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Reproductive biology of *Penaeus kerathurus* (Forskål, 1775) (Decapoda: Penaeidae) in the Sea of Marmara, Turkey

by

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Abstract

One of the economically important species is *Penaeus kerathurus* (Forskål, 1755), which is widespread in the Mediterranean ecosystem. This paper presents results of research on reproductive biology of *Penaeus kerathurus* in the Sea of Marmara. A total of 1404 specimens were dissected to determine the maturity stages, reproduction time, and length at first reproduction. The female-to-male ratio was 1:0.9. A high percentage of mature females was determined in April, May and July. Moreover, the value of the gonadosomatic index (GSI) decreased after July. The spawning period was observed between April and July, and its intensity increased in July. The carapace length at first sexual maturity was determined to be 39 mm.

Key words: caramote prawn, Sea of Marmara, gonadosomatic index, first reproduction length

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1. Introduction

One of the important species for fisheries is *Penaeus kerathurus*, which is widely distributed in the Marmara, Aegean and Mediterranean seas in Turkey. It is a demersal species that typically inhabits muddy and sandy shallow waters up to a depth of 50–70 m (Başçınar 2004).

The information on the biology and life history of *P. kerathurus* is scarce. Some studies on its reproductive biology were conducted in the Mediterranean Sea and the Adriatic Sea (Rodriguez 1987; Türkmen et al. 2007; Conides et al. 2008; Metin et al. 2008, Lumare et al. 2011; Küçükdeğirmenci & Lök 2012; Kevrekidis & Thessalou-Legaki 2013; Bolognini et al. 2017).

Although *P. kerathurus* is commercially important, the literature on the subject contains no data on its reproductive biology in the Sea of Marmara. Furthermore, there are no data that can be used in fisheries management aimed at sustainable production, preservation and protection of stocks.

The objective of the present study was to determine monthly maturity stages, reproductive period, and length at first sexual maturity. The results related to these parameters can be used to produce more viable fisheries policies for the region. Local fishing locations should be more sustainably exploited to put an end to the continuous decline of living resources. It is believed that the results obtained will contribute significantly to the development of future legislation on fishing, sustainable production, and species conservation.

2. Materials and methods

P. kerathurus samples were collected monthly between May 2018 and April 2019 from commercial fishermen in and around Karabiga and Erdek Bay in the Sea of Marmara (Fig. 1). A total of 707 male and 697 female specimens were analyzed.

The sex of individuals was determined by macroscopic observation. Monthly changes in gonad maturity stages, values of the gonadosomatic index (GSI), and the condition factor (K) were operationalized in gonad samples collected from female individuals in order to determine breeding periods. Sex ratios were estimated as the male-to-female ratio (male:female).

Sexual maturity stages were assessed based on a scale of five maturity stages (Kevrekidis et al. 2013): I (immature) – thin, transparent and dark gray gonads; II (developing) – light gray larger gonads and easily distinguishable anterior and median lobes; III (maturing) – light gray or yellow posterior lobe, yellowish anterior and median lobes, posterior lobe with slight folds, and larger gonad; IV (mature) – very distinctively yellow-orange, greenish gonads, larger median lobe tucked along the edge of the carapace; a significant volume increase in the posterior lobe with a curved structure; V (spawned) – gray gonads similar to those at the second stage, with a loose structure; some individuals with dark yellow loose, sporadically unlaid eggs.

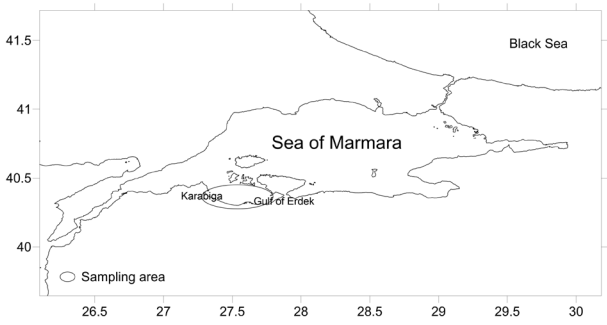

Figure 1
Sampling area in the Sea of Marmara

Monthly average GSI values were determined by operationalizing the relationship between the total individual body weight and the gonad weight in the examined samples. The following equation, proposed by Gibson & Ezzi (1978), was used in the calculation of GSI values: GSI = (Gonad Weight/Body weight) × 100. The condition factor was determined by using the formula $K = (W/L^3) \times 100$, where K is the condition factor, W is the body weight, and L is the total length.

