



## Sex-Based Analysis of Length-Weight Relationships and Condition Factor in a Wild Population of *Penaeus kerathurus* (Decapoda: Penaeidae) from a Southwestern Mediterranean Lagoon (El Mellah Lake –Algeria)

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### ABSTRACT

The autochthonous caramote prawn, *Penaeus kerathurus*, is highly exploited and widely studied throughout its distribution range in the Mediterranean. However, in Algeria, very few studies have been conducted on its biological aspects. In this research article, we provided for the first time a detailed analysis of the key parameters: length-weight relationships (LWRs) and condition factor (K) of prawns harvested from the unique coastal lagoon in the country, El Mellah Lake. Thus, the morphometric relationships between the total and carapace lengths against body weight were established for 1066 males, 608 females, and grouped individuals, revealing a negative allometric growth in all cases. Similarly, all K-obtained average values were less than the unit, indicating the poor nutritional status of prawns. Overall, the present findings showed that both parameters were sex-dependent and more likely reflect the population response to species growth and reproductive traits, biotic (new predator-prey relationship), and abiotic (lagoon's meso-oligotrophic status) stimuli. The present study will be useful for better enhancing our understanding about *P. kerathurus* in southwestern Mediterranean and lagoon habitats.

### INTRODUCTION

The length-weight relationship (LWR) is the most extensively investigated morphological trait of marine fishes and invertebrates in the Mediterranean Sea (Froese, 2006; Dimarchopoulou *et al.*, 2017). It is a crucial tool for gaining knowledge and understanding their biology and ecology (Robinson *et al.*, 2010; Özcan & Katağan, 2011; Hajjesmaeli *et al.*, 2019). LWR applications are numerous; they can provide

pertinent information on the growth trends, age structure, population dynamics and fitness of aquatic organisms (Bagenal & Tesch, 1978; Bolger & Connolly, 1989; Froese, 2006; Tsoumani *et al.*, 2006; Sousa *et al.*, 2020; Olentino *et al.*, 2021). Furthermore, it is a fundamental parameter required for sustainable fisheries management, as data from LWR is often used to assess individuals' well-being, estimate communities' biomasses, monitor stocks, and determine possible inter- and intra-population variations in the same species within and between habitats and regions (Pauly, 1993; Gaspar *et al.*, 2001; Santos *et al.*, 2002; Froese, 2006; King, 2007; Adamidou *et al.*, 2020; Sousa *et al.*, 2020). The condition factor (K), on the other hand, is a quantitative index commonly used as a reliable indicator reflecting the impact of biotic and abiotic factors such as nutritional condition, life cycle stages (growth and reproduction), and habitat changes on the general health condition of aquatics (Le Cren, 1951; Bagenal & Tesch, 1978; Jones *et al.*, 1999; Anene, 2005; Ndimele *et al.*, 2010; Lalrinsanga *et al.*, 2012; Khademzadeh & Haghi, 2017; Solanki *et al.*, 2020).

The present work aimed to provide for the first time a detailed analysis of the length-weight relationships and condition factor of the caramote prawn *Penaeus kerathurus*, the only exploited crustacean in the unique coastal lagoon in Algeria, El Mellah Lake. The latter is a healthy (low anthropogenic pressure) and biologically rich ecosystem (wetland of international importance, Ramsar Site no. 1424), particularly in terms of fishing (Bensaâd-Bendjedid *et al.*, 2022a, 2022b; Parisi *et al.*, 2022). Nevertheless, despite being one of the lagoon including the most abundant and harvested species, very little is known about the caramote prawn's eco-biological status at this site, whereas such data are crucial for rational management of aquatic stocks. Our findings would also add information to the species' database in the southwestern Mediterranean basin and lagoon habitats.

## MATERIALS AND METHODS

### 1. Study site

El Mellah Lake is the only coastal lagoon in Algeria. This body of water, situated in the extreme northeast of the country near the Algerian-Tunisian border, covers an area of 865 hectares within the El-Kala National Park (UNESCO biosphere reserve). El Mellah connects to the Mediterranean Sea through a single channel (870m). The lagoon supports extensive aquaculture and artisanal fishery activities and is renowned for its fisheries resources (*Dicentrarchus labrax*, *Sparus aurata*, *Liza aurata*, *Mugil cephalus*, *Anguilla anguilla*, *Penaeus kerathurus*).



