, were significantly higher than female's ones. This sexual dimorphism is in agreement with Sumer *et al* (2016) and Pezy and Dauvin1 (2015) who found that *P. marmoratus* males were larger than females. In the present study, in general, power linear and logarithmic regressions of the crab morphometric parameters with carapace length were positive and highly significant. Generally, magnitudes of these parameters followed the order: winter > spring > fall > summer, Al-Haniyah and Susa > Al-Hamamah. Single and combined interactions of season, site and sex on morphological traits of *P. marmoratus* were complex and did not follow simple trends. Yousef (2020), and Yousef *et al*. (2022**)** showed that qualitative and quantitative availability of *P. marmoratus* food items at Al-Hamamah, Al-Haniyah and Susa differed temporally and spatially, and, accordingly, can affect the growth rate of the crab. This, in addition to anthropogenic activity, pollution, and irrational exploitation of resources, play a role in shaping the morphometric plasticity of *P. marmoratus* in rocky intertidal shores (Michaud and Echternacht 1995, Meiri 2010, Deli *et al*. 2017, Yousef 2020, and Yousef *et al*. 2022).

In the present study, mean lengths of individual components of right and left chelipeds (ChL, ChW, DL, and PL) of *P. marmoratus* were not statistically different. The effect of seasons and site on chelipeds sizes was statistically positive in some cases. This is possibly an expression of differences in size of individual *P. marmoratus* found at different sites and different seasons. The crabs examined in the summer and in Al-Hamamah were smaller than crabs examined in the other seasons and sites, and

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consequently, their chelipeds components were smaller as well. The effect of sex on the length of chelipeds on the right hand compared to the left hand was insignificant. Protopapas *et al.* (2007) studied the relative growth of *P. marmoratus* using an information-theory approach. They reported that no differentiation in allometric growth was detected between right and left chelar propods in either sexes; initially, there were no differences in the size of the chelar propods between males and females, but as the crabs grew larger, males attained significantly larger propods. Deli *et al*. (2017) concluded that several biotic and abiotic factors may be involved in shaping the tendency to morphological diversity and polymorphism in crab species in different sites. In the present study, all regressions of lengths of chelipeds components vs. carapace length had high coefficients of determination (R^2). The regression constant "b" was positive in all cases and highly significant, meaning that chelipeds components grew at a faster rate than the rate at which the crab body grew, suggesting that bigger animals need to be better equipped for catching food than smaller ones to cope with the increasing demand.

In the present study, length frequency distribution of *P. marmoratus* population suggested four age groups for the crab population (+1, +2, +3 and +4 years). Flores and Paula (2002) determined the life span of *P. marmoratus* in the central Portuguese as up to four years, probably more in males, which agrees with results of the present study.

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