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Research Article

Population dynamics of *Parapenaeus longirostris* (Decapoda: Penaeidae) (Lucas, 1846), in Central Algerian waters (South-Western of Mediterranean Sea)

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Abstract

The deep-water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846), has an important economic value in the Algerian market. This work aimed to fill the knowledge gap on the species through the study of growth, mortality, and exploitation rate. The samples of *P.longirostris* were collected monthly in the Bou-Ismail Bay from 2016 to 2018. The carapace length (CL) of the females and males ranged from 15 to 43 mm and 14 to 38 mm with averages of 28.99±4.76 mm and 25.82±3.92, respectively. The species shows a sexual size dimorphism. The CL and total weight relationship established that growth in both sexes was negatively allometric. The Von Bertalanffy Growth Function parameters for females and males were $CL\infty$=48.80 mm, K=0.60 $year^{-1}$, and $CL\infty$=41.40 mm, K=0.62 $year^{-1}$, respectively. The instantaneous rates of total mortalities (Z) were 2.66 $year^{-1}$ for females and 2.03 $year^{-1}$ for males. The exploitation rates were 0.66 and 0.49 for females and males, respectively. The length at first capture for males and females is equal to 16.30 mm, 17.14 mm, respectively. The result indicates a beginning of the overfishing situation for *P. longirostris*. Thus, it encourages undertaking stock assessment studies in the area.

Keywords: Growth, Mortality, Exploitation rate, *Parapenaeus longirostris*, Bou-Ismail Bay, Fishing

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Introduction

The decapod crustacean *Parapenaeus longirostris* (Lucas, 1846) commonly name deep water rose shrimp is an epibenthic shrimp, belonging to the Penaeidae family. In the Mediterranean and its adjacent seas (Sea of Marmara), the species present a wide geographic distribution, on mud and sand bottoms at depth of 20 to750 m (Politou *et al*., 2005). Froglia (1982) found its greatest abundance between 200 and 350 m.

The deep water rose shrimp is one of the most important commercial crustaceans, being the fourth in importance when considering the bottom trawl landing composition in the western Mediterranean Sea (FAO, 2018). Thus, the species has attracted the interest of several scientific research programs (MEDITS, 2017) and where it has been classified by the General Fisheries Commission for the Mediterranean (GFCM, 2018) as a target species for fisheries stock assessment plans. However, researches on *P. longirostris* in the Mediterranean Sea are sparse and the data are fragmentary. This species has been studied in different areas such as Spain (García-Rodríguez et al., 2009; Sobrino et al., 2005, 2000), Italy (Arculeo et al., 2014; Ragonese and Bianchini, 2006; Rinelli et al., 2005), Greece (Kapiris *et al*., 2007, 2013), Egypt (Abdel-Razek *et al*., 2006), Turkey (Bayhan *et al*., 2005; Manaşirli *et al*., 2011), Mediterranean Coast of Moroco (Awadh and Aksissou, 2020) and Algerian waters (Nouar and Maurin, 2001; Bekadja *et al*., 2009; Nouar *et al*., 2011).

In Algerian waters, *P.longirostris* is one of the essential commercial shrimps and represents twenty percent of all crustacean landings (FAO, 2016). It is exploited by bottom trawlers, all the year from 200 to 400 m (Nouar and Maurin, 2001). Landings from 1970 to 2016 expressed large fluctuations, with a general upward trend, an average of 300 tonnes per year of landings (FAO, 2016). The species has a high commercial value and is highly appreciated by Algerian consumers. Consequently, it is in great demand on the market and is targeted by trawlers.

Despite the importance of the fishery, the population dynamics and stocks assessment of *P. longirostris* in Algeria are poorly known. Hence, this study aims to elucidate some aspects related to the growth and exploitation rate of *P. longirostris* in the central region of the Algerian waters, which could be considered as a step toward the enhancement of the fisheries assessment, and management of deep water rose shrimp in the indicated area.

Materials and methods

Study area and sampling

This study was carried out in Bou-Ismail Bay located in the South-Western Mediterranean Sea, which remains one of the most important areas in the central region of the Algerian waters and is located between 36.63°N, 2.40°E and 36.80°N, 2.89°E (Fig. 1).