**Fig. 1.** Location of El Mellah Lagoon

## 2. Data collection

A total of 1674 *P. kerathurus* specimens (1066 males, 608 females) were sampled in 2021 from El Mellah Lake's landings during the species' yearly fishing season (July to October). In the laboratory, fresh prawns were thoroughly washed and wiped. Once sorted by sex (presence or absence of the visible appendix masculina), each sample was weighed (BW: wet body weight) to the nearest 0.01g and measured along its total length (TL: distance from the tip of the rostrum to the extremity of the telson) with a graduated ruler ( $\pm 1\text{mm}$ ) and digital caliper ( $\pm 0.01\text{mm}$ ) along its carapace length (CL: distance from the orbit of the eye to the posterior margin of the cephalothorax).

## 3. Data processing and statistical analyses

After the normality of the dataset checked, possible differences in measured size (TL, CL, and BW) distributions between *P. kerathurus* from El Mellah Lagoon sexes were evaluated using a nonparametric test (Wilcoxon-Mann-Whitney test). The estimation of length-weight relationships was made separately for males, females, and the grouped sexes using the exponential equation  $W = a * L^b$  in its linear form after a logarithmic transformation (to meet the normality assumption):  $\log_{10} W = \log_{10} a + b \log_{10} L$  (le Cren, 1951; Froese, 2006), where  $W$  is BW the dependent variable, and the independent variable  $L$  is either TL or CL (Ben Mariem, 1995; Conides *et al.*, 2006), “ $a$ ” the intercept and “ $b$ ” the slope of the regression line. The determination coefficient “ $R^2$ ” was used to estimate the degree of association between variables. The pattern of growth (isometry vs. allometry) was tested using the Student's t-tests at the confidence level of  $\pm 95.0\%$  to determine if the  $b$  values obtained were significantly different from the isometric value 3 (Sokal & Rohlf, 1987). All tests were accepted with  $P < 0.05$  level significance. Additionally, regression coefficients for males and females were compared for

significant differences between the sexes using the analysis of covariance (ANCOVA) at the 95.0% confidence level. The Fulton's condition factor (K) of the prawns was calculated for each individual from the equation:  $K = W/L^3 * 100$ , where W is BW (g), and L is TL (cm), and the scaling factor "100" was used to bring the K close to the unit (1) (Rodriguez, 1987; Turkmen & Yilmazyerli, 2006). The normality of the obtained K values was verified using the Shapiro-Wilk test and subsequently compared using the Wilcoxon-Mann-Whitney test to evaluate significant differences between sexes.

All statistical treatments were performed under R software, version 4.1.2 (R Development Core Team, 2014).

## RESULTS

In the present study, *P. kerathurus* samples (1674) used for LWR and K estimations ranged, respectively, in total (TL) and carapace (CL) lengths from 40 to 159mm and 5.06 to 24.33mm, while the body weight (BW) varied between 0.99 and 30.87g. The descriptive statistics of the population under study's measured parameters by gender are displayed in Table (1). According to the Wilcoxon-Mann-Whitney test, females were significantly heavier and longer than males for both TL and CL (in all cases,  $P < 0.001$ ) indicating the presence of a sexual dimorphism in body mass and sizes.

**Table 1.** Summary statistics on morphometric measurements by gender of *P. kerathurus* from El Mellah lagoon.

Sex	N	TL mean± SD	CL mean± SD	BW mean± SD
		TL <sub>min</sub> - TL <sub>max</sub>	CL <sub>min</sub> - CL <sub>max</sub>	BW <sub>min</sub> - BW <sub>max</sub>
Males	1066	93.90 ± 9.79	11.56 ± 1.36	5.62 ± 1.85
		65 – 135	7.59 – 16.89	2.04 – 16.86
Females	608	102.6 ± 17.67	13.44 ± 2.59	8.14 ± 4.02
		40 – 159	5.06 – 24.33	0.99 – 30.87

