Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(6): 791 – 804 (2024)
www.ejabf.journals.ekb.eg

Length –Weight Relationship, Body Condition and Growth Parameters of the Deep-Water Rose Shrimp *Parapenaeus longirostris* (Decapoda, Dendrobranchiata) in GFCM- GSA04 (Central and Eastern Algeria)

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ARTICLE INFO

Article History:
Received: Sept. 1st, 2024
Accepted: Nov. 12, 2024
Online: Nov. 27, 2024

Keywords:
Parapenaeus longirostris,
Growth,
GFCM- GSA04,
Commercial landings

ABSTRACT

Along the Algerian coast (GFCM-GSA04), the deep-water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846), holds significant socio-economic value, yet its biological characteristics remain understudied. To fill this gap, the present study aimed to describe key traits of the species, including length-weight relationships (LWR), condition factors (CF), and growth parameters for 1560 specimens collected from commercial landings at four major harbors along the central and eastern coasts: Tenes (TN), Algiers (AL), Bejaia (BE), and Jijel (JL). The results revealed a negative allometric growth pattern, with the exponent b significantly less than 3 at all sites. The mean condition factor values averaged slightly above the unit, indicating a satisfactory condition with no significant spatial variation. The von Bertalanffy growth parameters were estimated as follows: TN: $CL\infty$= 46.73 mm, K= 0.41 y-1, and t0 = -0.3555; AL: $CL\infty$ = 44.63mm, K = 0.5 y-1, and t0 = -0.293; BE: $CL\infty$ = 34.13 mm, K = 0.69 y-1, and t0 = -0.2258; JL: $CL\infty$ = 41.48mm, K = 0.57 y-1, and t0 = -0.2609. These findings provide significant insights into the growth dynamics of *P. longirostris*, offering potential applications for the species' fishery management in Algeria.

INTRODUCTION

The deep-water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) is an epibenthic widespread crustacean species, predominantly inhabiting sandy-muddy bottoms, mainly in depths ranging from 70 to 400m both in the eastern North Atlantic Ocean and Mediterranean **(Holthuis, 1980; Fischer *et al.*, 1987; Holthuis, 1987; Sbrana *et al.*, 2019)**. In the latter and its adjacent seas, due to its economic value, *P. longirostris* is one of the main target species of demersal fisheries. In recent years, the deep-water

rose shrimp reached its maximum landing values with an average of 24,210 tons per year **(FAO, 2022)**, thus raising concerns about the sustainability of its stocks. However, the species seems to be subject to varying degrees of exploitation. Indeed, while south-central Mediterranean, Greek and Turkish waters showed signs of over- or full exploitation, in contrast, populations from other areas like the Ligurian, northern Tyrrhenian, and southern Adriatic Seas appeared to be more stable, indicating less fishing pressure **(Kapiris *et al.*, 2011; Ligas *et al.*, 2011; Kapiris *et al.*, 2013; Knittweis *et al.*, 2013; Sbrana *et al.*, 2019; İhsanoğlu & İşmen 2020)**. According to several authors **(Abelló et *al.*, 2002; Kapiris *et al.*, 2011)**, these local differences in catching efforts would be among the main variables driving the observed heterogeneity in population dynamics and life history characteristics of *P. longirostris*; this underlined the necessity of ongoing monitoring and region-adaptive management measures to guarantee the long-term viability of the species **(Abello *et al.*, 2002; Sobrino *et al.*, 2005; Ligas *et al.*, 2011; Fiorentino *et al.*, 2024)**.

Along the Algerian coast (Geographic Sub Area 04 of the General Fisheries Commission for the Mediterranean, GFCM-GSA 04), *P. longirostris* accounts with the red shrimp *Aristeus antennatus* for almost all crustacean captures **(Nouar, 2001; Nouar, 2007; Mouffok *et al.*, 2008; Nouar *et al.*, 2011)**. The deep-water rose shrimp, harvested year-round by artisanal and offshore fleet trawlers, significantly contributes to landings at most Algerian ports, making it a species of a great socio-economic importance **(Fellah *et al.*, 2021; Benallal *et al.*, 2023)**. From a scientific point of view, however, the status of *P. longirostris* in Algeria remains little documented. Studies on the subject are few in number, fragmented, and cover only limited areas, with most research conducted along the Oran coast (northwest Algeria) **(Bekadja *et al.*, 2009; Fellah *et al.*, 2021; Benallal *et al.*, 2023)**.

