Population dynamics of deep-water pink shrimp (*Parapenaeus longirostris* Lucas, 1846) (Decapoda, Penaeidae) in the coastal waters of Tuzla (Eastern part of the Sea of Marmara)

Erhan ÇİLOĞLU¹, Celal ATEŞ²

Cite this article as:
Çiloğlu, E., Ateş, C. (2022). Population dynamics of deep-water pink shrimp (*Parapenaeus longirostris* Lucas, 1846) (decapoda, Paenaeidae) in the coastal waters of Tuzla (Eastern part of the Sea of Marmara). *Aquatic Research*, 5(3), 196-208. https://doi.org/10.3153/AR22019

¹ Recep Tayyip Erdogan University, Turgut Kiran Maritime Faculty, 53900 Derepazar/Rize, Türkiye
² Muğla Sıtkı Koçman University, Fisheries Faculty, 48170 Kötekli/Muğla, Türkiye

ORCID IDs of the author(s):
E.C. 0000-0002-9995-0377
C.A. 0000-0002-7336-0387

Submitted: 28.12.2021
Revision requested: 17.02.2022
Last revision received: 16.03.2022
Accepted: 04.04.2022
Published online: 21.04.2022

ABSTRACT

In this study, the population parameters, recruitment period, exploitation rate, and stock status of deepwater pink shrimp (*Parapenaeus longirostris* Lucas, 1846) in the eastern Sea of Marmara were investigated. Growth showed negative allometry, and, b-values were significantly lower than 3 for females' and males' (p < 0.05). Females and males' growth performance indexes (φ) of *P. longirostris* were determined as 2.91 and 2.89, respectively. Asymptotic carapace lengths (CL∞), growth coefficients (K), and theoretical birth ages (t₀) of females and males were calculated as 32.55, 28.67 mm, and 0.760, 0.950, and −0.233, −0.769, respectively. The maximum exploitation rates (Emax) were calculated as 0.82 for females and as 0.90 for males. The first capture lengths (CL50) for females and males were estimated to be 18.78 and 18.07 mm, respectively. Two recruitment periods were determined for *P. longirostris* for females and males. The recruitment period was estimated to be between February and April, July and November. The yield per-recruit (YPR) analysis for females and males revealed that E₀.1 = 0.72 and 0.80 approached the maximum exploitation rate (Emax = 0.82 and 0.90), respectively, indicating that exploitation for *P. longirostris* was in quadrant category "C" in the Eastern Marmara Sea. This status demonstrated active fishing, according to the quadrant rule.

Keywords: Growth, Exploitation Rate, Mortality, *Parapenaeus longirostris*, Recruitment, Stock, Eastern Sea of Marmara
Introduction

Parapenaeus longirostris (Lucas, 1846) spreads from the State of Massachusetts, the USA to French Guiana in the West Atlantic, and from Portugal to the entire Mediterranean Sea, including Namibia and the Sea of Marmara (Holthuis, 1980; Kocataş, 1981; Morri et al., 1999). According to a study conducted by Sobrino et al., (2005), P. longirostris is located between 20 and 400 m in Guinea gulf, and from 50 to 500 m off Congo (Crosnier et al., 1970), as well as other marine areas of tropical Africa (Crosnier and Forest, 1973).

P. longirostris is a species of economic value in Europe and Turkey (Anonymous, 2021; FAO, 2008). It can be said to be the most important invertebrate species in the East Atlantic and the entire Mediterranean in countries such as France, Spain, Tunisia, Italy, and Greece (Deval et al., 2006).

The Marmara and Aegean coasts are well known for their high economic sea product potential (Bayhan et al., 2006). Among the ten commercially evaluated shrimp species (Peneaus semisulcatus, Melicertus kerathurus, Marsupenaeus japonicus, Parapenaeus longirostris, Metapenaeus monoceros, Metapenaeus stebbingi, Trachypenaeus curvirostris, and Melicertus hathostris), P. longirostris is the most caught species. According to data obtained, a total of 125,126,9 tonnes of pink shrimp have been captured from the Marmara Sea in the last ten years (from 2010 to 2020) (Anonymous, 2021). The amount of shrimp captured in the Sea of Marmara constitutes approximately 54.9% of the total amount of shrimp product in all Turkish seas. A total of 537 fishing boats with a length of 7–30 m, 9–670 HP engine power, and trawlers and two-way trawlers are widely used in shrimp fishing in the Sea of Marmara (Anonymous, 2020).