N: sample size; SD: standard deviation

The morphometric relationships relating BW to TL as well as CL, both for sexes separately and combined, were highly significant ( $P < 0.001$ ) and revealed a negative allometric growth in all cases ( $b < 3$ , *t*-test) (Table 2), suggesting that in *P. kerathurus* from El Mellah Lagoon, the shape changes with growth; thus, the increase in body weight occurs at a lesser rate than that of the body lengths. Additionally, ANCOVA analysis revealed significant differences between genders for equation parameters in regressions BW versus TL ( $F = 38427.31$ ,  $P < 0.001$ ) and BW versus CL ( $F = 6467.89$ ,  $P < 0.001$ ), denoting that the patterns of growth are different among males and females.

**Table 2.** Length-weight relationships, determination coefficient ( $R^2$ ) and t-test values in males (M), females (F), and overall populations of *P. kerathurus* from El Mellah Lagoon

Sex	N	Equation	R2	t-test	Relationship
Males	1066	Log BW= -4.9399 + 2.5769 log TL	0.929	3.586	- allometry
		Log BW= -1.5832 + 2.1806 log CL	0.663	28.154	- allometry
Females	608	Log BW= -4.6318 + 2.7389 log TL	0.968	5.826	- allometry
		Log BW= -1.775 + 2.3509 log CL	0.875	14.506	- allometry
Overall	1674	Log BW= -4.896 + 2.8604 log TL	0.954	5.3346	- allometry
		Log BW= -1.6828 + 2.2724 log CL	0.817	26.122	- allometry

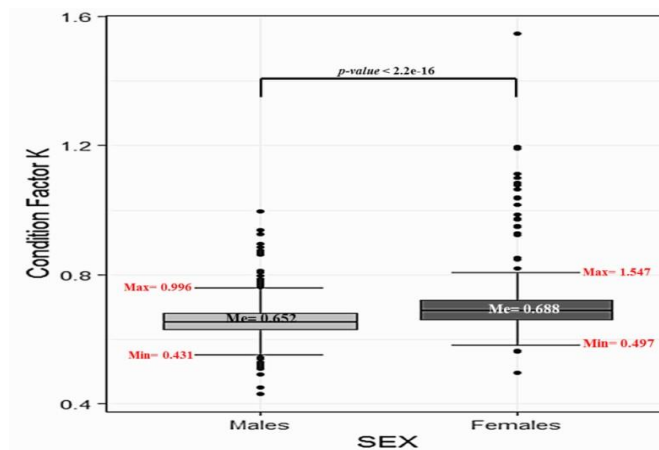
N: sample size,  $P < 0.001$  for all regressions

The condition factor (K) calculated for *P. kerathurus* from El Mellah Lagoon ranged from 0.43 to 1.55 and presented a non-normal distribution both for males ( $W = 0.9177$ ,  $P < 0.001$ ) and females ( $W = 0.6607$ ,  $P < 0.001$ ). The Wilcoxon-Mann-Whitney test indicated a significant difference among sexes ( $W = 177601$ ,  $P < 0.001$ ), with females providing a higher value than males and the common gender (Table 3, Fig. 2).

**Table 3.** Condition factor (K) of *P. kerathurus* from El Mellah Lagoon

Sex	N	K		
		Mean	SD	Range
Males	1066	0.66	0.05	0.43 – 0.99
Females	608	0.70	0.09	0.50 – 1.55
Overall	1674	0.67	0.07	0.43 – 1.55

N: sample size; SD: standard deviation



**Fig. 2.** Boxplot diagram of condition factor (K) for both sexes of *P. kerathurus* from El Mellah Lagoon (Min: minimum, Max: maximum, Me: median)

## DISCUSSION

The length-weight relationship is a key component of population dynamics in fisheries science. It is available for over 40% of aquatic Mediterranean species, particularly the valuable target ones, whose stocks are regularly evaluated (**Dimarchopoulou *et al.*, 2017**). In prawn species, LWR is considered an efficient instrument to measure growth variability and determine its pattern in both wild and farmed populations (**Froese, 2006**).