To calculate the length of the examined female individuals at first sexual maturity, they were divided into length groups with a class range of 1 mm. Moreover, proportional values of mature individuals corresponding to the length groups were calculated. Pineiro & Sainza (2003) provided the following equation: $P = 1/(1 + \exp[-rm(L - Lm_{50})])$, where rm is the slope of the curve, Lm is the mean total length (cm) at sexual maturity, L is the mean total length (cm), and P is the probability of the presence of mature fish.

3. Results

It was determined that 697 (49%) out of 1404 shrimps were female and 707 (51%) were male. The male-to-female ratio was determined to be 1:0.9. Monthly sex ratios varied from 0.5 to 4.4. The sex ratio was greater than 1:1 in April, May, June and July, reaching the maximum value of 1:4.4 in July and the minimum value of 1:0.5 in January. It was revealed

that the number of females per males increases as the reproductive period of the species approaches (Fig. 2).

Monthly analyses of the sexual maturity stages in *P. kerathurus* indicated that stages III and IV, referring to mature individuals, occurred in April, May, June, July and September (Fig. 3). The results on seasonal maturity showed that most of the females were about to spawn in July. Further, the percentage of mature females was 60.9%, 87.9% and 81.2% in April, May and July, respectively, but 0.0% in January, February and December.

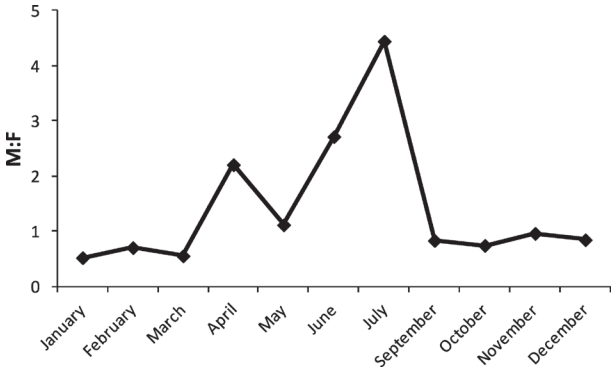

Figure 2

Monthly changes in the sex ratio in *P. kerathurus*

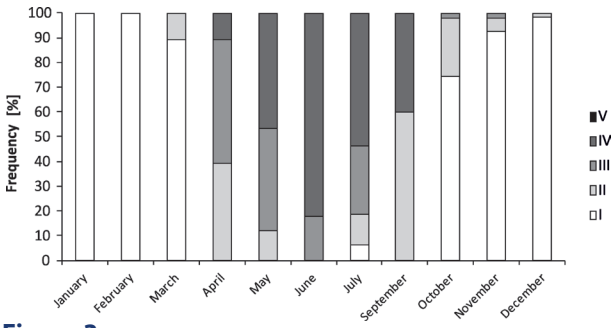

Figure 3

Monthly changes in maturity stages of *P. kerathurus*

The GSI values of individuals varied between 0.2 and 8.6. The lowest GSI value was recorded in January, while the highest in July, after which it started to decrease (Fig. 4). Unlike the GSI, the K of females reached the maximum value in November and decreased to its minimum value in July (Fig. 5). Based on the analysis of monthly changes in the GSI, K, and sexual maturity phases, it was concluded that the spawning period of *P. kerathurus* occurred between April and July and its intensity increased in July.