The data used come from a sampling of rose shrimp carried out on landings in Bouharoun port. The samples examined in this study were caught by bottom trawlers operating in Bou Ismail Bay, with a nominal value of 20 mm cod-end mesh.

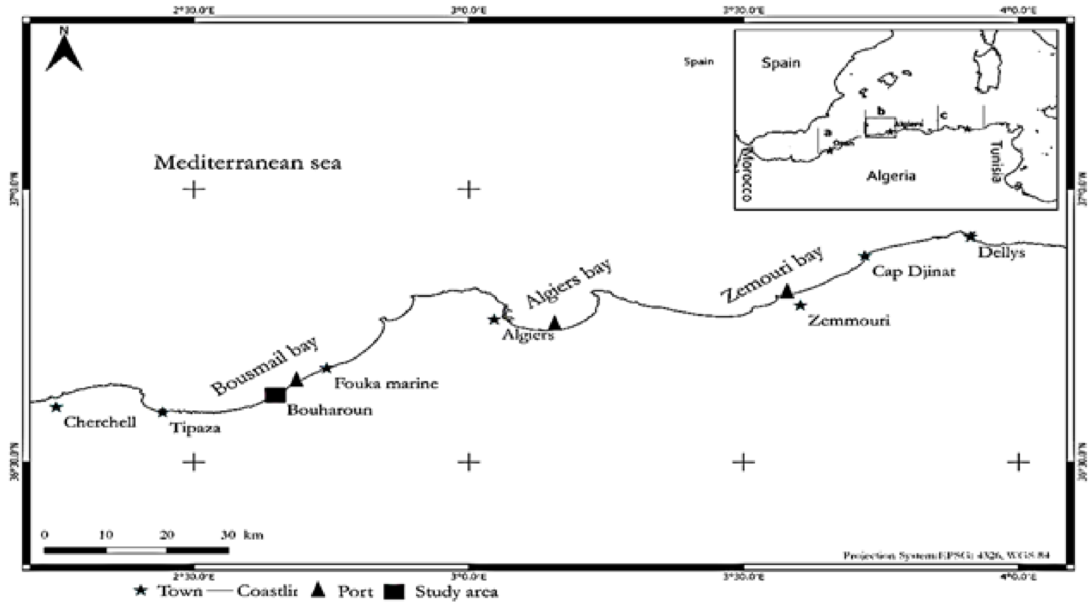

Figure 1: Map of the sampling area

Monthly samples were taken from March 2016 to April 2018 following a random scheme (Frontier, 1983) for commercial categories present in the catch. A total number of 2451 individuals (1172 females and 1279 males) of *P.longirostris* were sexed and both carapace length (CL) and total weight (TW) were recorded. CL was measured to the nearest mm (millimeters) from the posterior margin of the orbit to the posterior edge of the carapace; the total weight was determined with a technical balance to the nearest 0.1 g .

Data analysis

The difference in mean length between sexes was tested with t-test (Schwartz, 1996). Given samples from two normal populations of size n_1 and n_2 with unknown means μ_1 and μ_2 and known standard deviations σ_1 and σ_2.

$$\varepsilon = \frac{|\mu 1-\mu 2|}{\sqrt{\frac{\sigma 1^2+\sigma 2^2}{n1^2+n2^2}}}$$

If $\varepsilon < 1.96$ the difference in mean length between sexes is not significant.

If $\varepsilon > 1.96$ the difference in mean length between sexes is significant.

The length-weight relation was described by the equation (Froese, 2006; Le cren, 1951):

$TW = a\ CL^{b}$

Where TW is the total weight (g), CL is the carapace length (mm), b is is the allometric or slope parameter and a is the intercept of the regression or shape coefficient. The statistical deviation of estimated *b* from the isometric value

(3.0) was tested by Student t-test (ts) (Schwartz, 1996). When $b = 3$, the increase in weight is considered isometric. When the value of b is other than 3, the weight increase is allometric (positive allometry if $b > 3$, negative allometry if $b < 3$). The null hypothesis of isometric growth (H_0: $b = 3$) was tested by Student t-test (ts), using the formula:

$ts = |P_0 - P| / SP_0$ with: $SP_0^2 = (\sigma_x / \sigma_y)^2 - P_0^2 / n-2$

Where SP_0 is the standard error of the slope for $\alpha = 0.05$ for testing significant differences among slopes ($P_0 = b$) between two regressions; σ_x: Standard deviation of Log (CL), σ_y: Standard deviation of Log (TW), ddl= n-2.

