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Full Length Research Paper

Spawning period and first maturity size of deep water rose shrimp (*Parapenaeus longirostris*) in the Aegean Sea

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Parapenaeus longirostris **is one of the most important commercial crustaceans for the trawl fleet in the Aegean Sea. Spawning period and size at first sexual maturity of female *P. longirostris* were analysed from monthly samples collected by demersal trawls in the bay of Sığacık and Kuşadası in the Aegean Sea, from May 2008 to April 2009. The presence of ripe females was found between September and April (except March). The reproductive period, based on the percentages of maturity and gonadosomatic index (GSI), ranged throughout the year, reaching its peak two times; first peak occurred in autumn (September to November) and the second in spring (March to April). The minimum female size at maturity (carapace length) was 13.7 mm, and 50% of the female population was mature at about 24.6 mm carapace length at first maturity.**

Key words: *Parapenaeus longirostris*, reproduction, spawning period, Sığacık Bay, Aegean Sea.

INTRODUCTION

The deep water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846) shows wide geographic distribution in the eastern Atlantic from Angola to north of the Iberian Peninsula and in the western Atlantic from Guyana to Massachusetts. It also inhabits the entire Mediterranean and its adjacent seas (Tyrrhenian, Adriatic, Aegean and the Sea of Marmara) (Fischer et al., 1987; Sobrino and Garcia, 2007). In the Mediterranean, this species shows a wide bathymetric distribution between 20 to 750 m in depth (Tom et al., 1988). Biomass is more intensive at depths ranging between 200 and 400 m, and it shows a marked size-dependent distribution according to the depth. Small individuals are found at the edge of the continental shelf (Lembo et al., 1999; Abello et al., 2002).*P. longirostris* is one of the most important commercial crustaceans in the Mediterranean, grouped as the fifth important when considering the total biomass landed (Stamatopulos, 1993). The total amount of species landed were 16.428 tons in Mediterranean in 2005 (FAO, 2009). In Turkey, total catch for *P. longirostris* was reported as 4.668 tons (2008) and 22% (583 tons) of these were comprised from coast of Aegean Sea of Turkey (TUİK, 2009). Because of its commercial importance, the reproductive activity of *P. longirostris* was investigated by a number of authors (Heldt, 1938; Crosnier et al., 1970; De Ranieri et al., 1986; Tom et al., 1988; Sobrino and Garcia, 1994; Mori et al., 2000; Meriem et al., 2001; Abello et al., 2002; Bayhan et al., 2005; Sobrino et al., 2005; Manaşırlı and Avşar, 2008; Bianchini et al., 2010). Despite some variability, reproduction aspects of females show a common pattern across the geographical distribution: spawning activity can be extended a whole year, with one-to-three peaks in spring-summer and autumn-winter (depending on location, water temperature and females' size).

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Abbreviations: GSI, Gonadosomatic index; **CL_{m50},** carapace length at first maturity; **CL,** carapace length; **W,** body weight; **OW,** ovary weight; **GW,** gonad weight; **TW,** total weight; **K,** condition factor; **IM,** index of maturity.

