



## 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)

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### 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>

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Submitted: 28.12.2021

Revision requested: 17.02.2022

Last revision received: 16.03.2022

Accepted: 04.04.2022

Published online: 21.04.2022

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### 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 ( $\phi$ ) of *P. longirostris* were determined as 2.91 and 2.89, respectively. Asymptotic carapace lengths ( $CL_{\infty}$ ), growth coefficients (K), and theoretical birth ages ( $t_0$ ) 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 ( $E_{max}$ ) were calculated as 0.82 for females and as 0.90 for males. The first capture lengths ( $CL_{50}$ ) 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  $E_{0.1} = 0.72$  and 0.80 approached the maximum exploitation rate ( $E_{max} = 0.82$  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 (*Penaeus 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  $229.8 \pm 57.3 \text{ kg/m}^2$  and  $409.3 \pm 152 \text{ kg/m}^2$ , 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 (Babadillimanı 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 (Manaşırılı *et al.* 2011).

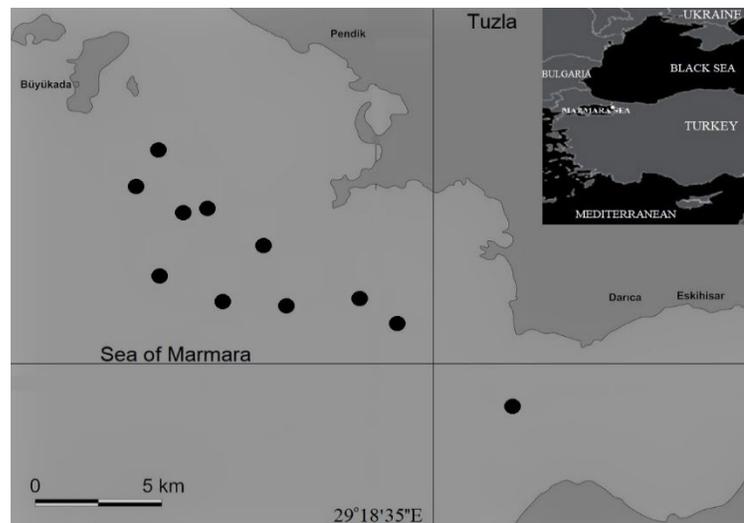
In this study, we evaluated the length at first capture, the recruitment model, the relative yield per-recruit, and the relative biomass per-recruit, as well as the growth and mortality parameters that are needed for stock management of *P. longirostris* in the eastern Sea of Marmara.

## 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,  $40^{\circ} 43' 52'' \text{ N}$ ;  $29^{\circ} 21' 04'' \text{ E}$ , and upper left,  $40^{\circ} 50' 00'' \text{ N}$ ;  $29^{\circ} 08' 08'' \text{ E}$ . *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.



**Figure 1.** Study area (Sampling points ●)

### 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: Length-weight relationships were calculated considering the allometric equation.  $W = a * CL^b$  (Sparre *et al*, 1989), 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:  $\log_{10}(-t_0) = -0.3922 - 0.275 * \log_{10}L_{\infty} - 1.038 * \log_{10}K$

(Maximum longevity (Tmax) was calculated by the following equation:  $T_{max} = 3/K + t_0$  (Pauly, 1983). The  $\phi$  was calculated by the formula:  $\phi = 2 \text{Log}L_{\infty} + \text{Log} K$  (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.