The von Bertalanffy growth model (Von Bertalanffy, 1938) described length at age:

$$CL = L\infty * (1 - e^{-K(t - to)})$$

Where CL: cephalothoracic length of at time 't' in 'mm' , $L\infty$ is the asymptotic CL (mm), K the growth curvature parameter and t_0 is the theoretical age when shrimp would have been at zero carapace length. The special VBGF (Von Bertalanffy Growth Function) was used to estimate growth parameters by the Electronic Length Frequency Analysis I (ELEFAN I) function, by seasonally data, included in FISAT II software (Gayanilo *et al*., 2005). The initial value of $CL\infty$ was computed according to the method obtained by Powell-Wetherall (Wetherall, 1986). The selection of growth parameters was based on the result of the index of goodness (Rn) calculated as ESP/ASP, where ESP (explained sums of peaks) is the sum of all peaks and troughs through which the growth curve passes, whereas ASP (available sums of peaks) is the sum of all values of available peaks.

The ELEFAN estimates only two growth parameters (L_∞ and K), thus the third parameter (t_0) was computed by the equation of (Pauly, 1983):

$$Log_{10}(-t_0) = -0.3922 - 0.2752 \, Log_{10} L\infty - 1.038 \, Log_{10} K$$

Natural mortality (M) was estimated from the empirical equation (Pauly, 1980):

$$Log(M) = -0.0066 - 0.279 \log(L_\infty) + 0.6543 \log(K) + 0.4634 \log(T)$$

Where $L\infty$ is the asymptotic total length (cm), K is in year^{-1}, and T is the mean water temperature considered as 13°C. In the Mediterranean Sea, at depths over 200 m, the temperature is constant at 13 °C (Hopkins, 1985). Pauly's formula was constructed initially for fish species but has also given plausible estimates for prawns (Pauly *et al*., 1984).

Total mortality (Z) was then estimated using a length-converted catch curve (Pauly and Ingles, 1981). Fishing mortality (F) was derived from the difference between Z and M, and the exploitation rate (E) from fishing mortality (F) /total mortality (Z).

The probability capture curve was used to evaluate the selection parameters obtained by the FISAT II software (Gayanilo *et al*., 2005). The length at first capture (Lc) was computed from the length-converted catch curve.

Results

The results obtained by sampling 2451 shrimp individuals consisted of 1172 females and 1279 males. The mean sizes are 28.99±4.76 mm and 25.82±3.92 mm, respectively for females and males. The comparison between these two means sizes is presented in Table 1.

Table 1: Results of the t-test between the mean size of the carapace length of males and females.

Sex	CL_{min}-CL_{max} (mm)	Means (mm)	Variance	σ	ε	α
Females	15 – 43	28.99	22.64	4.76	17.90	0.05
Males	14 – 38	25.82	15.31	3.92		

CL_{min}: Minimum carapace length; CL_{max}: Maximum carapace length; σ= standard deviation; ε= t-value.

As reported in this table, the results show that the calculated value of the Student test for the two length averages (males and females) of this species (ε=17.90) is higher than the value provided by the Student's table (εt =1.96) at a risk rate α of 5%. In this case, the mean size CL (carapace length) of females (CL=28.99±0.28 mm) is significantly greater than the mean size of males (CL=25.82±0.22 mm). Hence, analyses were made for males and females, separately.

The carapace length of females ranged from 15 to 43 mm and total weight oscillated between 1.1 and 18.7g with an average of 8.6±2.6 g. While male's sizes vary from 14 to 38 mm and the total weight ranged from 1.9 to 13.9 g with an average of 5.96±1.56 g.