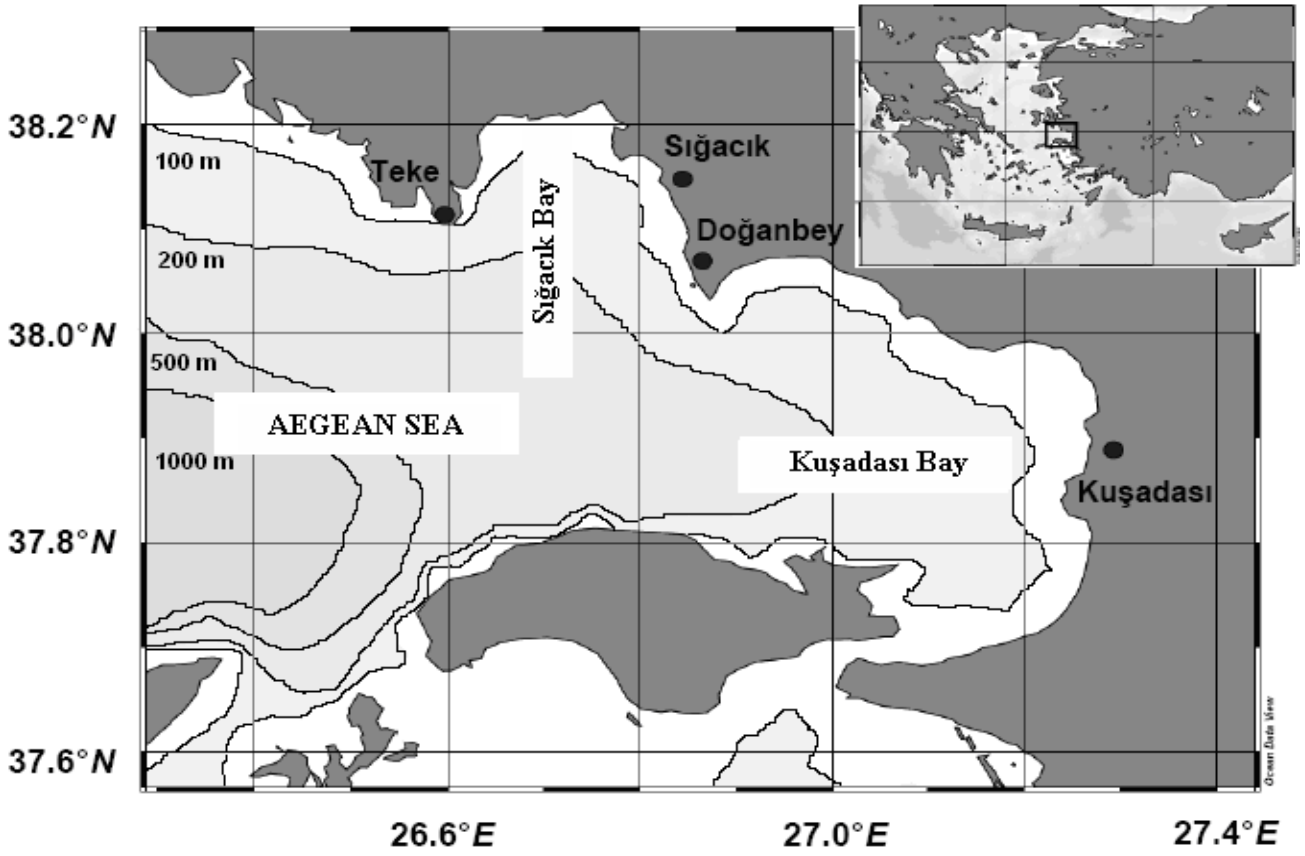

Figure 1. Map of the study area (Sığacık Bay and Kuşadası Bay of the Aegean Sea).

Studies about reproductive characteristics of species were carried out in Marmara Sea (Zengin et al., 2004; Bayhan et al., 2005) and in Babadıllimanı Bight in the northeastern Mediterranean (Manaşırlı and Avşar, 2008). However, there is no study about the reproductive characteristics of *P. longirostris* along the Turkish coast of the Aegean Sea. Therefore, the aim of this study was to obtain information on the reproductive characteristics of individiuals in the Aegean Sea, where the *P. longirostris* is an important target species for the trawl fleet.

MATERIALS AND METHODS

This study was implemented over a period of 12 months, which began in May 2008 and concluded in April 2009. Samples were collected at monthly intervals in three different strata (0 - 200, 200 - 400 and 400 - 600 m) in Sığacık Bay and Kuşadası Bay of the eastern Aegean Sea (Figure 1). Individuals were caught with a commercial stern trawler, "Hapuloğlu" (23.8 m length-over-all, with 550 hp main engine and 135 hp auxiliary engine power) using the modified bottom trawl, 1100 meshes round the fishing circle, (Aydın and Tosunoglu, 2009) with a 44 mm cod end mesh-size. The trawler starts to tow after the whole gear has been set out, and the towing duration was restricted to one hour with an average trawling speed of 2.5 knots. Samples were collected randomly from each haul and females and males were classified by checking the external genital organs (thelycum or petasma) to determinate the sex ratio. Sub-sample that was selected randomly through total sample was transported to the laboratory with cold chain (2 to 4°C) where females and males were sorted according to sex again. Chi-square test (χ^2) was used for comparisons of number of sex. A total of 2455 females were examined. Carapace length (CL) was measured using digital callipers with a precision of 0.01 mm as the distance from the postorbital margin to the mid-dorsal posterior edge of the carapace. Also body and ovary weight (W, OW) was measured using a digital balance with a precision of 0.01 g.

Estimation of spawning season

In order to estimate the spawning season, monthly mean gonadosomatic Index (GSI) values were calculated using the formula given by Garcia-Rodriguez et al. (2009) as;

$$GSI = \left(\frac{GW}{TW} \right) \times 100$$

Where, GW is the gonad weight and TW is the total weight.
Condition factor (K) was calculated using the formula given by Htun-Han (1978) as;

$$K = \left(\frac{TW - GW}{CL^3} \right) \times 100$$

Where, GW is the gonad weight; TW is the total weight and CL is

Table 1. Maturity stages of female shrimps (Sobrino, 1998).