In the present study, a clear sexual dimorphism in growth appears for *P. kerathurus* from El Mellah Lagoon, with females achieving better TL, CL, and BW values than males. Our findings are consistent with the data reported on the species from different parts of its Mediterranean range (**Ben Mariem, 1995; Kevrekidis & Thessalou-Legaki, 2006; Turkmen & Yilmazyerli, 2006; Kapiris & Conides, 2009; Kevrekidis & Thessalou-Legaki, 2011; Jaziri *et al.*, 2015; İhsanoğlu, 2020; Jaziri *et al.*, 2020; Marković *et al.*, 2022**). Several authors attribute the morphological variations between the carapace prawn genders to the marked differences in growth patterns of males (**Rodriguez, 1987; Kapiris & Conides, 2009; Jaziri *et al.*, 2015**). Thus, due to their faster growth rate and shorter lifespan, they reach sexual maturity earlier than females (**Rodriguez, 1985; El Mekki, 1994; Conides *et al.*, 2006; Kevrekidis & Thessalou-Legaki, 2011; Lumare *et al.*, 2011; Jaziri *et al.*, 2020**), thereby reducing energy investment in growth in favor of reproduction, leading to smaller body sizes. According to **Kevrekidis and Thessalou-Legaki (2006, 2011)**, differentiation in growth patterns between sexes observable from the juvenile stages onward could reflect species' dynamic nature. This constitutes the main reason why **Ishak *et al.* (1980)** recommended that the growth studies on *P. kerathurus* must be conducted separately for the two genders.

In *P. kerathurus* from El Mellah Lagoon, for sexes separately and combined, a significant negative allometric growth was observed in LT vs. BW and CL vs. BW. The exponent  $b$  values were all less than 3 ( $b < 3$ ), suggesting that the shape of prawns changes to be slenderer as they grow; in other words, individuals grow faster than they gain weight. Nonetheless, this pattern seems more pronounced in males than females, as the latter showed greater weights at a given length. A comparable allometry profile has also been established in the Aegean Sea (**Turkmen *et al.*, 2007**), Tunisia (**Jaziri *et al.*, 2015**), and Montenegro (**Markovic *et al.*, 2022**). However, other authors have reported isometric and even further positive allometric growth for females (**Ishak *et al.*, 1980; Ben Mariem, 1995; Conides *et al.*, 2006; Turkmen & Yilmazyerli, 2006; Udoinyanget *et al.*, 2016**). **Jaziri *et al.* (2015)** stated that sex-specific differences in *P. kerathurus*' LWRs would be a direct consequence of sexual dimorphism in sizes and weights among genders. However, if we refer back to the same authors, it might also be caused by the difference between males' and females' energetic profile utilization during spawning

season; indeed, the former mobilized all available energy to gonadic production, resulting in a poor body condition (b values), while the latter split energy allocation simultaneously between reproduction and body growth, leading to good somatic and gonadic states. Similar conclusions for the red shrimp, *Aristeus antennatus*, have also been reported, suggesting that the reproductive process could affect the allometric features of the species (Kapiris & Kavvadas, 2009; Kapiris & Thessalou-Legaki, 2009). However, various intrinsic and extrinsic factors, including physiological conditions (health, growth and reproductive stages, age, diet), environmental and spatiotemporal effects (geographic area, biotope conditions, year, season), fishing time, and gear, are recognized to significantly influence the intra and inter-variability in LWRs in aquatic organisms (Le Cren, 1951; Bagenal & Tesch, 1978; Pauly, 1984; Jennings *et al.*, 2001; Froese, 2006). On the other hand, it is noteworthy to mention that the high values (over 80%) of determination coefficients ( $R^2$ ) obtained in the assessment of LWRs (LT vs. BW and CL vs. BW) for the entire population allow us to suggest that both total and carapace lengths are good predictors of body weight in *P. kerathurus* from El Mellah Lagoon, and extrapolation in future catches is possible from either.