The seasonal length-frequency analysis for females, given by sampling 208 individuals in winter, 250 in spring, 316 in summer, and 398 in autumn, revealed that the maximum carapace length (43 mm) and the maximum total weight (18.7 g) were recorded in spring and summer and that the smallest (15 mm -1.9 g) were reported only in summer. For males, seasonal results obtained by sampling 175 individuals in winter, 406 in spring, 377 in summer, and 321 in autumn show that the maximum carapace length and maximum total weight (38 mm - 13.9 g) were recorded in spring and summer while the smallest (14 mm - 1.9 g) was recorded in summer and autumn.

Moreover, the distribution of length frequencies of males showed one and/or two well-separated modes, the 25 mm mean carapace length is maintained for the seasons, winter and summer whereas the highest mean carapace length (31 mm) is observed in spring and the lowest in autumn (23 mm) (Fig. 2). On the other hand, modal groups in females varied between two and three modal lengths with the highest mean carapace length (34 mm) in winter and the lowest in autumn (26mm) (Fig. 3).

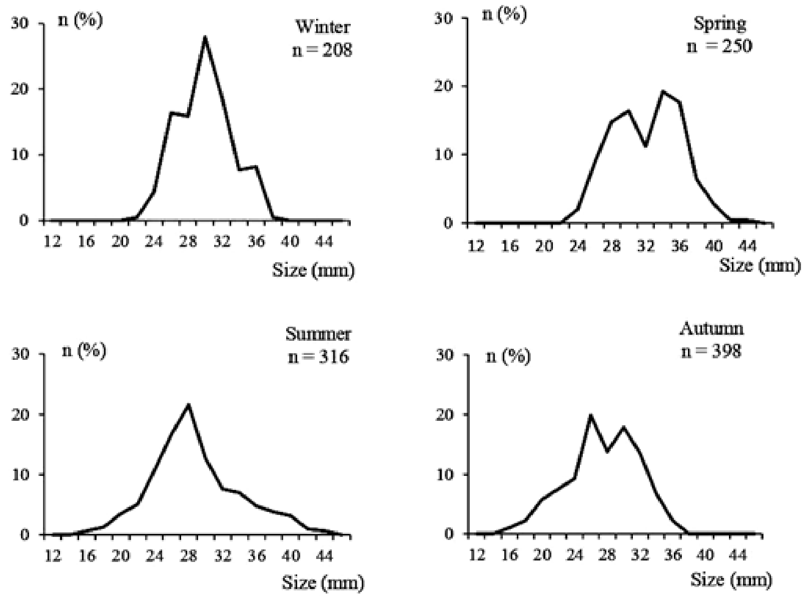

Figure 2: Seasonal carapace-length frequency distribution for females of *P.longirostris* during 2016-2018.(n (%): Relative frequency).

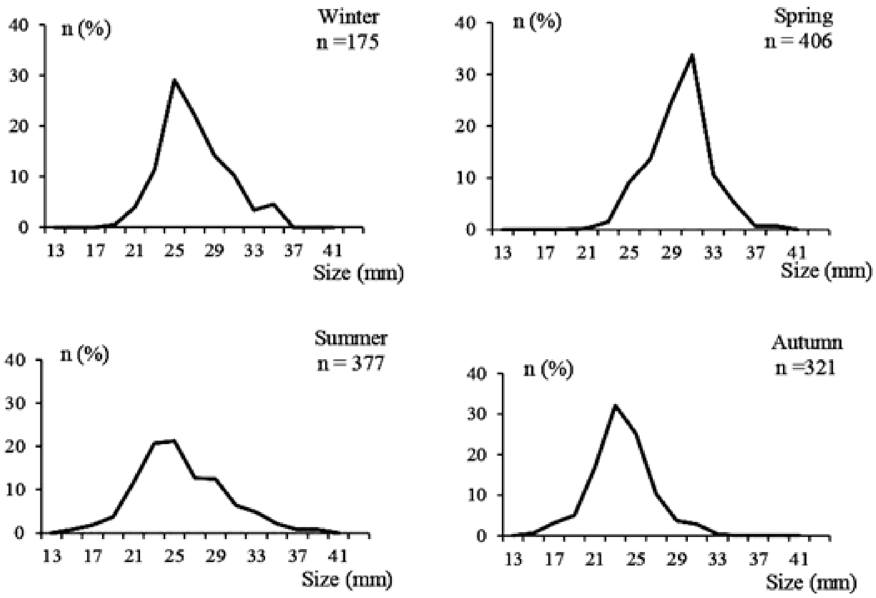

Figure 3: Seasonal carapace-length frequency distribution for males of *P. longirostris* during 2016-2018. (n (%): Relative frequency).