The Sea of Marmara is an inland sea connecting the Mediterranean and to the Black Sea. Therefore, the Sea of Marmara is a part of the Mediterranean water system. Various aquatic species live in the Sea of Marmara. One of the most important species is the deep-water rose shrimp (P. longirostris Lucas, 1846) (Kocataş, 1981). The number of studies on the stock structure of P. longirostris living in the East Marmara Sea is not enough, and such a study will be crucial for the best management of this resource. On the Marmara and Aegean Sea coasts, P. longirostris has significant economic potential (Bayhan et al., 2006; Zengin et al., 2007). In a study comparing the sizes of P. longirostris individuals living in the Sea of Marmara and in the Aegean Sea, it was reported that the difference between the ages and lengths of P. longirostris individuals in these two seas was insignificant (Tosunoğlu et al., 2009). In a study on the biodiversity of the Marmara Sea, İhsanoğlu and İşmen (2020) reported that the areas where P. longirostris is most abundant are the southern Marmara region and the waters of the Kapıdağ peninsula. It has been determined that P. longirostris, which is the target species in South eastern Marmara waters, constitutes 64.5% of the total product (Bayhan et al., 2006). Öztürk (2009) conducted a study in the Sea of Marmara, stating that in 1987, the pink shrimp shell length varied between 85 mm and 306 mm, but the maximum shell length measured in his study was 126 mm. He emphasised that according to this result, shrimp stocks were in danger due to fishing pressure. In another study conducted in the Marmara Sea, the effect of trawl net material and different net cod-ends on the amount of P. longirostris was investigated, and it was stated that 32 mm PE and 32 mm PA net cod-ends were not efficient for shrimp fishing (Deval et al., 2006). The product quantities obtained from the bottom trawl and beam trawl operations of P. longirostris in the Marmara Sea were calculated by the "area scanning method" as 229.8 ± 57.3 kg/m² and 409.3 ± 152 kg/m², respectively (Zengin et al., 2007). The bathymetric distribution of P. longirostris, as well as seasonal growth and mortality rates according to Elefan, Projmat, and SLCA methods, was investigated in a study conducted in Saros Bay, in the Aegean Sea. It was reported that the shrimp stocks exploited in Saros Bay were compatible with the shrimp stocks in other regions, and ELEFAN was the most suitable method for the shrimp population among the mentioned seasonal growth patterns (Bilgin et al., 2009). In a study conducted in the Mediterranean (Babiddillimani bay) on the bio-ecology and population dynamics of P. longirostris, it was reported that the most intensive breeding occurred between December and March, and April and June. In the same study, it was reported that the total mortality rate (Z), natural mortality rate (M), fishing mortality rate (F), and exploitation rate (E) were 4.0, 1.29, 2.71, and 0.67, respectively (Manasırli et al., 2011).

In this study, we evaluated the length at first capture, the recruitment model, the relative yield per-recruit, and the relative biomass per-recruit, as well as the growth and mortality parameters that are needed for stock management of P. longirostris in the eastern Sea of Marmara.

Material and Methods

Sampling Area and Sample Collection

This research was conducted in the coastal waters of Tuzla, Eastern Marmara Sea (Figure 1). The sampling area's endpoint coordinates are lower right, 40° 43' 52" N; 29° 21' 04" E, and upper left, 40° 50' 00" N; 29° 08' 08" E. P. longirostris specimens were sampled from 11 fishing areas (Figure 1). Samples were caught using a beam trawl in eastern the
Marmara Sea at depths ranging from 90 to 120 m. The width of the beam trawls used by the fishermen was 3 m, and the height was 40 cm. Shrimp were randomly sampled from commercial fishing vessels between February 2008 and May 2009.

**Data Analysis**

*P. longirostris* samples collected monthly during the study were directly brought to the laboratory. A total of 3826 shrimp were sampled in the study. The carapace length (CL) was measured to the nearest 0.1 mm as the shortest distance from the orbital edge to the mid-dorsal posterior margin of the carapace using vernier callipers. The total length (TL) was measured to the nearest 1 mm, from the tip of the rostrum to the end of the telson. The body weight (W) was measured to the nearest 0.01 g using a digital balance. Differences in the size distribution of shrimp between males and females were evaluated using the Kolmogorov-Smirnov two-sample test in the "Statistica" program. The sex-ratio was calculated and compared to the 1:1 proportion using the chi-square ($\chi^2$) goodness fit test.

**Growth Parameters**

The relationship between size and weight for females and males was determined by the following non-linear equation:

$$W = a \times CL^b$$

where $W$ is the shrimp weight, $CL$ is the shrimp carapace length, "a" is the regression constant, and "b" is the coefficient of allometry. The growth type was defined by using Student’s t-test by the equation according to Sokal and Rohlf (1987). Length-frequency distribution analysis was used to estimate growth in *P. longirostris* following the Von Bertalanffy technique. The von Bertalanffy Growth Function (VBGF) adapted to FISAT II was used to attain the growth indexes, where the growth rate (K), the asymptotic carapace length (CL$_\infty$) and the growth performance index($\phi$). The Powell-Wetherall Plot adapted to FISAT II was used to obtain the rate of Z/K for the fish species evaluated. Growth of individual fishes on average towards L$_\infty$ at K with length at the time (t) was calculated using the VBGF (Pauly, 1979):

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

The theoretical age at birth was estimated separately, employing the mathematical equality:

$$log_{10}(-t_0) = -0.3922 - 0.275 \times log_{10}L_\infty - 1.038 \times log_{10}K$$

(Maximum longevity (Tmax) was calculated by the following equation: $T_{max} = \frac{3}{K} + t_0$ (Pauly, 1983). The $\phi$ was calculated by the formula: $(\phi) = 2 \times LogL_\infty + LogK$ (Munro and Pauly, 1983).