In female individuals of *P. kerathurus*, the carapace length at first sexual maturity was CL_{50} = 39 mm (Fig. 6). The smallest size at first sexual maturity was

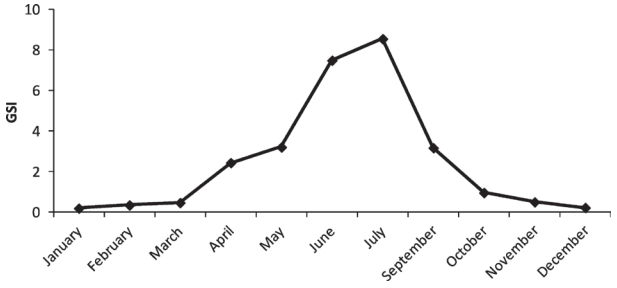

Figure 4

Monthly changes in the GSI values for *P. kerathurus*

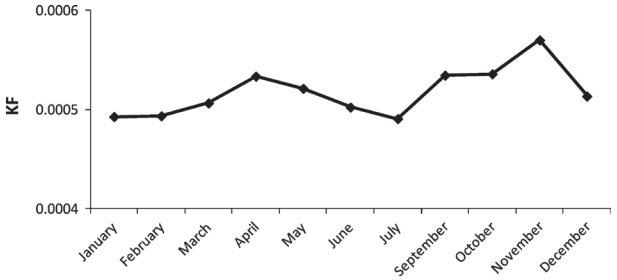

Figure 5

Monthly changes in the K values for *P. kerathurus*

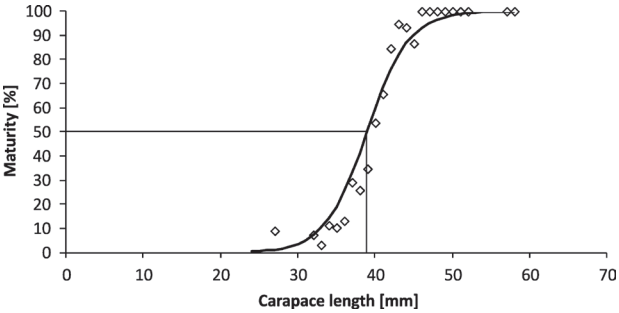

Figure 6

Length at first sexual maturity in female individuals of *P. kerathurus*

determined as 27 mm CL in April. All females (100%) were mature among individuals with 46 mm CL. The mean carapace length (37 mm) in female individuals was lower than the length at first sexual maturity.

4. Discussion

P. kerathurus is an economically important species, but its stock in Turkey's seas is declining every year due to overfishing (Metin et al. 2009). According to the 2019 statistics, the catch from the Marmara Sea is quite low, amounting to 2.8 t. In this context, the biology of this species of high economic value should be known

in detail and the causes of the stock decline should be identified. In addition, precautions should be taken to determine the source and degree of fishing pressure on the species in order to eliminate it.

According to the catch production data, the *P. kerathurus* production volume in Turkish seas increased from 2007 to 2011. The production in 2011 reached 643 t and then decreased to 203 t in 2018. In 2018, a total of 2.1 t were harvested in the Sea of Marmara, 42.9 t in the Aegean Sea, and 174.4 t in the Mediterranean Sea. The catch of the species in the Marmara Sea amounted to 16 t in 2007 and it increased to 300 t in 2011. In 2012, however, it dropped to 15 t, after which it continued to decrease, showing some fluctuations until 2019. In 2019, the amount of catch decreased to 2.8 t (TUİK 2020; Fig. 7).