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

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 ( $^{\circ}\text{C}$ ). The input requirement in the procedure was the value of  $T = 15.5^{\circ}\text{C}$  (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 ( $L_{c50}$ )

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 ( $L_{c50}$ ) 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  $L_{\infty}$  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 ( $B'/R$ )

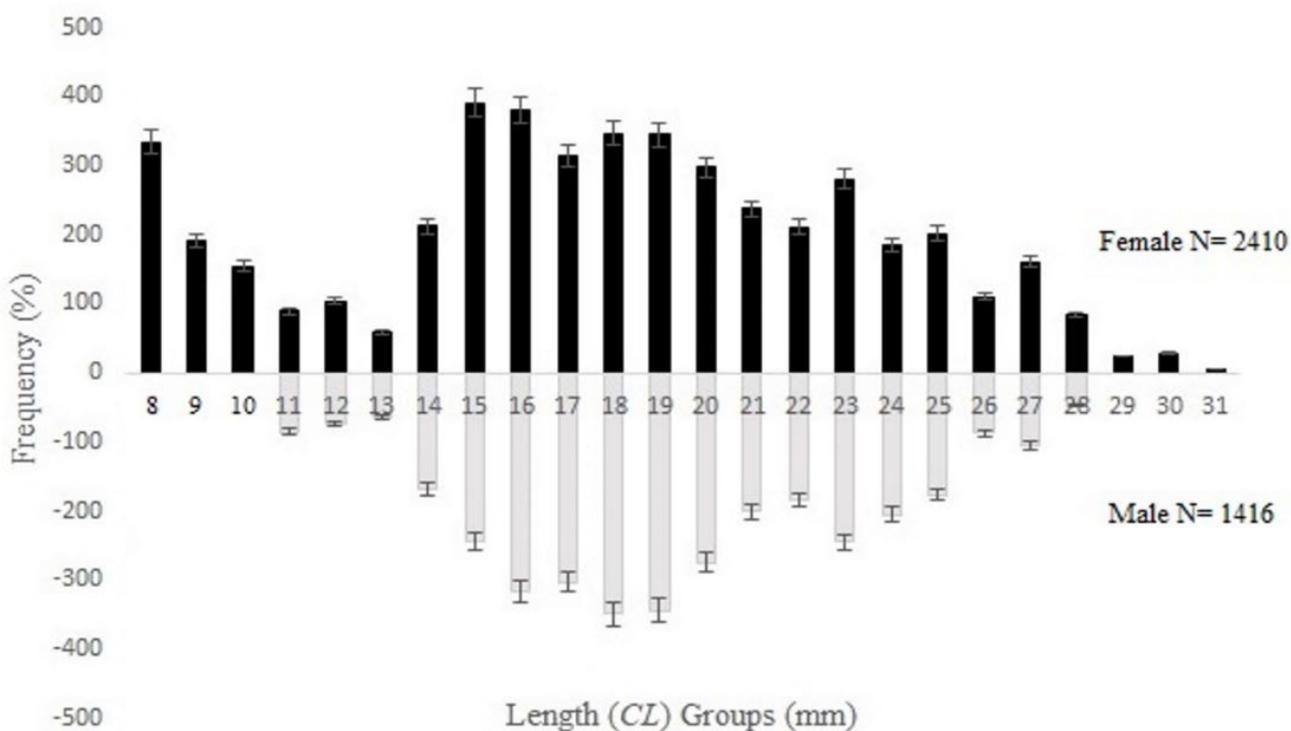
The relative biomass per recruit ( $B'/R$ ) was estimated as  $B'/R = (Y'/R)/F$ . The  $E_{max}$ , which refers to an exploitation rate producing maximum yield,  $E_{0.1}$  suggesting an exploitation rate at which the marginal increase of  $Y'/R$  is 10% of its virgin stock with  $E_{0.5}$  indicating 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' represent 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 ( $\pm 2.72$  SE) and 5.17 g ( $\pm 1.043$  SE), respectively. Female and male CL distributions were significantly different (Kolmogorov-Smirnov two-sample test:  $nf = 2410$ ,  $nm = 1416$ ,  $D = 0.1290$ ,  $p < 0.05$ ).