**Mortality**

The total mortality rate (Z) was estimated using the length-converted catch curve Pauly (1984) approach. The natural mortality rate (M) was estimated using Pauly's (1980) empirical relationship.

$$Log(M) = -0.0066 - 0.279 \times Log(CL_{\infty}) + 0.6543 \times Log(K) + 0.4634 \times Log(T)$$

where: $CL_{\infty}$ is the asymptotic carapace length, M is the natural mortality, K is the VBGF growth coefficient, and T is the average annual seawater water temperature (*°C). The input requirement in the procedure was the value of $T = 15.5$ °C (Anonymous, 2010). After M and Z were estimated, fishing mortality was determined employing the following relationship:

$$F = Z - M$$

where Z= is the total mortality, F= is the fishing mortality, and M= is the natural mortality. The exploitation rate (E) was calculated by the Gulland (1971) formula E=F/Z.

**Length at First Capture (Lc50)**

The probability of capturing each length class equipped with FISAT II was estimated using the increasing left arm of the length-converted catch curve. The CL at first capturing (Lc50) was determined by plotting the cumulative probability of capturing against the mid-length of the resulting curve. In addition, the lengths of the 25% and 75% catches were calculated to represent the cumulative possibilities of 25% and 75%, respectively.
Recruitment Pattern

The recruitment pattern was inferred using a backwards analysis of the length axis of the length-frequency data set defined in FISAT. This method produced the recruitment pulse from a time series of length-frequency data to determine the number of pulses each year and the pulse's relative strength (Amin et al, 2008). Input parameters contained both L∞ and K. The Normal Distribution of the recruitment pattern was estimated employing the NORMSEP FISAT (Pauly and Caddy, 1985).

Relative Yield per-Recruit \([Y'/R]\) and Relative Biomass Per–Recruit \([B'/R]\)

The relative biomass per recruit \([B'/R]\) was estimated as \([B'/R] = (Y'/R)/F\). The \(E_{\text{max}}\), which refers to an exploitation rate producing maximum yield, \(E_{0.1}\) suggesting an exploitation rate at which the marginal increase of \(Y'/R\) is 10% of its virgin stock with \(E_{0.5}\) indicating an exploitation rate under which the stock is reduced to half of its virgin biomass, was computed using the procedure incorporated in the FiSAT II Tool, using the Knife-edge option.

Results and Discussion

Length-Frequency Distribution

CL frequency distributions of samples ranged from 8.00 mm to 31.00 mm for females and from 11.00 mm to 28.00 mm for males (Figure 2). The sex ratio proportion was found to be 1:1.7 (F:M). The females represented 63.0% and the males’ represented 37.0% of the analyzed population. The sex ratio proportion presented a statistically difference from the 1:1 proportion (\(p < 0.05, \chi^2\)). The mean W of females and males were 7.06 g (± 2.72 SE) and 5.17 g (± 1.043 SE), respectively. Female and male CL distributions were significantly different (Kolmogorov-Smirnov two-sample test: \(n_f = 2410, n_m = 1416, D = 0.1290, p < 0.05\)).

**Figure 2.** Length-frequency of *P. longirostris* in coastal waters of Tuzla, eastern Sea of Marmara
Growth Parameters

The relationship between carapace length and weights was determined as \( W = 0.0105CL^{2.6866} \) and \( W = 0.0126CL^{2.6103} \) for females and males, respectively. Both the CL and the weight values were determined seasonally and annually. The values did not show a statistically significant different considering seasons and years (\( p > 0.05 \)). The CL-weight relationship for both sexes indicated negative allometric growth (\( b<3; \) t-test, \( P<0.05 \)).

The estimated VBGF parameters for the Sea of Marmara \( P. \) longirostris females and males were: \( CL_\infty = 32.55, 28.67 \) mm, \( K = 0.760, 0.950 \) yr\(^{-1} \), respectively (Figure 3, Table 1). The estimated growth performance indexes (\( \phi \)) for females and males were 2.91 and 2.90, respectively. Figure 3. A and B show reconstructed length-frequency data superimposed on the estimated growth curve, demonstrating approximately three cohorts for females and almost two cohorts for males. The calculated \( t_0 \) and \( T_{max} \) for females and males were estimated to be \(-0.233, 3.71 \) and \(-0.769, 2.39 \), respectively (Table 1).

![Figure 3](https://example.com/figure3)

**Figure 3.** Von Bertalanffy growth curves for females and males. \( P. \) longirostris, for females (A) and males (B), is superimposed on the re-structured carapace length-frequency histograms. The black and white bars of three length groups represent pseudo-cohorts.
Table 1. Population parameters of *P. longirostris* by sex in the coastal waters of Tuzla, eastern Sea of Marmara

| Population parameters                          | Female | Male |
|-----------------------------------------------|--------|------|
| Asymptotic Length (CL∞) in mm                 | 32.55  | 28.67|
| Growth coefficient (K, yr⁻¹)                  | 0.760  | 0.950|
| Theoretical age at birth (t₀)                 | −0.233 | −0.769|
| Lifespan (t_max)                              | 3.71   | 2.39 |
| Growth performance index (φ)                  | 2.91   | 2.89 |
| Natural mortality (M, yr⁻¹)                    | 1.09   | 1.33 |
| Fishing Mortality (F, yr⁻¹)                    | 1.20   | 0.71 |
| Total mortality (Z, yr⁻¹)                      | 2.29   | 2.04 |
| Exploitation rate (E)                          | 0.52   | 0.35 |
| M/K                                           | 1.43   | 1.40 |
| Lc₅₀/L∞                                      | 0.58   | 0.63 |
| Allowable limit of exploitation (E_max)        | 0.82   | 0.90 |
| E₀.5                                          | 0.39   | 0.40 |
| E₀.1                                          | 0.72   | 0.80 |
| Mean surface temperature (°C)                  | 15.50  | 15.50|
| Number of samples (N)                          | 2410   | 1416 |

For each monthly sampling, mode lengths were estimated by cohorts. The modal length groups of the *P. longirostris* population were estimated to consist of maximum three age groups in females and two age groups in males, ranging from 17.61 mm to 30.44 mm and from 14.22 mm to 24.34 mm, respectively (Figure 4, Table 2).