Given the context outlined, the present work attempted to document several key population parameters of *P. longirostris* from the Algerian coast namely: the length-weight relationship (LWR), condition factor (CF), and growth parameters of the species based on landings collected at four major harbors along the central and eastern coastline of the country. Our findings may address the current data gap in the biology of the deep-water rose shrimp in GFCM-GSA 04; additionally, this information could also contribute to the development of effective monitoring programs and management strategies for shrimp populations.

MATERIALS AND METHODS

1. Sampling

Between Febrary and July 2023, 1560 deep-water rose shrimp specimens were randomly collected from bottom trawlers landings at four Algerian harbors namely: Tenes (TN) 36°31'26''N- 1°19'08''E, Algiers (AL) 36°46'53''N- 3°03'50''E, Bejaia (BE) 36°45'05''N- 5°05'30''E and Jijel (JL) 36°49'04''N- 5°46'24''E (Fig. 1). Once transferred

to the laboratory, fresh samples were washed & wiped, and each sample was weighed (BW: wet body weight) to the nearest 0.01g and was measured for its carapace length (CL: distance from the orbit of the eye to the posterior margin of the cephalothorax) using a digital caliper (±0.01mm). To prevent measuring procedure bias, all measurements were performed under identical conditions.

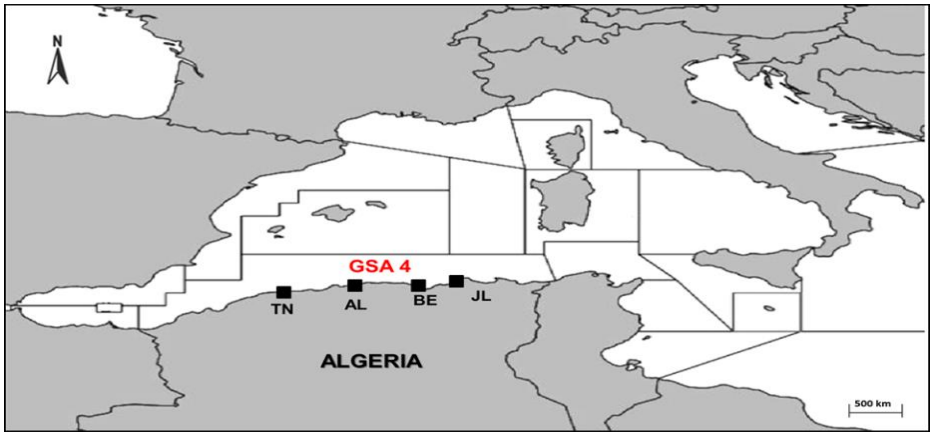

Fig. 1. A map showing collection sites within the geographical sub-area – GSA 4 (Algeria)

2. Data processing

The relationship between body weight (BW) and carapace length (CL) was determined using the allometric equation logW = log a + b logL **(le Cren, 1951; Froese, 2006)**, derived from the original form described by **Ricker (1973)**:

$W = a \times L^b$.

Where, W= BW (dependent variable); L= CL (independent variable); *a* = intercept (initial growth coefficient); *b* = slope (coefficient of allometry). The determination coefficient "R^2" was used to assess the degree of association between the measured variables, and the least squares method was applied to calculate both constants (*a* and *b*). To check the growth type of the shrimps, a student's *t-test*, as described by **Sokal and Rohlf (1987)**, was used to determine whether the b value deviated from the isometric hypothetical value (*b*= 3, growths in CL and BW are proportional). A significant deviation ($P \leq 0.05$) indicates an allometric relationship, either negative (*b*< 3, CL increases faster than BW) or positive (b > 3, BW increases faster than CL).