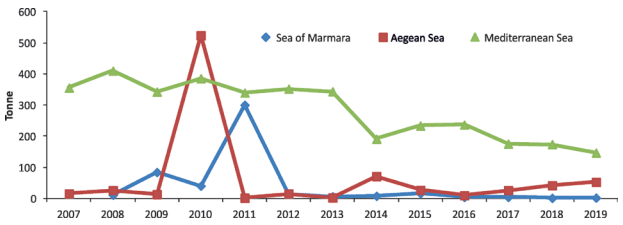

Figure 7

Capture production of *P. kerathurus* in Turkish Seas

In communique No. 2016/35 on the regulation of commercial fishing prepared by the Ministry of Agriculture and Forestry in Turkey, fishing for any shrimp species using any types of fishing gear was prohibited in the Marmara Sea between 15 April and 31 August and between 1 January and 31 January. However, fishing for *P. kerathurus* with a gillnet is allowed from 15 May to 1 August. The legal fishing season corresponds to the spawning season that was identified in this study. In the research carried out in the Aegean Sea, Metin et al. (2008) found a significant reduction in gillnet catches in July and August, which covered the entire spawning period of the species. Metin et al. (2008) observed that there are no length restrictions related to the species and suggested that the length at first breeding of the species should be imposed as the minimum catch size. In this sense, the catching season specified in the communique should be revised. It may be appropriate to prohibit fishing for *P. kerathurus* with all types of fishing gear in the Sea of Marmara between April to August.

In this study, the maturity period of the species was determined to occur between April and July. In other studies, the reproduction period was reported as May–September, May–August and summer in the Mediterranean Sea (Rodriguez 1987; Conides et al. 2008; Bolognini et al. 2017) and May–October, April–September and June in the Aegean Sea (Türkmen et al. 2007; Metin et al. 2008; Küçükdeğirmenci & Lök 2012). Although all studies concluded that the breeding season falls in the summer months, there are some differences. This may be due to regional differences, sediment composition, hydrographic characteristics and nutrient content.

In this study, the species' length at first maturity was calculated as LC_{50} = 39 mm for the carapace length of females. The length at first reproduction was determined to be greater than the average length (37 mm). For this reason, it should be recommended to increase mesh openings and to regulate the selectivity of fishing gear. Grid spacing is closely related to the carapace width of shrimps allowing them to go away (He & Balzano, 2012). Grid systems that increase species selectivity may be applied and square mesh cod-end can be used instead of diamond mesh cod-end. Other studies also support this suggestion. In the studies carried out in the Aegean Sea, the species' length at first maturity was reported as 48 mm CL (Türkmen et al. 2007), 40.7 mm CL (Kevrekidis & Thessalou-Legaki 2013) and 15 cm TL (Metin et al. 2008). In the studies conducted in the Mediterranean Sea, the length at first reproduction was determined as 120 mm TL (Rodriguez 1987), 45.2 mm CL (Conides et al. 2008) and 30.5 mm CL (Bolognini et al. 2017). Lumare et al. (2011) indicated that the length at first reproduction in the Adriatic Sea was 127.56 TL (31.42 mm CL; Table 1).

Table 1

Length at 50% maturity LC_{50} of *P. kerathurus* in other studies

Study	Area	L_{50}	Maturity period
Rodriguez 1987	Atlantic	120 mm TL	May–September
Turkmen et al. 2007	Gulluk Bay	48 mm CL	May–October
Metin et al. 2008	Aegean Sea	15 cm TL	April–September
Conides et al. 2008	Amvrakikos Gulf	45.2 mm CL	May–August
Lumare 2011	South Adriatic Sea	31.42 mm CL	May–August
Kevrekidis & Thessalou-Legaki 2013	Thermaikos Gulf	40.7 mm CL	April–October
Bolognini et al. 2017	Mediterranean Sea	30.5 mm CL	Summer
This study	Marmara Sea	39 mm CL	April–September

The Communique does not indicate any restrictions as to the size of the species. Therefore, the length at first reproduction (LC_{50} = 39 mm) determined in this study can be adopted as the minimum catch length of the species.

No previous studies are available on the reproduction period and the length at first maturity in the Marmara Sea. This study is the first comprehensive study on the reproduction of the species in the Marmara Sea. It is believed that this research will contribute to the revision and amendment of the regulations on the capture, sustainable production, and conservation of *P. kerathurus*.

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