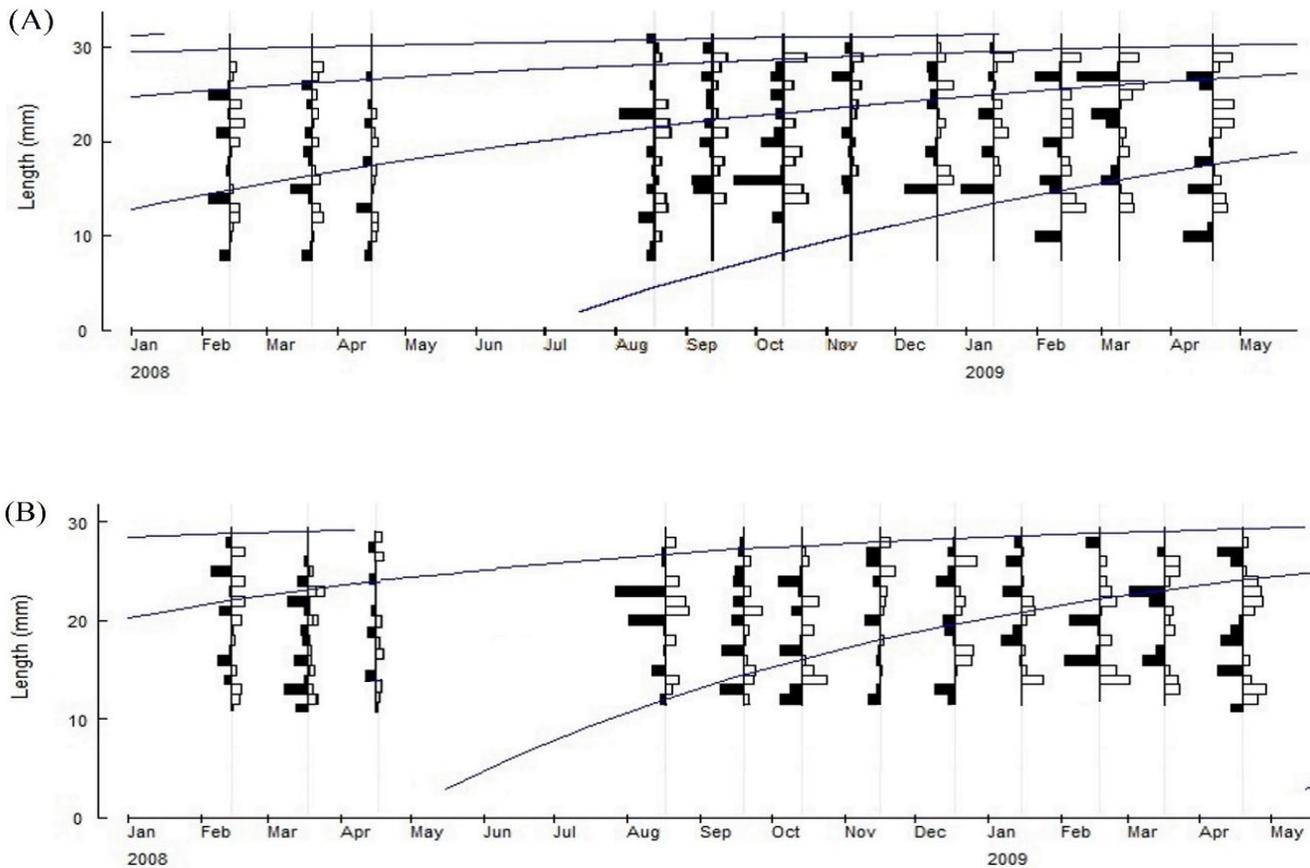


**Figure 2.** Length-frequency of *P. longirostris* in coastal waters of Tuzla, eastern Sea of Marmara

### 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 difference 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<sup>-1</sup>, 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.** 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