The shrimps' body condition was assessed for each individual through the relative condition factor (CF) **(Le Cren, 1951)** based on the formula: $CF = BW/a \times CL^b$, where *a* and *b* represent the intercept and slope, respectively, obtained from the previous relationship between BW and CL. Once the normality of the obtained CF values was checked (the Shapiro-Wilk test), the Kruskal–Wallis test was used to evaluate significant differences between shrimp's populations, at the 95.0% confidence level. Statistical treatments were performed using R software, version 4.1.2 **(R Development Core Team, 2014)**.

For the deep-water rose shrimp under study, the von Bertalanffy growth function (VBGF) parameters were determined using length-frequency data analyzed at 1-mm intervals. The ELEFAN I program within the FiSAT II software **(Gayanilo *et al.*, 2005)** was used to calculate the asymptotic maximum carapace length (CL∞, mm) and the growth coefficient (K, year-1). The VBGF is defined by the equation: $CL = CL\infty\ [1 - e^{-K\ (t - t0)}]$. The theoretical age at zero length (t0) was calculated using **Pauly's (1979)** empirical equation: Log (-t0) = -0.392 - 0.275 log L∞ - 1.038 log K. The length-weight relationship (LWR) was used to convert the asymptotic carapace length to the corresponding asymptotic body weight (BW∞, g).

RESULTS

In the present study, specimens of *P. longirostris* collected along the Algerian coast, which were used for length-weight relationship (LWR), condition factor (CF), and growth parameter estimations, exhibited a carapace length (CL) ranging from 8.04 to 44mm and a body weight (BW) from 1.02 to 20.33g. Descriptive statistics for these measured variables at the four sampled sites are detailed in Table (1). Globally, in the four-site sampling, the majority of the harvested shrimps belonged to size classes between 14 and 31mm CL (Fig. 2). This might be explained by similarities in the current fishing techniques used for the species along the Algerian coast, including the mesh sizes of the nets and the average depth at which the specimens were caught.

Table 1. Summary statistics on measured parameters of *P. longirostris* collected along the central and eastern Algerian coasts

Site	N	Carapace length (mm)			Body weight (g)		
		Min	Max	Mean ± SE	Min	Max	Mean ± SE
TN	366	12.01	44	23.26 ± 0.27	1.49	20.33	7.32 ± 0.16
AL	255	12.31	42.02	26 ± 0.3	2.2	20.96	8.57 ± 0.17
BE	387	8.04	32.58	20.09 ± 0.27	1.04	14.17	5.45 ± 0.15
JL	552	11.11	39	20.31 ± 0.21	1.02	15.57	4.28 ± 0.11

N: Sample size; Min: Minimum value; Max: Maximum value, SE: Standard error of mean.

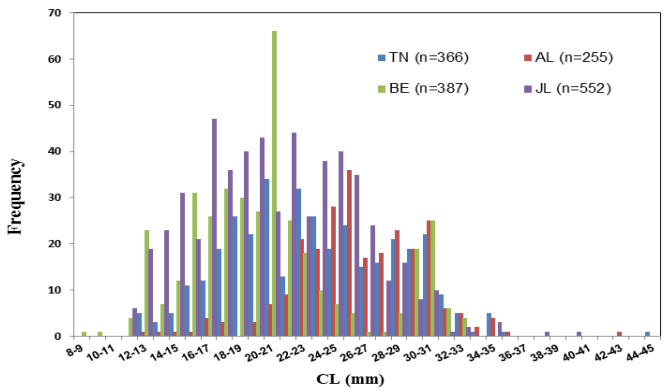

Fig. 2. Length-frequency distribution of *P. longirostris* collected along central and eastern Algerian coasts

The carapace length-weight relationship of *P. longirostris* at all the four sampling sites were strong ($R^2 > 0.70$), highly significant ($P < 0.001$), and revealed a negative allometric growth in all cases ($b < 3$, *t-test*) (Table 2), indicating that the increase in body weight (BW) occurs at a lesser rate than that of the carapace length for shrimps caught along the Algerian coast.