**Mortality and Exploitation Rate**

Using the length-converted capture curve, the total mortality rates (Z) for female and male shrimp were estimated to be 2.29 and 2.04 yr⁻¹, respectively (Figure 5). Based on the total mortality rate (Z) obtained from the length-converted catch curve, the fishing mortality rates (F) of males and females were determined as 1.20 and 0.71 yr⁻¹, respectively (Table 1).

Based on these data, the exploitation rates (E) for female and male *P. longirostris* in the eastern sea of Marmara were calculated as 0.52 and 0.35, respectively (Table 1).
Table 2. Result of Bhattacharya method to identify *Parapeneus longirostris* modal components (annual cohort) by sex in the coastal waters of Tuzla, the eastern sea of Marmara.

| Sex | Cohort | Computed mean | SD   | SI  |
|-----|--------|---------------|------|-----|
|     |        |               |      |     |
| Female | 1      | 17.61         | 3.430| n.a |
|       | 2      | 25.88         | 2.840| 2.210|
|       | 3      | 30.44         | 0.520| 2.160|
| Male  | 1      | 14.22         | 2.370| n.a |
|       | 2      | 24.34         | 2.620| 2.470|
|       | 3      | --            | --   | --  |

Figure 5. In the length-converted capture curve for females (A) and males (B), the darkened full points represent the points used in the calculation via least-square linear regression, and the open points represent either the not fully recruited point or the estimate of total mortality near $t_0$.

**Length at First Capture (CL_{50})**

As part of the length-converted catch curve analysis, the CL_{50} (at which 50% of the population of *P. longirostris* is vulnerable to fishing gear) was estimated. The estimated values for females and males were CL_{50} = 18.78 and 18.07 mm, respectively. The lengths at which 25% and 75% of the females and males caught with beam trawls were determined by the analysis were CL_{25\%} = 14.56, 15.46 mm, and CL_{75\%} = 22.99, 20.69 mm, respectively (Figure 6).

**Recruitment Pattern**

The recruitment pattern of *P. longirostris* had two peaks in both sexes during the year. 1st and 2nd recruit rates of females and males were 26.28%, 15.32% and 15.54%, 13.11%, respectively. Significant recruitment took place in October for females and in March for males. The highest and lowest recruitments for females and males occurred in October, November and March, August, respectively (Figure 7).
Relative Yield Per-Recruit (Y'/R) and Relative Biomass Per-Recruit (B'/R)

The simplest assumption is that selectivity is knife-edge at some standardized length Lc50, i.e. all fish smaller than Lc50 is not vulnerable to fishing mortality and only experience natural mortality, while all fish larger than Lc50 is fully vulnerable to fishing mortality. The relative Y'/R and B'/R analyses of females and males P. longirostris were estimated using the knife-edge method assumptions. The input parameters for females and males for the model were the values of Lc50/L∞= 0.58 and 0.63, and M/K = 1.43 and 1.40, respectively. The maximum exploitation rate (E_max) providing maximum relative yield per recruit, was calculated from the analysis.

The maximum exploitation level (E_max) giving the maximum relative yield per stock was calculated as 0.82 and 0.90 for females and males, respectively (Figure 8). The economic exploitation rates (E_0.1) of females and males were 0.72 and 0.80, where the marginal increment in relative yield per recruit was 10% of the marginal increase estimated at the slight rate in exploitation (Table 1). The rate of exploitation (E_0.5) of the non-exploited stock was 0.40, corresponding to 50% of relative biomass per-recruit. Yield per recruit for male and female P. longirostris populations in Tuzla coastal waters of the Eastern Marmara Sea was estimated using a wide E range and fishing pressure in both isopleths and CL50 (Figure 8).
In the former studies in the Marmara Sea, the male and female percentages of *Parapenaeus longirostris* were 44.2% and 55.8% (İhsanoğlu and İşmen, 2020) and 35.4% and 64.6% (Tosunoğlu *et al.*, 2009) and 44.2% and 55.8% (Zengin *et al.*, 2007), 37.7 and 62.3% (Bayhan *et al.*, 2006). In a previous study in the Mediterranean, the percentages of males and females were found to be 72.75% and 23.75 (Manaşırılı *et al.*, 2011). In our study, a significant skewness was observed in the sex ratio in the Marmara Sea and in the Mediterranean, but no bias in the sex ratio was observed in the Aegean Sea.