Length-weight relationship (CL - TW) estimated from 999 individuals (Fig. 4) illustrates (651 females and 348 males) and the results are summarized in Table 2.

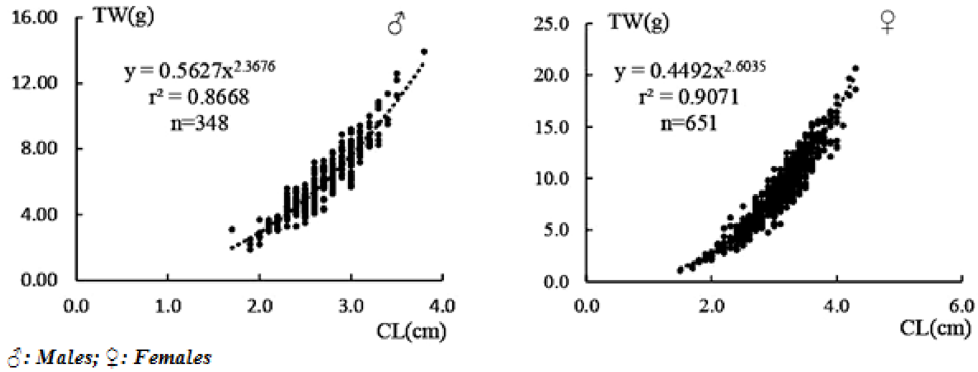

Figure 4: CL-TW relationship of *P. longirostris* in Bou Ismail bay, Algeria (2016-2018).

Table 2: Parameters of the estimated length-weight relationship for *P.longirostris.*

	N	a	b	Sb	r^2	ts
Females	651	0.449	2.60	0.03	0.91	12.12
Males	348	0.562	2.37	0.31	0.87	1.98

N=Sample size, a=Intercept, b=slope; Sb=The standard error of the slope, r^2 =Determination coefficient, ts= t- value

The t-test based on the comparison of the theoretical and observed slopes provides values above 1.96 at the risk of error α=5% for males and females. Therefore, the growth of *P. longirostris* for males and females is negative allometry.

The growth analysis using seasonal length-frequency data and the Powell-Wetherall method gave an initial asymptotic carapace length value of CL_∞= 41.40 mm for males and CL_∞=48.80 mm for females. These values were introduced into the ELEFAN program to obtain the optimized growth parameters for the best fit. The parameters of the Von Bertalanffy growth equation and the asymptotic total weight (TW_∞) for males and females, obtained are summarized in Table 3.

Table 3: Parameters of the von Bertalanffy growth equation and the asymptotic total weight for males and females for *P.longirostris.*

	SS	SL (mm)	CL_∞ (mm)	K (yr^{-1})	t_0 (year)	ESP/ASP	CL_{max}/0.95 (mm)	TW_∞(g)
Females	1	25	48.80	0.60	-0.53	0.328	45.26	27.84
Males	3	22	41.40	0.62	-0.54	0.368	40	16.25

SS: Starting Sample; SL: Starting Length; $CL\infty$=Asymptotic carapace length, K=Growth coefficient, t_0=Theoretical age at zero length; CL_{max}/0.95=$L\infty$:Approximation of Pauly; TW_∞=Asymptotic total weight; ESP=Explained sums of peaks; ASP=Available sums of peaks.

The instantaneous natural mortality rate (M) calculated using the equation of Pauly (1980) was equal to 0.89 $year^{-1}$ (on the basis of $TL\infty$=18.9 cm and K=0.55 yr^{-1}) for females and 1.04 $year^{-1}$ for males (on the basis of $TL\infty$=17.55 cm and K=0.6 yr^{-1}). The total mortality rate (Z) was estimated applying the length-converted catch method (Fig. 5) and the values obtained for females and males are respectively Z= 2.66 year^{-1} and Z=2.03 year^{-1}. The instantaneous rates of fishing mortality (F) and exploitation rate (E) for females and for males are F=1.77 year^{-1}, F= 0.99 year^{-1}, E = 0.66 , E = 0.49 respectively.