Table 2. Length-weight relationships and type of growth of *P. longirostris* collected along the central and eastern Algerian coasts

Sites	N	Equation	R^2	t-test	Relationship
TN	366	Log BW= -1.8395 + 1.9648 Log CL	0.81	13.943	- A
AL	255	Log BW= -1.9464+ 2.0269 Log CL	0.71	14.40	- A
BE	387	Log BW= -1.9448 + 2.0339 Log CL	0.89	14.717	- A
JL	552	Log BW= -2.1995 + 2.1358 Log CL	0.79	22.75	- A

N: Sample size, R^2 =Determination coefficient, - A= Negative allometry, $P < 0.001$ for all regressions.

The relative condition factor (CF) calculated for sampled individuals of *P. longirostris* from the central and eastern Algerian coasts ranged from 0.39 to 3.72 (Table 3). The lowest and highest mean CF values, 1.019 (± 0.25) and 1.051 (± 0.2), were recorded for shrimps caught in TN and JL, respectively; however, no significant differences among the four populations were detected (Kruskal-Wallis, $P > 0.05$) (Fig. 3).

Table 3. Condition factor (CF) of *P. longirostris* collected along the central and eastern Algerian coasts

Site	N	CF		
		Range	Mean ± SD	Median
TN	366	0.56-2.56	1.019 ± 0.25	1.01
AL	255	0.62-3.61	1.021 ± 0.33	1.01
BE	387	0.45-3.72	1.041 ± 0.33	1.03
JL	552	0.39-2.54	1.051 ± 0.2	1.04

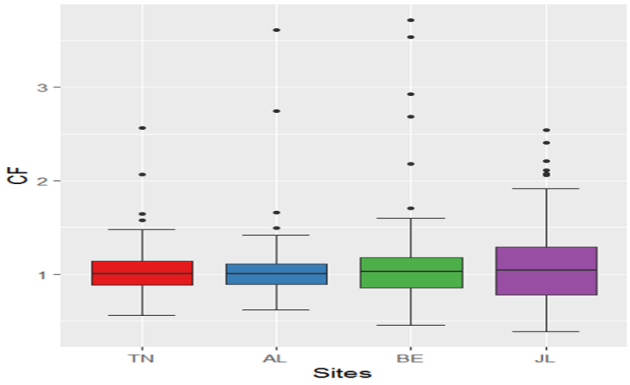

Fig. 3. Boxplot diagram of condition factor for *P. longirostris* collected along the central and eastern Algerian coasts (median: line inside the box; box: first and third quartiles; whiskers: minimum and maximum)

Using length-frequency distribution analysis via the ELEFAN program and calculating t_0 based on **Pauly's (1979)** equation, the von Bertalanffy growth parameters for *P. longirostris* collected from the central and eastern Algerian coasts are presented in Table (4).

Table 4. The von Bertalanffy growth parameters and the asymptotic total body weight for *P. longirostris* collected along the central and eastern Algerian coasts

Site	CL∞ (mm)	K (y^{-1})	t_0 (y)	BW∞ (g)
TN	46.73	0.41	- 0.3555	27.6
AL	44.63	0.5	- 0.293	24.96
BE	34.13	0.69	- 0.2258	14.91
JL	41.48	0.57	- 0.2609	18.03

DISCUSSION

The length-weight relationship (LWR) is a fundamental tool in marine sciences and fisheries management, providing insights into growth's variability and patterns, health, and overall condition among species and populations across different regions, habitats, and environmental conditions **(Bagenal & Tesch, 1978; Pauly, 1993; Moutopoulos & Stergiou, 2002; Froese, 2006)**. It is used in assessing fish and invertebrate population dynamics, estimating biomass based on easily obtained length data, and monitoring ecological changes **(Ricker, 1975; Anderson & Gutreuter, 1983; Froese *et al.*, 2011)**. Thus, its applications are essential for biodiversity conservation, sustainable management, and stock assessments **(Dimarchopoulou *et al.*, 2017)**. In the Mediterranean Sea, LWR is the most extensively investigated morphological trait of marine organisms; it has been documented for nearly half of the aquatic species, focusing

on those of commercial importance that undergo regular stock assessments **(Froese, 2006; Dimarchopoulou *et al*., 2017)**.