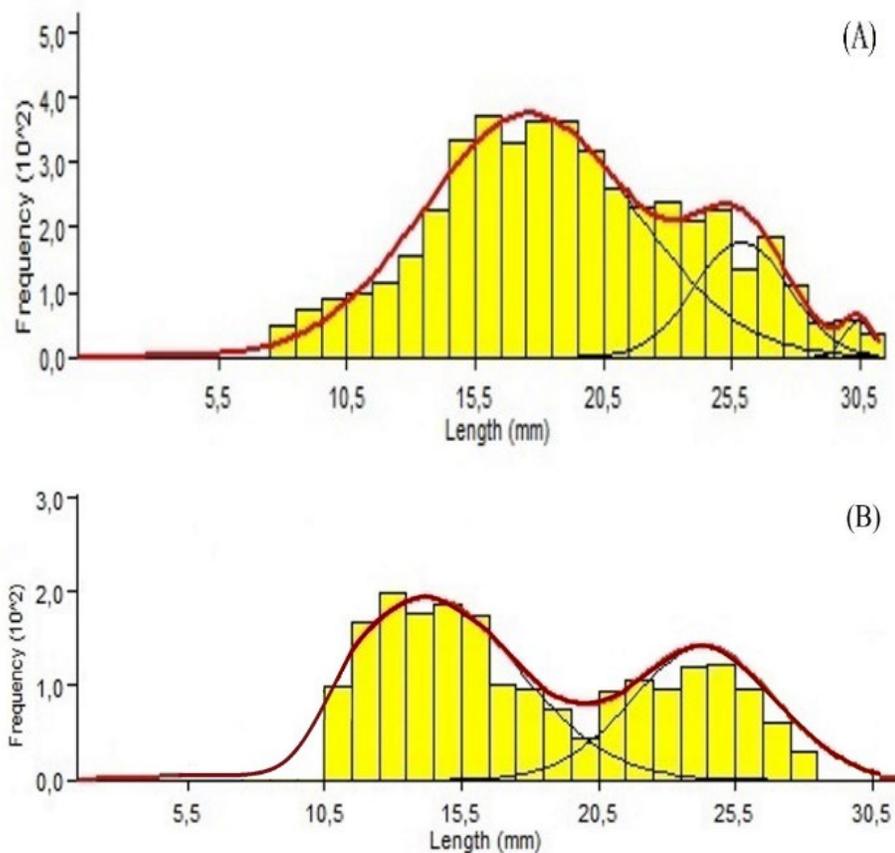
Population parameters	Female	Male
Asymptotic Length ( $CL_{\infty}$ ) in mm	32.55	28.67
Growth coefficient ( $K$ , $\text{yr}^{-1}$ )	0.760	0.950
Theoretical age at birth ( $t_0$ )	-0.233	-0.769
Lifespan ( $t_{\max}$ )	3.71	2.39
Growth performance index ( $\phi$ )	2.91	2.89
Natural mortality ( $M$ , $\text{yr}^{-1}$ )	1.09	1.33
Fishing Mortality ( $F$ , $\text{yr}^{-1}$ )	1.20	0.71
Total mortality ( $Z$ , $\text{yr}^{-1}$ )	2.29	2.04
Exploitation rate ( $E$ )	0.52	0.35
M/K	1.43	1.40
$L_{c50}/L_{\infty}$	0.58	0.63
Allowable limit of exploitation ( $E_{\max}$ )	0.82	0.90
$E_{0.5}$	0.39	0.40
$E_{0.1}$	0.72	0.80
Mean surface temperature ( $^{\circ}\text{C}$ )	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