Stage	Description
Stage 1 (Immature or virgin)	Very small, transparent and difficult visibility of gonads.
Stage 2 (Developing)	Bigger gonads than early stage. Lobes in abdomen and carapace are of good visibilities, although thin. Dark shadows start but this situation is not throughout posterior lobe.
Stage 3 (Active-developing)	Gonads are dark purple (green) colour. They are prominent throughout abdomen and pad in carapace.
Stage 4 (Spawning)	Gonads are bigger than previous stage and same colour. However, posterior lobe which lie throughout abdomen is wider.

the carapace length.
Index of maturity (IM) was calculated using the formula given by Meriem et al. (2001) as;

$$IM = \frac{GW}{CL}$$

Where, GW is the gonad weight and CL is the carapace length to assess the maturity and the condition of *P. longirostris*.
The carapace length-total weight (CL-TW) relationship of females was determined by using the regression analysis tool of MS Excel 2003 and was calculated using the formula $TW = a \times CL^b$ (Ricker, 1975) by the least squares regression after log transformation of both TW and CL. The association degree between the variables was calculated by the determination coefficient (R^2).

Determination of maturity

The maturity stage of females was determined by using four staged scale defined by Sobrino (1998) which was based on the macroscopic examination of the gonads (development and colouring) (Table 1). In order to determine the first maturity size for 50% of individuals to reach maturity, the percentage of maturity for each size of females were calculated during the spawning period. The mature individuals (Stages III and IV) and the immature (Stages I and II) were proportioned for the each size group. Then, the carapace length at 50% maturity, CL_{m50}, was determined from the relationship between the percentage *p* of mature individuals and the carapace length CL (Gunderson, 1977) which is described by the logistic function (Fryer, 1991).
Regression coefficients *(a* and *b*) were calculated with *p* values.

$$p(CL) = \frac{\exp(a + bCL)}{1 + (\exp(a + bCL))}$$

$$a + bCL = \log e\left(\frac{r(CL)}{1 - r(CL)}\right)$$

The parameters *a* and *b* were estimated by using the log-likelihood method of Fryer (1991) and developed for trawl selectivity studies, which allows the estimation of the 95% confidence intervals for CL_{m50}. This method may be very useful for maturity studies. The value of CL_{m50} can be estimated from the following expression:

$$CL_{m50} = \frac{-a}{b}$$

Data were analysed with "Solver" in MS-Excel programme of Tokai (1997). Sea surface temperature was measured with a mercury thermometer.

RESULTS

Among 46.621 specimens, 49.21% were identified as males and 50.79% as females. The ratio of males to females was 1: 0.97 and the females were dominant in 0 to 200 m and 400 to 600 m strata (Figure 2). There were significant differences between the number of female and male ($\chi^2 = 5.23$; $p<0.05$).
In order to determine the spawning period, gonad weight of 2455 females was measured and maturity stages were determined (Figure 3). Also, the data related to monthly found maturity stages, the mean K, GSI and IM values were used to identify the spawning period as shown in Figures 4 to 6. It was determined that water temperature was not correlated with GSI, K and IM. Mature female individuals (Stage 3 and 4) were found between September and April (except March) (Figure 3). GSI were of high values in autumn (September-December) and spring (March and April) (Figure 4). Also, analysing the condition factor (K) in detail, it can be seen that K decreased until August, and then it increased in September when the spawning began (Figure 5).
İn addition, the carapace length-total weight (CL-TW) relationship of females was determined as $TW = 0{,}0012*CL^{2{,}7054}$ ($R^2 = 0{,}9488$) (Figure 6). Index of maturity values were high in autumn (September to December)