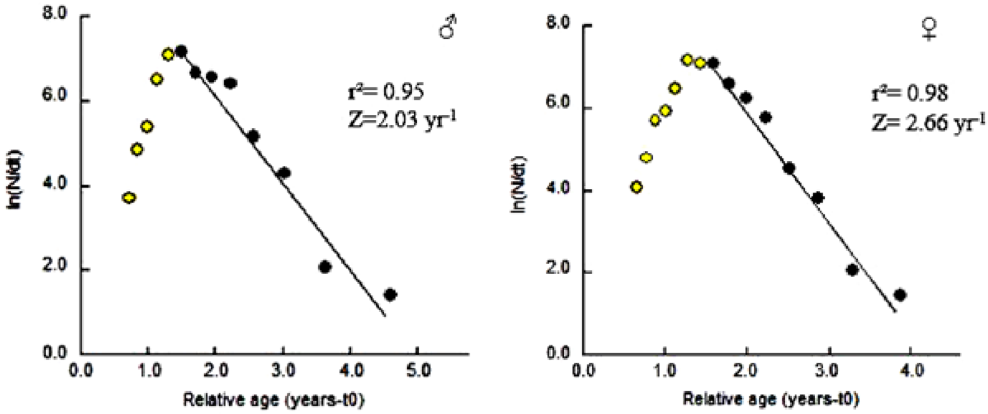

Figure 5: The length-converted catch curve of *P. longirostris* in Bou Ismail bay, Algeria (2016-2018).

The Figure 6 illustrate the catch probabilities (*P*) as a function of size class centres (mm), allowing the graphical estimation of L25, L50 and L75 for both sexes.

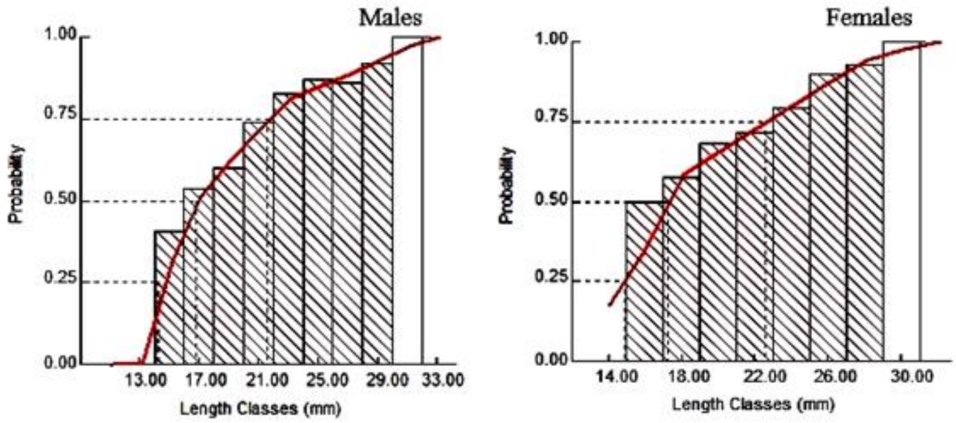

Figure 6: Length at first capture (L_{c50}) of *P.longirostris* in Bou Ismail bay, Central Algerian waters.

The length at first capture (Lc50) for both males and females is equal to 16.30 mm, 17.14 mm, respectively. Whereas, the carapace length where the capture probability of *P. longirostris* is about 25% and 75% are respectively 14.79 mm and 22.05 mm for females and 13.99 mm and 19.85 mm for males.

Discussion

In Bou Ismail Bay, a size sexual dimorphism was noticed for rose shrimp, this result seems to be common to Penaeidae shrimp (Boschi, 1969). The same dimorphism sexual pattern was proved in previous studies on *P. longirostris* (Bayhan *et al.*, 2005;

Sobrino *et al*., 2005; Kapiris *et al*., 2013). A similar observation has also been found for other Penaeidae such as *Trachysalambria curvirostris* (Ohtomi and Hossain, 2010), *Penaeus kerathurus* (Ben Meriem, 2004), *Xiphopenaeus kroyeri* (Da Silva *et al*., 2019), and *Metapenaeopsis sibogae* (Rahman and Ohtomi, 2018). The female's larger size may be due to their reproductive strategy to increases fertility (Yamada *et al*., 2006).