In our study, 3 age groups for females and 2 age groups for males were determined. The $3^{+}$ age group for *P. longirostris* females and males was determined in a study conducted in the Eastern Mediterranean Babadil Bay (Manaşırılı *et al.*, 2011). In another study conducted with samples obtained from the north, south, and west of the Marmara Sea, 4 age groups for females and 3 age groups for males were determined (İhsanoğlu and İşmen, 2020). Other studies reported a maximum of 6 years in the Aegean Sea (Tosunoğlu *et al.*, 2009). A study conducted previously in the sea of Marmara indicated 3 years of age of the *P. longirostris* (Zengin *et al.*, 2007). It can be thought that this difference is due to environmental conditions, nutrient abundance, sampling season, and sampling methods.

In this study, $CL_\infty$ and $K$ of female and male *P. longirostris* were determined as 32.55, 28.67 mm and 0.760, 0.950 yr$^{-1}$, respectively. In the Eastern Mediterranean coastal waters of Turkey, Manaşırılı *et al.* (2011) estimated $L_\infty$ and $K$ values to be 32.30, 31.20 mm and 0.76, 0.77 for female and male individuals, respectively. These results are very close to the results of our study. Deval *et al.*, (2006) used three different cod ends to investigate the effect of beam cod end size and net materials on fishing activity and mortality in the Sea of Marmara. These are results, total mortality ($Z$), natural mortality ($M$), fishing mortality ($F$), and exploitation rate ($E$) were calculated between 1.16 and 2.83, 0.97 and 1.16, 0.60 and 1.86, 0.45 and 0.65, respectively. In a study conducted in
Siğacık Gulf, the Aegean Sea, the CL$_{\infty}$ and K values for females and males were calculated as 41, 257 mm, 0.314 and 34.991 mm, 0.41, respectively. In the same study, the total mortality rate (Z) for females and males was 2.48 and 1.21, the fishing mortality rate (F) was 1.71 and 0.54, the natural mortality rate (M) was 0.77 and 0.67, and the exploitation rate (E) was 0.69 and 0.45, respectively (Dereli, 2010). İhsanoğlu and İşmen (2020), in a study conducted in the north, south and west of the Marmara Sea, calculated the CL$_{\infty}$ and K values for females and males as 41 mm, 0.27 and 36.8 mm, 0.37, respectively. In the same study, the total mortality rate (Z) for females and males was 1.09 and 2.22, the fishing mortality rate (F) was 0.57 and 1.56, and the natural mortality rate (M) was 0.52 and 0.66, respectively. The exploitation rate (E) for females and males was found to be 0.52 and 0.70, respectively. Accordingly, when the results of these studies are compared, it can be said that the total mortality rates (Z) and fisheries mortality rates are close to each other, while the natural mortality rates (M) and exploitation rates are slightly higher in our study results. This difference can be associated with habitat conditions and fishing pressure.

In their research in the Gulf of Saros (Aegean Sea), Bilgin et al. (2009) estimated CL$_{\infty}$ to be 34.7 mm and 27.0 mm, K to be 1.05 and 1.49, and Z to be 1.19 and 4.73 for _P. longirostris_. These results are quite close to the findings of our study, but the K value is higher. This situation can be associated with environmental conditions and nutrient abundance. In another study conducted in the Mediterranean waters of Morocco, the L$_{\infty}$ (52.87 mm) value was found to be high, while the K value was determined as 0.39 Awadh and Aksissou (2020). In the same study, Z was calculated as 3.49. M and F were calculated by two different methods and estimated to be 1.98, 1.36 and 1.51, 2.13, respectively. These differences can be attributed to environmental factors (temperature, nutrients, predators, etc.). Although the total mortality rate was higher, M and F estimates were somewhat closer to each other in our findings. In two different locations in the South Tyrrhenian Sea, Arculeo _et al._, (2014) determined the shortest CL and largest CL$_{\text{max}}$ for male and female _P. longirostris_ at Terrasini location was estimated to be 9.0 mm and 32.0 mm, respectively. The VBGF was CL$_{\infty}$ = 38.5 mm, F = 0.65 years$^{-1}$ for females, and CL$_{\infty}$ = 32.5 mm, F = 0.8 years$^{-1}$ for males. The smallest and largest carapace lengths (CL) for females and males at the Porticelli location were 8 mm, 31 mm, 13 mm and, 26 mm, respectively. VBG parameters for female and male individuals were CL$_{\infty}$ = 40 mm, F = 0.60 yr$^{-1}$ and CL$_{\infty}$ = 30 mm, F = 0.76 yr$^{-1}$, respectively (Arculeo _et al._, 2014). These results are close to the findings estimated for male and female individuals in our study. The smallest carapace length measured in our study was 8.00 mm for females and males, and the CL$_{\text{max}}$ was 31.28 mm. The largest and smallest measured CL were very close to each other. _P. longirostris_ was estimated to have a CL$_{\infty}$ of 45 mm and a K of 0.34 yr$^{-1}$ in a study conducted in the Gulf of Alicante (Spain) (Garcia-Rodriguez _et al._, 2009). Study findings in the Bay of Alicante showed a longer asymptotic length but a lower K value than our findings. An increase in CL$_{\infty}$ was striking as it approached from the east of the Mediterranean Sea to the west of the Atlantic Ocean. These differences may be due to the abundance of nutrients in the environment and seawater temperatures (Ren _et al._, 2021). In another study conducted in the Central Mediterranean, VBGF results were close to our findings, but K = 0.63 was lower (Levi _et al._, 1995). This may be due to environmental conditions (Ren _et al._, 2021). The mortality rates (Z = 1.4, M = 0.17, and F = 0.79) were considerably lower than the findings of this study. On the other hand, the exploitation rate (E = 0.67) was higher. In another study conducted in West Africa, the CL$_{\infty}$ and K value were estimated as 17.61 mm and K = 0.78, respectively (Yacouba _et al._, 2014). While the K value (0.78) was close to our findings, the CL$_{\infty}$ = 17.61 was lower than our study result. These differences can be thought to be due to environmental conditions. The mortality rates were close to our findings. However, (F = 3.74) and (E = 0.77) were higher. These differences are due to the high rate of exploitation due to fishing pressure (Colloco _et al._, 2017).