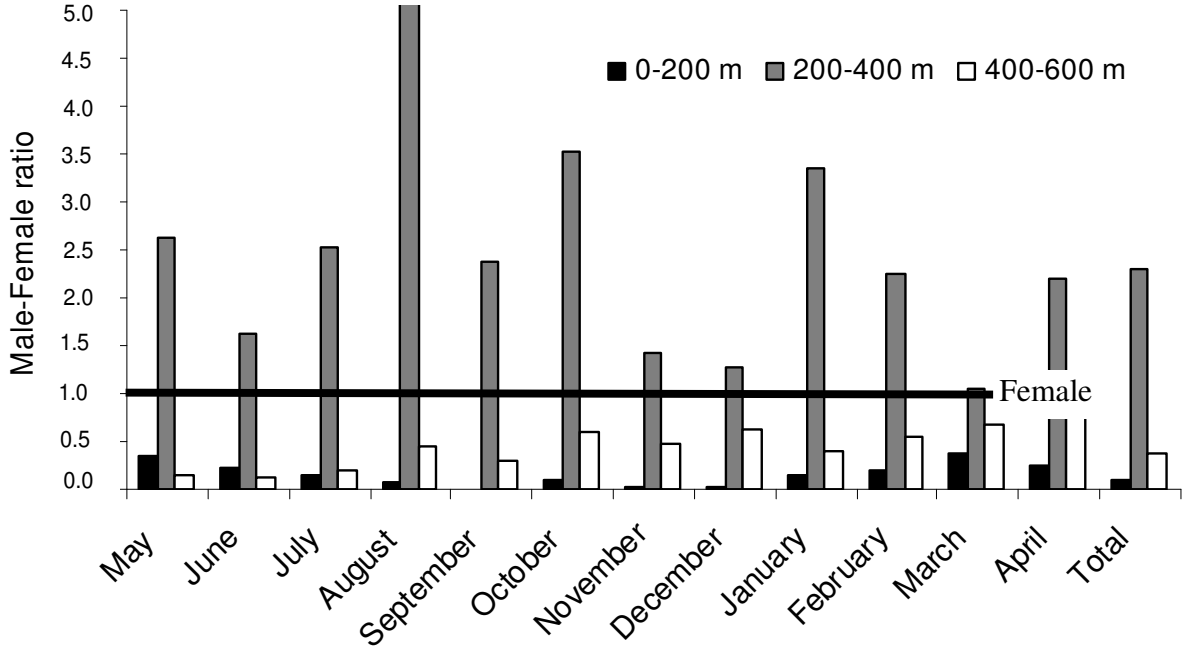

Figure 2. Sex ratio in different strata and months.