The length-frequency analysis is classically the method most used for age determination of crustacean populations (Oh *et al*., 2001) including in nearly 83% of the studies (Kilada and Driscoll, 2017). Other methods have been developed, such as lipofuscin analysis and growth band counting (Kilada and Driscoll, 2017), but they are not practical enough for regular use.

The frequency distribution by size class of *P.longirostris* shows an alternation between unimodal and bimodal distribution patterns over the seasons for both sexes, revealing a stable population structure. However, unimodal and bimodal distributions are common for crustaceans. This, generally reflects recruitment pulses, differential or catastrophic mortality, or behavioral changes. The unimodality usually reflects continuous recruitment with no class break, and constant mortality rates (Conde and Diaz, 1989).

The maximum carapace length of males and females were found to be 38 mm and 43 mm, respectively. The result are similar to that obtained by (Awadh and Aksissou, 2020) and indicates the largest carapace length of *P.longirostris* compared to the other studies (García-Rodríguez *et al*., 2009; Manaşirli *et al*., 2011; Kapiris *et al*., 2013; Arculeo *et al*., 2014) who reported that the larger individuals captured of females and males were respectively (32 mm, 26 mm), (42 mm, 34 mm), (38 mm, 29 mm) and (30.9 mm, 23.5 mm), in carapace length. The differences can be explained by the environmental condition (temperature, differences in feeding) (Kapiris *et al*., 2013), and the mode of exploitation of the species, i.e. the mesh size of the net used as well as the average depth in which the specimens were caught (Arculeo *et al*., 2014). In addition, the state of exploitation of the resource can be a key element that has to be considered.

In the present study , the asymptotic carapace length value is close to that obtained in the Mediterranean Coast of Moroco and is higher than that found from other parts of the Mediterranean Sea (Table 4). Additionally, the western Mediterranean Sea presents greater values than those reported in the Central and Eastern regions. This difference could be due to the variation of environmental characteristics depending on trophic conditions and productivity (Arculeo *et al*., 2014). Indeed, *P. longirostris* is considered a species with a preference for warm waters, being more abundant in the South-eastern Mediterranean than in the North-western basin (Abelló *et al*., 2002). However, the warming phase of sea surface temperature observed in recent years may well have favored the *P.*

longirostris population in the western Mediterranean (Ligas *et al*., 2011).

Table 4: Growth parameters for *P. longirostris* in the Mediterranean literature.

Sex	CL∞ (mm)	K year^{-1}	Region	Reference	Area
Females	37.2	0.76	Ionian Sea	(Kapiris *et al*., 2007)	Eastern and central Mediterranean Sea
Males	32.2	0.68			
Females	34.7	1.05	Aegean Sea (Saros Bay)	(Bilgin *et al.*, 2009)	
Males	27	1.49			
Females	32.3	0.77	Mersin (Turkey)	(Manaşirli *et al*., 2011)	
Males	31.2	0.76			
Females	44	0.73	Balearic Islande	(Guijarro *et al*., 2009)	Western Mediterranean Sea
Males	35	0.90			
Females	47	0.43	S.E.Spain	(García-Rodríguez *et al*., 2009)	
Males	36	0.49			
Females	44.48	0.54	Western Algerian Coast	(Bekadja *et al*., 2009)	
Males	34.03	0.68			
Females	40	0.60	Tyrrhenian Sea	(Arculeo *et al*., 2014)	
Males	30	0.76			
combined sex	52.87	0.39	Mediterranean Coast of Moroco	(Awadh and Aksissou, 2020)	
Females	48.80	0.60	Central Algerian Coast	Present study	
Males	41.40	0.62			

In the present study, the length-weight relationships of male and female *P. longirostris* showed negative allometry growth. These results are similar to those estimated by other authors in the Mediterranean (Arculeo et al., 2014; Awadh and Aksissou, 2020; Bayhan et al., 2005; Bekadja et al., 2009; García-Rodríguez et al., 2009; Kapiris et al., 2013; Sobrino et al., 2005). It is a common phenomenon in Penaeidae such as *H. sibogae* (Baelde, 1994), *P. fissuroides* (Farhana and Ohtomi, 2017), and *M. sibogae* (Rahman and Ohtomi, 2018).