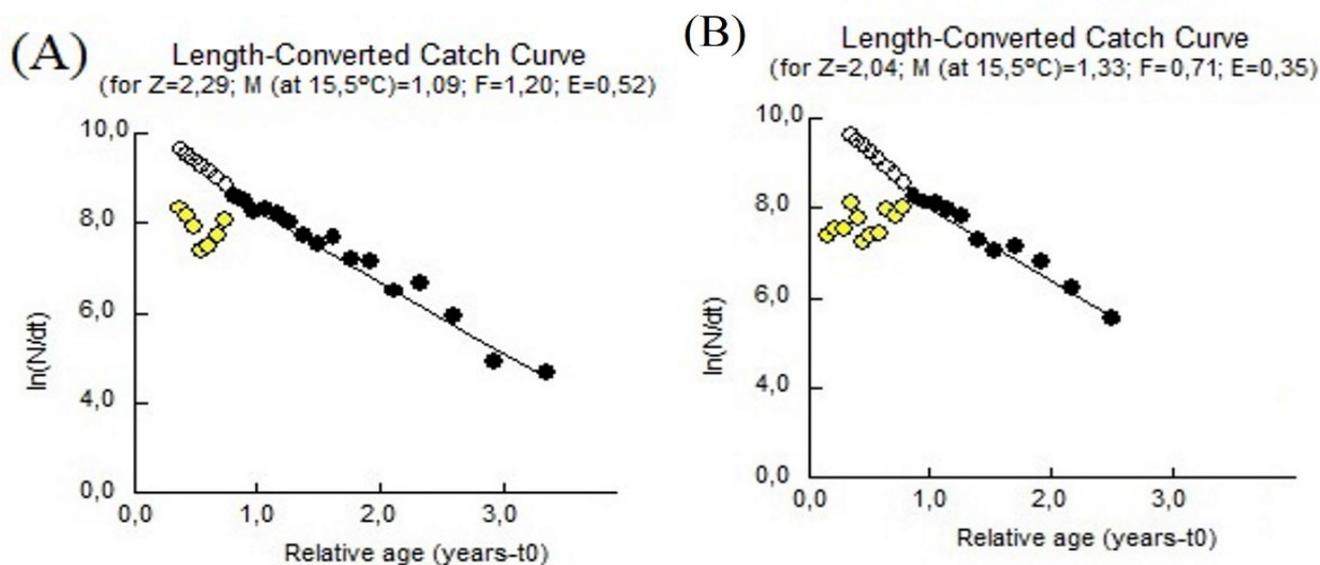
Using the length-converted capture curve, the total mortality rates ( $Z$ ) for female and male shrimp were estimated to be 2.29 and 2.04  $\text{yr}^{-1}$ , respectively (Figure 5). Based on the total mortality rate ( $Z$ ) obtained from the length-converted catch curve, the fishing mortality rates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

**Figure 4.** Age estimation of female (A) and male (B) individuals of *P. longirostris* according to Bhattacharya's method

**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	--	--	--



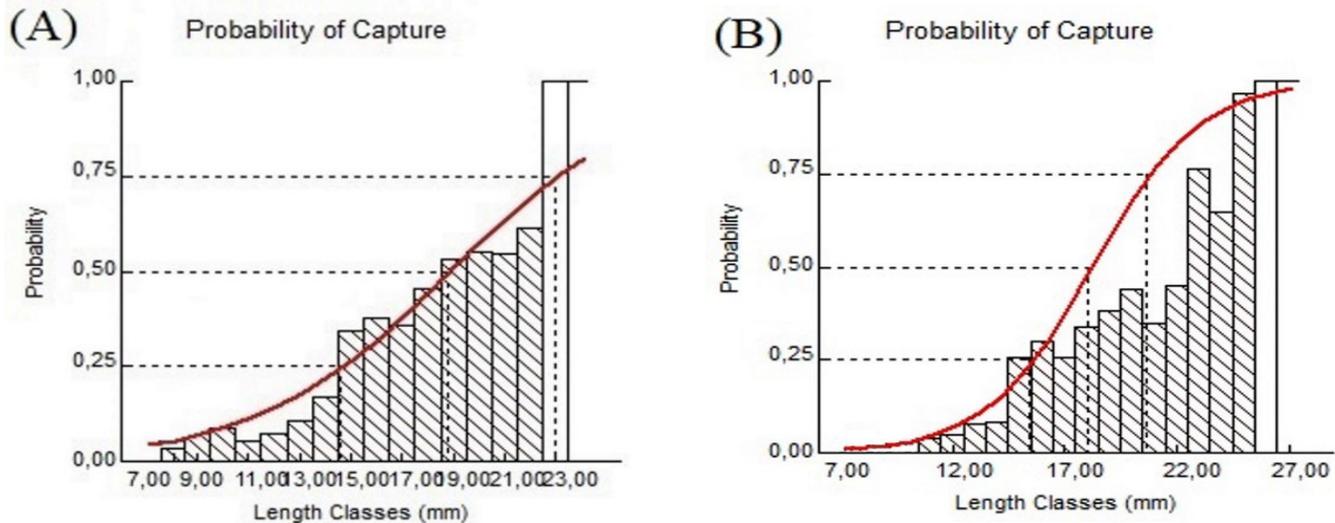
**Figure 5.** In the length-converted capture curve for females (A) and males (B), the darkened full points represent the points used in the calculation via least-square linear regression, and the open points represent either the not fully recruited point or the estimate of total mortality near  $t_0$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