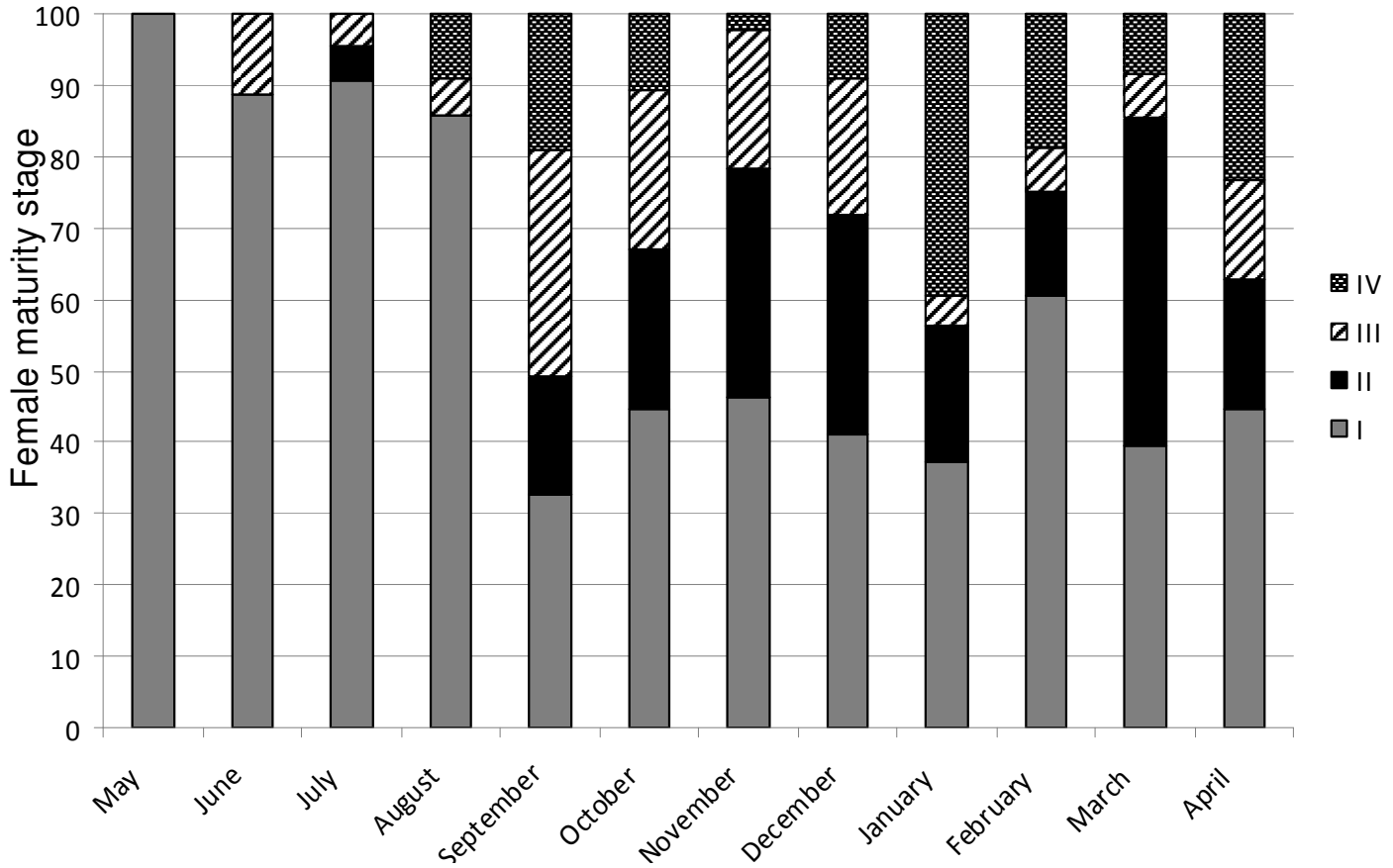

Figure 3. Monthly changes of female maturity stages of *P. longirostris.* I, immature; II, developing; III, active-developing; IV, spawning.

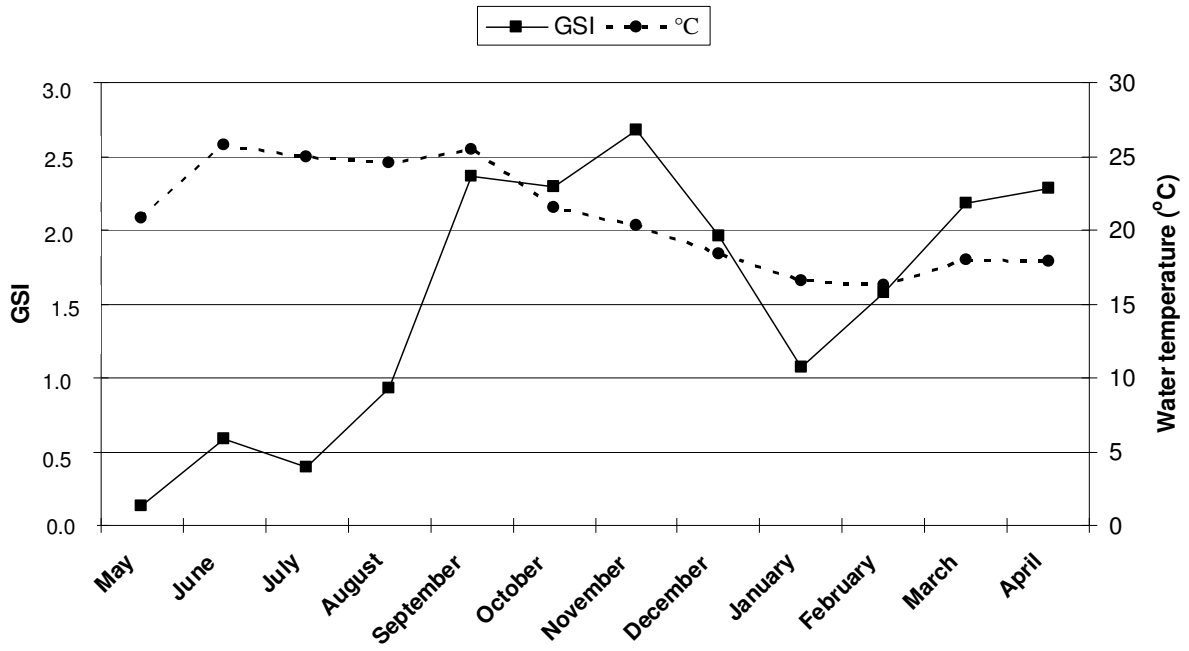

Figure 4. Monthly changes of GSI of female *P. longirostris* and water temperatures.