In a study conducted in the Strait of Sicily and Tunisian waters, the length CL$_{\infty}$ for females and males was calculated as 43.0, 42.41 mm, 34.3, and 32.82 mm, respectively. The K and M values for females and males estimated were calculated as 0.68, 0.66, 1.07, 1.03 and 0.73, 0.73, 1.53, 0.86, respectively (Knittweis _et al._, 2013). Estimated CL$_{\infty}$ for males and females was lower in our study, but these values were also higher in the studies of İhsanoğlu and İşmen (2020), and Dereli (2010). K values were found to be higher for both sexes. The M were estimated higher in our results for both sexes. All these differences can be attributed to the ecological conditions of the Mediterranean waters and the bio-ecological conditions of the East Marmara Sea waters (Ceraulo _et al._, 2018).

In our study, two peaks were determined for the recruitment of _P. longirostris_, occurring in February and July and August for females and males. In their study conducted in the Eastern Mediterranean Turkish waters, Manaşırılı _et al._ (2011) stated that the recruitment period was in March, and the spawning period was in the 2nd period. Yacouba _et al._ (2014) found two peaks for the recruitment of _P. longirostris_, corresponding to February and September, in his research in West African waters. All these results support the findings of our study. These results might be influenced by the number of predators and competitors as well as the fishing pressure and mesh size of...
fishing gear (Sparre and Venema, 1992). The length of the first capture is a crucial input in the estimation of the relative yield-per-recruit and relative biomass-per-recruit. In this study, the highest Y/R and Emax was calculated as 0.82 and 0.90, respectively. Pauly and Soriano (1986) classified the relative yield isopleths into four groups (or quadrants) based on the critical size level (Lc50/L∞) (related to mesh size).

In this study, isopleths with Lc50/L∞, E0.1, and Emax are seen in Figure 8 (A, B, C, D). It indicated an exploitation ratio where the marginal increase in Y'/R which is 10% of the virgin stock (E0.1), and the Emax is close to each other. The fishing regime for P. longirostris in the eastern Marmara Sea was estimated in the "C" quadrant, indicating advanced fishing (Pauly and Soriano, 1986). Results from the analysis of the E based on the mortality estimate and the Y'/R indicate that the fishing is above the level of optimum based on the E0.1 principle. The state of P. longirostris populations is of concern. If these rates of exploitations and fishing pressures are sustained, stocks of P. longirostris could be damaged in a short time. P. longirostris stocks will suffer if current fishing pressure continues.

Conclusion

The population and stock status of P. longirostris, which is an economically valuable resource, should be routinely evaluated and stock management should be planned well. In long-term stock management for P. longirostris, we think that the findings of this study will contribute to stock management together with the results of other studies.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential, or perceived conflict of interests.

Ethics committee approval: Ethics committee approval is not required.

Funding disclosure: -

Acknowledgments: -

Disclosure: -

References

Amin, S.N., Arshad, A., Japar, S.B., Siraj, S.S. (2008). Growth, mortality and yield-per-recruit of sergestid shrimp, Acetes intermedium Omori, 1975 (Decapoda: Sergestidae) from length frequency analysis in the coastal waters of Malacca, Peninsular Malaysia. Pertanika Journal of Tropical Agricultural Science, 31(1), 95-106.

Anonymous (2021).
https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr (accessed 10.02.2022)

Anonymous (2020).
https://www.tarimorman.gov.tr/BSGM/Belgeler/Icerikler/Su%20%C3%9Cr%C3%B0nleri%20Ve%20Urunleri-%C4%B0statistikleri/denizSuyu/Marmara-Deniz-Suyu-Sicakligi-Analizi-2021.pdf (accessed 10.02.2022)

Arculeo, M., Brullo, S.L., Cannizzaro, L., Vitale, S. (2014). Growth and reproduction of the deep-water rose shrimp, Parapeneaus longirostris (Lucas, 1846) (Decapoda, Penaeidae), in the Southern Tyrrhenian sea. Crustacea, 87(10), 1168-1184. https://doi.org/10.1163/15685403-0003334

Awadh, H., Aksissou, M. (2020). Population dynamics and stock assessment of deep water rose shrimp Parapeneaus longirostris (Lucas, 1846) from the Mediterranean Coast of Morocco. Indian Journal of Fisheries, 67(2), 8-14.

Bayhan, Y.K., Ünlüer, T., Akkaya, M., (2006). Some biological aspects of Parapeneaus longirostris (Lucas, 1846) (Crustacea, Decapoda) inhabiting the Sea of Marmara. Turkish Journal of Veterinary and Animal Sciences, 29(3), 853-856.