#### Length at First Capture ( $CL_{50}$ )

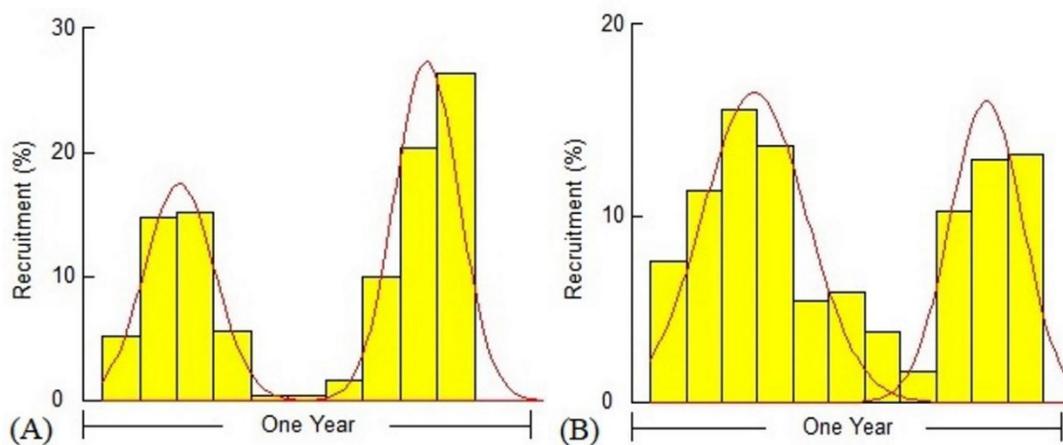
As part of the length-converted catch curve analysis, the  $CL_{50}$  (at which 50% of the population of *P. longirostris* is vulnerable to fishing gear) was estimated. The estimated values for females and males were  $CL_{50} = 18.78$  and  $18.07$  mm, respectively. The lengths at which 25% and 75% 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. 1<sup>st</sup> and 2<sup>nd</sup> 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).