In the present study, the carapace length-weight relationships of *Parapenaeus longirostris* caught from central and eastern Algerian coasts indicated significant negative allometric growth, as the exponent *b* values were all less than 3 ($b < 3$) at the four sampling sites (TN, AL, BE, and JL). These findings are consistent with results reported by several authors in the Mediterranean (GFCM Geographical subareas, Table 5) and support the observation of **García-Rodríguez *et al*. (2009)** and **Kapiris *et al*. (2013)** that this type of allometric growth is expected and characteristic of the relative growth of this decapod crustacean throughout the entire Mediterranean Sea. Moreover, according to several authors, this growth pattern appears to be common within the Penaeidae family **(Baelde, 1994; Farhana & Ohtomi, 2017; Rahman & Ohtomi, 2018; Bensaâd-Bendjedid *et al.*, 2024)**. Nonetheless, numerous intrinsic and extrinsic factors, such as physiological conditions (including health, growth, reproductive stages, age, and diet), environmental and spatiotemporal influences (geographic location, habitat conditions, year, and season), as well as the timing and type of fishing gear used, are acknowledged to significantly affect the intra- and inter-specific variability in LWRs among aquatic organisms **(Le Cren, 1951; Bagenal & Tesch, 1978; Pauly, 1984; Jennings *et al*., 2001; Froese, 2006)**.

Table 5. Length-weight relationship parameters analyzed with CL reported for *P. longirostris* populations in the Mediterranean

GFCM subregions	GSA	Area	*a*	*b*	R^2	Source
Eastern Mediterranean	22	Aegean Sea-Turquey	0.546	2.743	0.97	**Tosunoglu *et al*. (2009)**
Black Sea	28	Marmara-Turquey	0.0022	2.52	0.94	**İhsanoğlu and İşmen (2020)**
Central Mediterranean	15-16	Sicily-Italy	0.0061	2.266	-	**Levi *et al.* (1995)**
	15-16	Sicily-Italy	0.0025	2.543	-	**Fiorentino *et al*. (2013)**
	12	Northern Tunisia	0.002	2.556	-	**Fiorentino *et al*. (2013)**
Western Mediterranean	4	Central Algerian Coast	0.003	2.482	0.988	**Ainouche (2009)**
	6	Alicante Bay-Spain	0.0019	2.611	0.96	**García-Rodríguez *et al*. (2009)**
	5	Balearic Island-Spain	0.0022	2.568	0.98	**Guijarro *et al.* (2009)**
	3	Morrocco Mediterranean coast	0,00340	2,312	0.978	**Awadh and Aksissou (2020a)**

4	Tenes- Central Algerian Coast	0.0145	1.9648	0.81	**Present study**
	Algiers- Central Algerian Coast	0.0113	2.0269	0.71	
	Bejaia- Estern Algerian Coast	0.0114	2.034	0.89	
	Jijel- Estern Algerian Coast	0.0063	2.1358	0.79	

The condition factor (CF) is a critical quantitative index used to assess the physiological status of aquatic populations across time and locations. Through its variations, CF reflected the influence of both biotic and abiotic factors such as habitat changes, nutrition and physiological factors **(Le Cren, 1951; Bagenal & Tesch, 1978; Jones *et al.*, 1999; Hossain *et al.*, 2012; Lalrinsanga *et al.*, 2012; Solanki *et al.*, 2020)**. It provided information into the fatness and the degree of the well-being of aquatic species, based on the assumption that heavier individuals at a given length are considered to be in better condition **(Froese, 2006)**. According to several authors, high CF values (≥ 1) indicate that aquatics are thriving and well-suited to their environments, while low values (< 1) suggest they may be under adverse conditions in their habitats **(Le Cren, 1951; Ujjania *et al.*, 2012)**.