Bilgin, S., Ozen, O., Ismen, A., Ozekinci, U. (2009). Bathymetric distribution, seasonal growth and mortality of the deep-water rose shrimp Parapeneaus longirostris (Decapoda: Penaeidae) in an unexploited stock in Saros Bay, Aegean Sea. Journal of Animal and Veterinary Advances, 8(11), 2404-2417.

Ceraulo, M., Papale, E., Caruso, F., Filiciotto, F., Grammata, R., Parisi, I., Buscaino, G. (2018). Acoustic comparison of a patchy Mediterranean shallow water seascape: Posidonia oceanica meadow and sandy bottom habitats. Ecological Indicators, 85, 1030-1043. https://doi.org/10.1016/j.ecolind.2017.08.066

Colloca, F., Scarcella, G., Libralato, S. (2017). Recent
Trends and Impacts of Fisheries Exploitation on Mediterranean Stocks and Ecosystems, *Frontiers in Marine Science*, 14.
[https://doi.org/10.3389/fmars.2017.00244](https://doi.org/10.3389/fmars.2017.00244)

Crosnier, A., Fontana, A., Le Guen, J.C., Wise, J.P. (1970). Ponte et croissance de la crevette Peneide *Parapenaeus longirostris* (Lucas) dans la region de Pointe-Noire (Republique du Congo). *Cahiers ORSTOM. Serie Oceanographie*, 8(4), 89-102.

Crosnier, A., Forest, J. (1973). *Les crevettes profondes de l'Atlantique oriental tropical* (Vol. 19). IRD Editions. Retrieved from [https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/Fau_trop/06903.pdf](https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/Fau_trop/06903.pdf) (accessed 03.03.2022)

Dereli, H. (2010). Sığacık Körfezinde Dip Trol Ağları ile Yakalanlan Derin Su pembe Karidesi (*Parapenaeus longirostris* Lucas, 1846)’nın bazı Biyolojik ve Popülasyon özellikleri, Doktora Tezi, 158 p, Ege üniversitesi, İzmir Türkiye.

Deval, M., Tosunoğlu Z., Bök T., Ateş, C. (2006). The effect of mesh size and cod end material on the mortality and yield of the rose shrimp, *Parapenaeus longirostris* (Lucas, 1846) (Decapoda, Penaeidae) in the Turkish beam trawl fishery. *Crustaceana*, 79(10), 1241-1249.
[https://doi.org/10.1163/15685400678859533](https://doi.org/10.1163/15685400678859533)

FAO (2008). Global study of shrimp fisheries, FAO fisheries technical paper, 475, Rome.
[https://www.fao.org/3/i0300e/i0300e00.pdf](https://www.fao.org/3/i0300e/i0300e00.pdf)

García-Rodriguez, M., Gil, J.L.P., Barcala, E. (2009). Some biological aspects of *Parapenaeus longirostris* (Lucas, 1846) (Decapoda, Penaeidae) in the gulf of Alicante (SE Spain). *Crustaceaea*, 82(3), 293-310.
[https://doi.org/10.1163/156854009X409108](https://doi.org/10.1163/156854009X409108)

Gulland, J.A. (1971). Science and fishery management. *ICES Journal of Marine Science*, 33(3), 471-477.
[https://doi.org/10.1093/icesjms/33.3.471](https://doi.org/10.1093/icesjms/33.3.471)

Holthuis, L.B. (1980). FAO species catalogue. Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries. *FAO Fish Synopsis*, 125(1), 271.

İhsanoğlu, M.A., İşmen, A. (2020). Marmara denizi biyoçeşitliliği ve Derinsu pembe karidesi av miktarı. *Aquatic Research*, 3(2), 85-97.
[https://doi.org/10.3153/AR20008](https://doi.org/10.3153/AR20008)

İhsanoğlu, M.A., İşmen, A. (2020). Biological traits and population dynamic of *Parapenaeus longirostris* (Lucas, 1846) in the Marmara Sea, Turkey. Ege Journal of Fisheries and Aquatic Sciences, 37(3), 275-283.
[https://doi.org/10.12714/egejfas.37.3.10](https://doi.org/10.12714/egejfas.37.3.10)

Knittweis, L., Arneri, E., Ben Meriem, S., Dimech, M., Fiorentino, M., Gancitano, V., Harboui, O., Mbarek, K.B., Cериola, L. (2013). Stock status and potential yield of deep water rose shrimp (*Parapenaeus longirostris*, Lucas 1846) in the south-central Mediterranean Sea. GCP/RER/010/ITA/MSM-TD-28. MedSudMed Technical Documents. No 28: 15 pp.

Kocatas, A. (1981). Liste préliminaire et répartition des Crustacés Décapodes des eaux Turques. *Rapports de la Commission Internationale pour l’Exploration Scientifique de la Mer Méditerranée*, 27(2), 161-162.