**Figure 6.** Probability of capture of each Carapace length ( $CL_{50}$ ) class of females (A) and males (B)

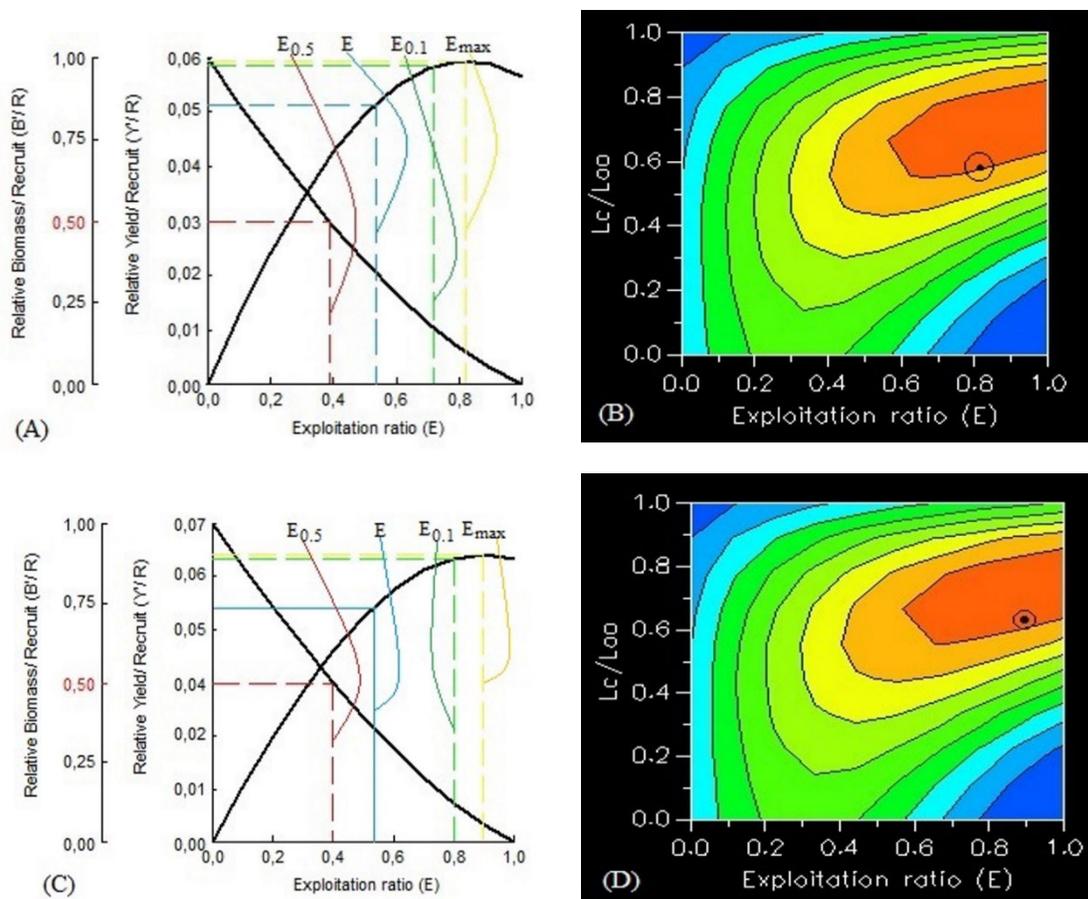


**Figure 7.** Recruitment pattern of (A) female and (B) male *P. longirostris* in the coastal waters of Tuzla, eastern Sea of Marmara showing two main peaks.

#### 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  $L_{c50}$ , i.e. all fish smaller than  $L_{c50}$  is not vulnerable to fishing mortality and only experience natural mortality, while all fish larger than  $L_{c50}$  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  $L_{c50}/L_{\infty} = 0.58$  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  $CL_{50}$  (Figure 8).



**Figure 8.** Relative yield per recruit  $Y'/R$  and relative biomass per recruit  $B'/R$  for females (A) and males (C) and using knife-edge procedure for yield isopleths diagrams for females (B) and males (D) in Tuzla coastal waters, eastern Sea of Marmara

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<sup>+</sup> 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  $\text{yr}^{-1}$ , 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 code 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

Sığacık 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  $CL_{max}$  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,  $F = 0.65 \text{ years}^{-1}$  for females, and  $CL_{\infty} = 32.5$  mm,  $F = 0.8 \text{ years}^{-1}$  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,  $F = 0.60 \text{ yr}^{-1}$  and  $CL_{\infty} = 30$  mm,  $F = 0.76 \text{ yr}^{-1}$ , 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  $CL_{max}$  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  $0.34 \text{ yr}^{-1}$  in a study conducted in the Gulf of Alicante (Spain) (Garca-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 estimated 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 2<sup>nd</sup> 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  $E_{\max}$  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 ( $L_{C50}/L_{\infty}$ ) (related to mesh size).

In this study, isopleths with  $L_{C50}/L_{\infty}$ ,  $E_{0.1}$ , and  $E_{\max}$  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 ( $E_{0.1}$ ), and the  $E_{\max}$  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  $E_{0.1}$  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:** -

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