The asymptotic carapace length of *P.longirostris* males and females can be further transformed to asymptotic total weights (TW∞); the results obtained were expected because the TW∞ of female Penaeidae would be larger than those of males, making females more economically viable.

The values of natural mortality of *P. longirostris* in the study area for females and males respectively (0.89 yr^{-1}, 1.04 yr^{-1}) are close to those observed on the west coast of Algeria and lower than those reported in the eastern Mediterranean (Table 5). Abiotic factors like temperature, hypoxia, and salinity, or biotic factors such as predation, disease, or restriction of food supply, can cause the natural mortality of Penaeidae shrimp to differ between regions (Haywood *et al*., 1993). Moreover, even small variations in the growth parameters may seriously distress the computed mortality rates, as the results depend on the data set used and could be different in another case (Tserpes and Tsimenides, 2001).

Table 5: Comparison of mortalities rates (M and Z) for *P. longirostris* in the Mediterranean literature.

Sex	M ($year^{-1}$)	Z ($year^{-1}$)	Region	Reference	Area
Females	1.51	2.93	Aegean Sea (Saros Bay)	(Bilgin *et al*., 2009)	Eastern Mediterranean Sea
Males	1.41	3.51			
Females	1.29	3.41	Mersin (Turkey)	(Manaşirli *et al*., 2011)	
Males	1.31	5.17			
combined sex	0.92	4.28	Western Algerian Coast	(Bekadja *et al*., 2009)	Western Mediterranean Sea
combined sex	1.98	3.49	Mediterranean Coast of Moroco	(Awadh and Aksissou, 2020)	
Females	0.89	2.66	Central Algerian Coast	Present study	
Males	1.04	2.03			

The total mortality rate (Z) of females is higher than that of males. Other authors explain that mortality is different by sex and exploitation suggests being related to the size of the individuals as well as their standard behaviour with the fishing activity (Conides *et al*., 2012). Probably because they require specific nutritional (energy, micronutrients) related with egg-laying. (García-Tarrasón *et al*., 2015). The strategy of the females requires a high rate of consumption and large body size; these characteristics are associated with large clutch size. Nevertheless, this strategy makes the female relatively sensitive to food shortage, less mobile, and more vulnerable to predation due to her large size and many moults (Berglund, 1981), this will tend to reduce female survivorship.

Furthermore, the values of E (0.66 and 0.49) for females and males respectively, lead to suggest a beginning of overfishing situation for *P. longirostris* as the parameter is considered optimal when its values are between 0.4 and 0.5 (Gulland, 1971; Patterson, 1992).

The probability of capture of *P.longirostris* in the present work showed a small carapace length at first capture for females and males, respectively (17.14 mm,16.30 mm). As well, in the western of Algerian coast, the estimated size for females at the first maturity was about 19.6 mm (Bekadja *et al*., 2009), this indicates that the commercial part of the catch consists of immature individuals. The results showed a smaller size at first catch than that observed in other studies (Sobrino *et al*., 2000; Andrade and Campos, 2002) who reported respectively a size at first capture of 19.33mm CL for a cod-end mesh size of 52.7mm, and 20.8–21.8 mm CL for a cod-end mesh size of 55 mm. Thus, increasing the mesh size of the cod-end would result in improved exploitation of the resource, which would increase the spawning stock biomass (Rinelli *et al*., 2005).

Finally, this work provides updated information on growth and exploitation indices that would be useful to the fisheries biologist. The results on the population dynamic of *P. longirostris* in the Algerian waters can have a significant part in the stock assessment process. Thus, for sustainable management of the fishery, it would be advisable to improve the monitoring of landings and fishing efforts. It is also central to study the lesser-known bioeconomic aspects of this economically important species.

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