King, M. (2013). Fisheries biology, assessment and management. John Wiley & Sons. ISBN: 9781118688038
[https://doi.org/10.1002/9781118688038.ch5](https://doi.org/10.1002/9781118688038.ch5)

Levi, D., Andreoli, M.G., Giusto, R.M. (1995). First assessment of the rose shrimp, *Parapenaeus longirostris* (Lucas, 1846) in the central Mediterranean. *Fisheries Research*, 21(3-4), 375-393.
[https://doi.org/10.1016/0165-7836(94)00298-B](https://doi.org/10.1016/0165-7836(94)00298-B)

Manasrlı, M., Avşar, D., Yeldan, H. (2011). Babadillimani Koyu'ndaki (Silifke-Mersin) derinsu pembe karidesi (*Parapenaeus longirostris*)nin büyüme, ölüm oranları ve stokdan yararlanma düzeylerini belirlemesi. *Ekoloji*, 20(79), 38-44.

Morri, C., Bianchi, C.N., Cocito, S., Peirano, A., De Biase, A.M., Aliani, S., Paisini, M., Boyer, M., Fedrighini, F., Pestarino, M., Dando, P. (1999). Biodiversity of marine sessile epifauna at an Aegean island subject to hydrothermal activity: Milos, eastern Mediterranean Sea. *Marine Biology*, 135(4), 729-739.
[https://doi.org/10.1007/s002270050674](https://doi.org/10.1007/s002270050674)

Munro, J.L., Pauly, D. (1983). A simple method for comparing the growth of fishes and invertebrates. *Fishbyte*, 1(1), 5-6.

Öztürk, B. (2009). Investigations of the rose shrimp *Parapenaeus longirostris* (Lucas, 1846) in the Northern Marmara Sea. *Journal of Black Sea/Mediterranean Environment*, 15, 123-134.
Pauly, D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculators, ICLARM Stud. Rev. (8), 325. Retrieved from https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/3445/Pub SR76 8.pdf?sequence1=0 (accessed 25.02.2022)

Pauly, D. (1983). Some simple methods for the assessment of tropical fish stocks (No. 234). Food & Agriculture Org. FAO Fisheries Technical Paper No. 234, p. 52, Food and Agriculture Organization of the United Nations. Retrieved from https://s3-us-west-2.amazonaws.com/legacy.seaaroundus/doc/Researcher+Publications/dpauly/PDF/1983/Books+and+Chapters/SomeSimpleMethodsAssessmentTropicalFishStocks.pdf (accessed 01.03.2022)

Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES Journal of Marine Science, 39(2), 175-192. https://doi.org/10.1093/icesjms/39.2.175

Pauly, D. (1979). Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. Retrieved from https://www.semanticscholar.org/paper/Gill-size-and-temperature-as-governing-factors-in-a-Pauly/0fa1e026ce7358e473f778b517211d5bd932de8c (accessed 03.03.2022)

Pauly, D., Caddy, J.F. (1985). A modification of Bhattacharya's method for the analysis of mixtures of normal distributions (Vol. 781). FAO. Retrieved from https://s3-us-west-2.amazonaws.com/legacy.seaaroundus/doc/Researcher+Publications/dpauly/PDF/1985/Books+and+Chapters/ModificationBhattacharya%27sMethodAnalysisMixturesNormalDistri.pdf (accessed 25.02.2022)

Pauly, D., Soriano, M.L. (1986). May. Some practical extensions to Beverton and Holt’s relative yield-per-recruit model. In The first Asian fisheries forum (pp. 491-496). Manila: Asian Fisheries Society.

Ren, X., Wang, Q., Shao, H., Xu, Y., Liu, P., Li, P. (2021). Effect of Low Temperature on Shrimp and Crab Physiology, Behavior, and Growth: A Review. Frontiers in Marine Science, 8, 746177. https://doi.org/10.3389/fmars.2021.746177

Sobrino, I., Silva, C., Sbrana, M., Kapiris, K. (2005). A Review of the Biology and Fisheries of the Deep Water Rose Shrimp, Parapenaeus longirostris, In European Atlantic and Mediterranean Waters (Decapoda, Dendrobranchiata, Penaeidae), Crustacea 78(10), 1153-1184. https://doi.org/10.1163/156854005775903564

Sokal, R.R., Rohlf, F.J. (1987). Introduction to biostatistics. New York Freeman, 352 pp. ISBN: 0-7167-1806-7

Sparre, P., Venema, S.C. (1992) Introduction to Tropical Fish Stock Assessment. Part 1. Manual, FAO Fisheries Technical Paper, 306. No. 1, Review 1, FAO, Rome, pp. 376

Sparre, P., Ursin, E., Venema, S.C. (1989). Introduction to tropical fish stock assessment. FAO Fish Tech Pap, 306/1, pp. 407.

Tosunoğlu, Z., Akyol, O., Dereli, H., Yapıcı, S. (2009). Sığacık Körfezi’nde Dip Trol Ağları ile Yakalanan Derin Su Pembe Karidesi (Parapenaeus longirostris Lucas, 1846)’nin Bazı Biyolojik ve Populasyon Özelliklerinin Araştırılması. TUBİTAK Project Report, No 108Y102, 156 pp.

Yacouba, S., Zacharie, S., Joanny T. (2014). Biological aspects and yield of the shrimp Parapenaeus longirostris, West Africa. International Journal of Agricultural Policy and Research, 2(4), 132-140.

Zengin, M., Karakulak, F.S., Polat, H., Kutlu, S. (2007). A study on the stocks of the deep-water pink shrimp (Parapenaeus longirostris Lucas, 1846) in the Marmara Sea. Rapp. Comm. Int. Mer Medit., 38, p. 642, 09-13 April 2007, İstanbul.