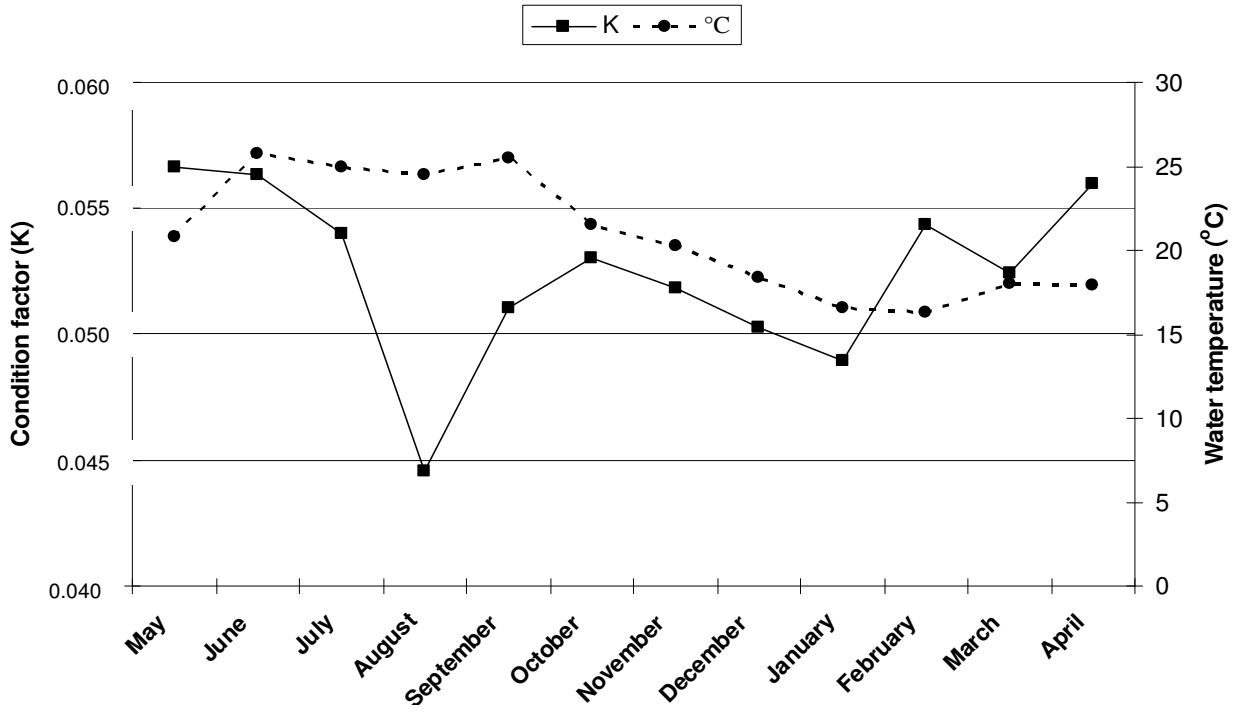

Figure 5. Monthly changes of K and water temperatures.

and spring (March and April), as in GSI (Figure 7). The smallest females with ripe ovaries were 13.7 mm CL and the largest size was 36.1 mm CL. The carapace length at first maturity (CL_{m50}) for females was found to be 24.6 mm CL (Figure 8).

DISCUSSION

The results in this study represented the first data for reproduction of *P. longirostris* along the Turkish coast of Aegean Sea. In this study, we found that females

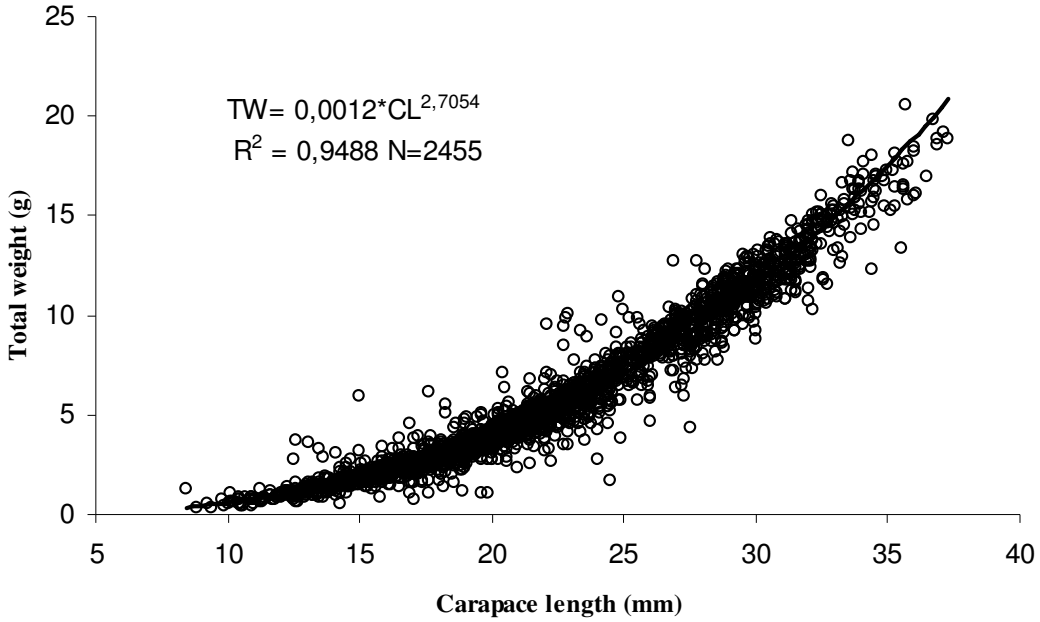

Figure 6. Carapace length-total weight relationship of female *P. longirostris*.