The results from the present work showed that the body condition of the deep-water rose shrimp from the central and eastern Algerian fisheries is consistently satisfactory, with CF mean values slightly exceeding one across all four sampling locations. This uniformity suggested good health and adequate energy reserves among individuals, with no significant differences observed between the different zones. These outcomes are close to those reported for the species on the Algerian west coast **(Bekadja, 2015)**. This similarity may be attributed to the species' active feeding behavior, particularly during the spring **(Kerfouf *et al.*, 2022)**, which coincides with much of the study period, along with the abundant availability of food resources in the fishing grounds. Indeed, **Moffok *et al.* (2008)** emphasized the enrichment and high primary production of the deep waters along the Algerian slope, indicating that these conditions are more significant compared to neighboring Mediterranean areas.

Studying von Bertalanffy growth parameters in marine organisms is essential for effective fisheries management and conservation efforts, as it helps predict growth rates, assess environmental impacts, and guide sustainable harvesting practices. This widely-used model is a fundamental tool in population dynamics and stock assessment for marine species **(Beverton & Holt, 1957; Pauly, 1980; Haddon, 2011)**.

In this study, the asymptotic carapace lengths (CL∞) obtained in the GFCM-GSA04 regions of central and eastern Algeria at the four sampling locations, were generally close to those reported for the species across the Mediterranean, although slightly larger values were observed in the western areas (Table 6). This variation is likely influenced by

regional environmental factors such as trophic conditions, productivity, and sea temperature, which have become increasingly favorable for the development of the deep-water rose shrimp in the western Mediterranean in recent years **(Ligas *et al*., 2011; Arculeo *et al*., 2014)**. Additionally, these differences appear to be genetically determined, as several studies have found that when the species is separated by sex, females tend to achieve higher CL∞, while males typically exhibit faster growth rates (K) **(Sobrino *et al*., 2005; Fellah *et al*., 2021)**.

Table 6. von Bertalanffy growth parameters analyzed with CL reported for *P. longirostris* populations in the Mediterranean

GFCM subregions	GSA	Area	CL∞ (mm)	K (y^{-1})	t_0 (y)	Source
Black Sea	28	Marmara-Turquey	42	0.35	-0.39	**İhsanoğlu and İşmen (2020)**
Central Mediterranean	16	Sicily-Italy	30.5	0.63	-0.19	**Levi *et al*. (1995)**
	12	Northern Tunisia	37.06	0.695	-0.17	**Fiorentino *et al*. (2013)**
	16	Sicily-Italy	37.1	0.53	-0.46	**Fiorentino *et al*. (2013)**
Western Mediterranean	5	Balearic Island-Spain	40	0.84	-0.49	**Guijarro *et al*. (2009)**
	6	Alicante Bay-Spain	45	0.39	-0.102	**García-Rodríguez *et al*. (2009)**
	3	Morrocco Mediterranean coast	52.85	0.39	-0.35	**Awadh & Aksissou (2020b)**
	4	Oran-Western Algerian Coast	38.5	0.63	-0.40	**Bekadja (2015)**
		Tenes- Central Algerian Coast	46.73	0.41	-0.355	**Present study**
		Algiers- Central Algerian Coast	44.63	0.5	-0.293	
		Bejaia- Estern Algerian Coast	34.13	0.69	-0.225	
		Jijel- Estern Algerian Coast	41.48	0.57	-0.26	

CONCLUSION

This paper provides basic, lacking data on the current status of the deep-water rose shrimp *Parapenaeus longirostris* in the GFCM-GSA04 region. This information

may be valuable for the sustainable scientific management of the species' fishery in Algeria, where the deep-water rose shrimp has a major socio-economic importance. Further research into the biology and stock parameters of the species across the entire Algerian coast is necessary to ensure effective long-term management of this resource.

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