The Fulton's condition factor (K) is a standard indicator of the general state of aquatics as it reflects, through its variations, their physical and biological conditions, health status, and interactions with their environments (Le Cren, 1951; Bagenal & Tesch, 1978). Thus, high K values ( $\geq 1$ ) suggest that organisms are in good condition and well adapted to their habitats, and conversely, low values ( $< 1$ ) indicate that they are not doing well in their biotopes (Le Cren, 1951; Ujjania *et al.*, 2012). In the case of *P. kerathurus* from El Mellah Lagoon, the average condition factors obtained for each gender separately and pooled population were all less than 1, indicating the poor nutritional status of prawns throughout the sampling period. This finding suggests that *P. kerathurus* may be under adverse conditions constraining the species' development, a fact that could be attributed to the meso-oligotrophic state of the lagoon (Draredja *et al.*, 2019). Indeed, according to Lumare *et al.* (1996), the more *P. kerathurus*' habitat is productive, the better their body performances are. Similar findings are those noted by Anastasiadou *et al.* (2009), who focused on the effects of trophic status and nutrient loading in aquatic environments on the lacustrine and riverine shrimp, *Palemonetes antennarius*. The authors reported that the species exhibits its best development in eutrophic-hypertrophic habitats. On their part, Ishak *et al.* (1980) attributed the lower condition factors of *P. kerathurus* in the Egyptian coastal lake populations to the species' feeding and migrating behaviors in its early stages of development.

Moreover, we hypothesize that the low values of K for *P. kerathurus* from El Mellah Lagoon might also be due to an additional cost of energy induced by a new predator-prey relationship between the species and the highly invasive blue crab, *Calinectes sapidus*. Indeed, in 2021, this aggressive, omnivorous decapod was first reported in the lagoon by Kara and Chaoui (2021), who found a large and well-established population. According to several authors, the caramote prawn is a regular prey item of the American blue crab in various Mediterranean transitional waters (Kampouris *et al.*, 2019; Izquierdo-Gómez, 2022; Ortega Jiménez *et al.*, 2024; Prado *et al.*, 2024). We confirm these observations also in El Mellah, where the authors witnessed, during a fyke-net retrieval, crabs feeding on the trapped prawns, a

phenomenon, according to local fishermen, that has become common since the apparition of the allochthonous species in 2019. The same predation strategy was also described in Papapouli Lagoon (Greece) by **Kampouris *et al.* (2019)**.

On the other hand, the K values achieved in the present study may reflect the *P. kerathurus* density status at the study site. Numerous studies have shown that lower body condition values correspond to higher populations' densities and inversely (**Martin & Vander Zanden, 2023**). However, for *P. kerathurus* from El Mellah, neither a population analysis nor a quantification of the impact of the fishery pressure has ever been assessed; thus, this speculation needs further investigation.

Moreover, the condition factor of El Mellah prawns appeared to be sex-dependent, as our findings showed significant variations among genders, with females exhibiting higher values than males; this is in line with the outcomes of numerous previous studies on the *Penaeus* spp. including the caramote prawn (**Ishaq *et al.*, 1980; Turkmen & Yilmazyerli, 2006; Turkmen *et al.*, 2007; Udoinyang *et al.*, 2016; Kaka *et al.*, 2019; Mohamed Harris *et al.*, 2019**). Several authors linked these differences observed in various prawn species to their reproductive cycle and attributed them to the presence of gravid females as their gonads are larger and heavier than the testis (**Hossain *et al.*, 2012; Lalrinsanga *et al.*, 2012; Udoinyang *et al.*, 2016; Rahman & Ohtomi, 2018; Kaka *et al.*, 2019**). Moreover, in *P. kerathurus*, **Kevrekidis and Thessalou-Legaki (2006)** and **Jaziri *et al.* (2015)** reported that during their gonadal maturation, females remain active feeders, keeping good body growth, while males display a depletion of their somatic condition.

## CONCLUSION

In conclusion, the current study provides for the first time baseline data for the condition factor (K) and length-weight relationships (LWRs) of the caramote prawn, *P. kerathurus*, in the southwest Mediterranean lagoon "El Mellah." Our results suggest that these two key parameters are sex-dependent, and their variations may reflect the population's response to specific physiological processes and various biotic and abiotic stimuli. This work will be of a significant aid for further investigations (biomass estimation and stock assessment) and for the sustainable management of this resource in the lagoon.



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