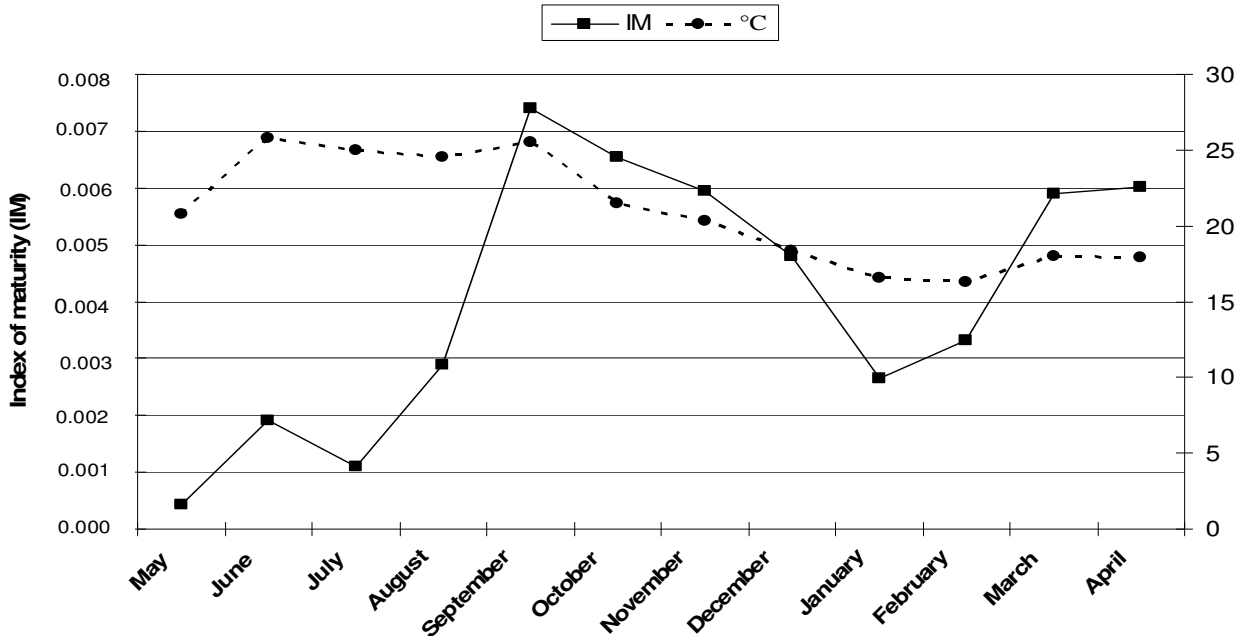

Figure 7. Monthly changes of IM and water temperatures.

dominated the population in 0 to 200 m and 400 to 600 m strata. Some researchers stated that female domination is a general situation in shrimps and tend to explain this with their low fecundity (Rao, 1967; Mori et al., 2000; Courtney et al., 1989). When we considered three strata together, it was observed that the females and males number are equal in the population. This situation was not similar in other studies which were carried out in Marmara Sea (Zengin et al., 2004; Bayhan et al., 2005; Tosunoğlu et al., 2008) and Babadıllimanı Bight in northeastern in Mediterranean (Manaşırlı and Avşar, 2008). The difference may be that these studies were carried out in different depth strata. In the present study, the smallest mature female was found as 13.7 mm CL. This value is approximately in Babadıllimanı Bight in northeastern in Mediterranean (Manaşırlı and Avşar,

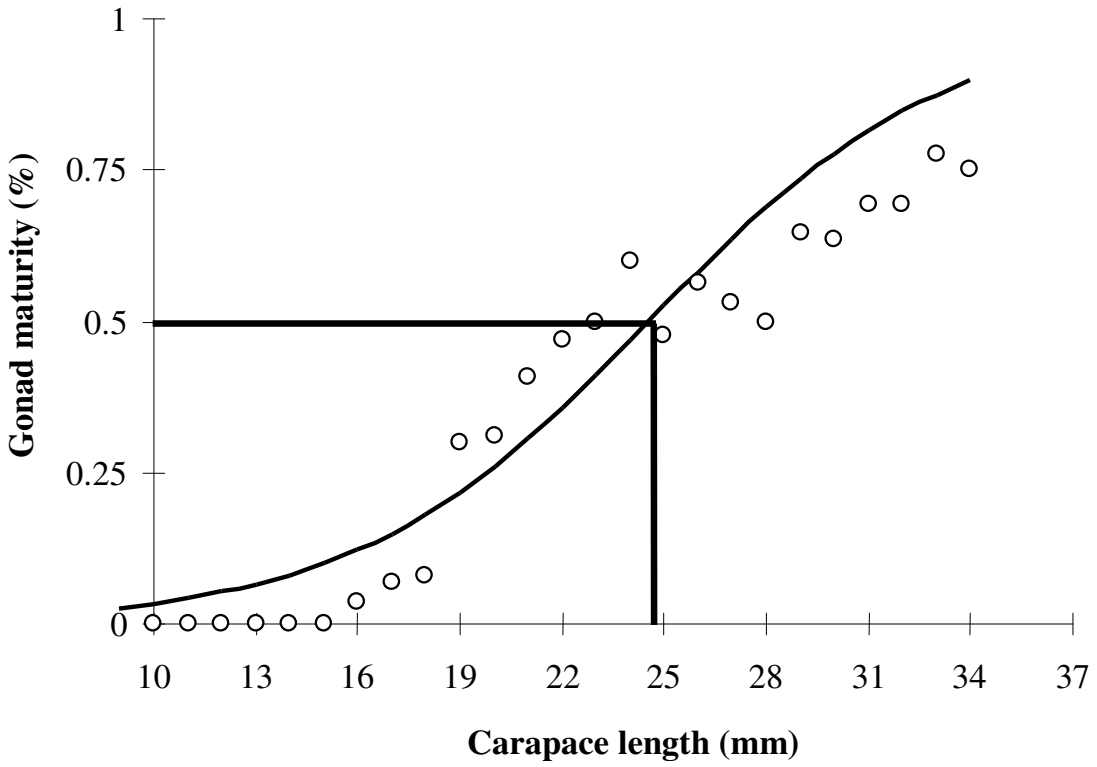

Figure 8. Carapace length at first maturity (CL_{m50}) for female *P. longirostris*.

2008) and is lower than results found in other studies (Ribeiro and Arrobas, 1987; Crosnier et al., 1970; Tom et al., 1988; De Ranieri et al., 1998; Spedicato et al., 1996; Relini et al., 1999).

The value of size at first maturity (24.6 mm CL_{m50}) for the present study was higher than many of those obtained results in Atlantic and Mediterranean (Crosnier et al., 1970; Sobrino and Garcia, 1994, 2007; Sobrino and De Cardenas, 1996; Sobrino, 1998; Sobrino et al., 2000; Ribeiro-Cascalho, 1988; Sobrino and Fernandez, 1991; Meriem et al., 2001; Ragonese et al., 2002; Mori et al., 2000; De Ranieri et al., 1998; Relini et al., 1999; Manaşırlı and Avşar, 2008) and lower than some results (Ribeiro-Cascalho and Arrobas, 1987; Garcia-Rodriguez et al., 2009; Guijarro and Massuti, 2006; Guijarro et al., 2009; Sobrino and Garcia, 1994; Spedicato et al., 1996). Maturity size of females increased from 20 to 28 mm (CL50*)* depending on the depth increase, according to Sobrino et al. (2005). Differences with other studies may arise from the different catching depths and water temperatures (Crosnier et al., 1970; Tom et al., 1988).The reproductive period was defined on the bases of the maturity percentages and the development of GSI and fluctuation of K and IM of the females. Mature females (in stage 3 and 4) were covered with dark green gonad in their carapace and abdomen; there were high percentages except summer (May to August). When GSI and IM were evaluated together, the two maturity peaks detected was one in spring (March and April) and another at the autumn. High K values between February and July arise from individuals recruit in spring use to feed for both gonad development and muscle development. It were also found that reproductive season for female *P. longirostris* were of very different times and spawning of species reached peaks in a year in the studies carried out in eastern Atlantic and Mediterranean. The differences may be because of different hydrographical characteristics of various areas that are under consideration. In this study, the peaks were determined as autumn and spring, and they were similar with some studies carried out off Congo (Crosnier et al., 1970), in Gulf of Cadiz (Sobrino and Garcia, 2007), in Atlantic and Mediterranean coasts of Europe (Sobrino et al., 2005), in Strait of Sicily (Levi et al., 1995), in Ionian Sea (Abdel et al., 2006) and in Marmara Sea (Zengin et al., 2004; Bayhan et al., 2005).

More also, the absence of juveniles (7 to 15 mm CL) all over the year indicates that there is continuous spawning for the species investigated in this study. The continuous spawning is common both in the Mediterranean (Nouar, 1985; Tom et al., 1988; DEÜ/DBF-JICA, 1993; Spedicato et al., 1996; Mori et al., 2000; Meriem et al., 2001; Zengin et al., 2004; Bayhan et al., 2005) and the Atlantic (Ribeiro-Cascalho and Arrobas, 1987; Sobrino and García, 1994; Dos Santos, 1998). In the Aegean Sea, there were two spawning peaks during the year, one in autumn (September to November) and another in spring (March and April). This hypothesis is supported by the

size frequency distributions obtained from this trawl study. The size frequency distributions showed that juveniles were of higher percentages (> 10%) in population between October to April.

In conclusion, this study provides the first information of spawning period and first maturity size of *P. longirostris* determined along the Turkish coast of the Aegean Sea. These results provide useful information for a better understanding of the reproductive characteristics of this species, which are important data for the fisheries management.

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