NAT. CROAT. | VOL. 31 | No 2 | 365-374 | ZAGREB | December 30, 2022

original scientific paper / izvorni znanstveni rad
DOI 10.20302/NC.2022.31.26

REPRODUCTION OF THE CARAMOTE PRAWN, *MELICERTUS KERATHURUS* (FORSKÅL, 1775) (DECAPODA, PENAEIDAE) IN BOKA KOTORSKA BAY, MONTENEGRO (SOUTH-EASTERN ADRIATIC SEA)

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Marković, O., Đurović, M., Ikica, Z. & Pešić, A.: Reproduction of the Caramote prawn, *Melicertus kerathurus* (Forskål, 1775) (Decapoda, Penaeidae) in Boka Kotorska bay, Montenegro (South-eastern Adriatic). Nat. Croat., Vol. 31, No. 2, 365-374, 2022, Zagreb.

The aim of this study was to investigate for the first time some aspects of the reproductive activity of the Caramote prawn, *Melicertus kerathurus,* in Montenegrin waters. This species is considered a target species in the small-scale fishery in Boka Kotorska Bay, being a species of high commercial value. Sampling was carried out on a monthly basis from April 2019 to December 2019 by trammel nets. The spawning season was estimated based on monthly changes in the gonadosomatic index, condition factor and gonadal maturity stages. The main spawning season for females extends from April-May to September, with a clear peak in June. The total sex ratio (males/females) was 1:1. Sexual differences related to the length-weight relationship were noted.

Keywords: crustaceans, *Melicertus kerathurus*, spawning season, South Adriatic Sea

Marković, O., Đurović, M., Ikica, Z. & Pešić, A.: Neki biološki aspekti razmnožavanja velike kozice *Melicertus kerathurus* (Forskål, 1775) (Decapoda, Penaeidae) u Bokokotorskom zaljevu, Crna Gora (jugoistočna obala Jadranskog mora). Nat. Croat., Vol. 31, No. 2, 365-374, 2022, Zagreb.

Cilj ove studije bio je po prvi put istražiti neke aspekte reproduktivne aktivnosti velike kozice u vodama Crne Gore. U Bokokotorskom zaljevu predstavlja vrstu velike komercijalne vrijednosti koja se lovi mrežama malog obalnog ribolova. Uzorkovanje je obavljeno jednom mjesečno od travnja 2019. do prosinca 2019. godine trostrukim mrežama stajaćicama. Sezona mrijesta procijenjena je na osnovu mjesečnih promjena gonadosomatskog indeksa, faktora kondicije i stupnja zrelosti gonada. Glavna sezona mriještenja ženskih jedinki traje od travnja do rujna s maksimumom u lipnju. Odnos spolova (mužjaci/ženke) bio je 1:1. Utvrđene su razlike vezane uz odnos dužine i mase između mužjaka i ženki.

Ključne riječi: rakovi, *Melicertus kerathurus*, sezona mriještenja, južni Jadran

INTRODUCTION

Melicertus kerathurus, commonly known as the Caramote prawn, is distributed in the Eastern Atlantic, from the south coast of England to Angola and the entire Mediterranean (Holthuis, 1980) and lives in coastal marine or brackish waters on muddy or muddy-sand substrata (Kevrekidis & Thessalou-Legaki, 2011) at depths ranging

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from 0.5 to 90 m, but usually at less than 60 m depth (Froglia *et al*., 2013). This species is a highly valuable fishery resource in the northern and central part of the west Adriatic (Froglia *et al*., 2013), while along the eastern Adriatic coast it occurs mainly in the southern part. According to Ševčić (1990), this species is frequent near the Neretva river mouth. In Montenegrin territorial waters, *M. kerathurus* is only recorded in the areas of the Bojana River estuary and the Boka Kotorska Bay.

Information regarding *M. kerathurus* in Montenegrin territorial waters is very scarce and focuses mainly on the species' distribution (Merker-Poček, 1970, 1971). Reports place this species in the mouth of the Bojana river as well as in Boka Kotorska Bay (Karaman & Gamulin Brida, 1970; Merker-Poček, 1971; Stjepčević & Parenzan, 1980). The seasonal and day-night fluctuations in the trawl catch at the Bojana River estuary at depths between 10 and 40 m were studied by Merker-Poček & Radujković (1974). All the authors mentioned sampled *M. kerathurus* by bottom trawls in all areas investigated. Recently, bottom and pelagic trawling has been prohibited in Boka Kotorska Bay, according to the Law on Marine Fisheries and Mariculture of Montenegro (OG of Montenegro No. 8/11), and the Caramote prawn can only be caught using trammel nets, gillnets and traps.

The aim of this study was to investigate some aspects of the Caramote prawn's reproductive activity in Montenegro waters such as gonadosomatic index and condition factor and to compare the findings with similar data from other regions in the Mediterranean and Adriatic.

MATERIAL AND METHODS

Study area

The study area is Boka Kotorska Bay, situated in the southern part of the eastern Adriatic, with a coastline of 105.7 km, an area of 87.3 km^2 and a maximum depth of 64 m. Boka Kotorska Bay is subdivided into four smaller bays: Kotor Bay, Risan Bay, Tivat Bay, and Herceg Novi Bay (Fig. 1). In each bay the depth increases toward the central part, except in Kotor Bay where the maximum depth is near the northern coast (Perast). According to the latest data, the average depth of Boka Kotorska Bay is 27.6 m, and its maximum is 64 m (Kotor Bay). Given its depth, the whole of Kotor Bay belongs to the coastal or littoral system. It is well known that Boka Kotorska Bay has a specific position in the Adriatic Sea. The life conditions in this bay differ considerably from those of the open sea part of the Adriatic (Stjepčević, 1967). The hydrographical measurements (temperature, salinity, transparency, and physical composition of the sea bottom), may have considerable and different significances in the distribution of zoobenthos in Boka Kotorska Bay. The Bay is affected by a great influx of fresh water from numerous water streams and submarine springs.

Sampling and samples analysis

Individuals of Caramote prawn were obtained from the local fishermen who were using trammel nets (160 m max length, 1.5 m height, 56 mm mesh size) deployed from early afternoon until dawn the next day. Samplings were carried out between 20 and 45 m of depth in Boka Kotorska Bay on a monthly basis from April 2019 to December 2019. Samples from November and December had only a small number of individuals

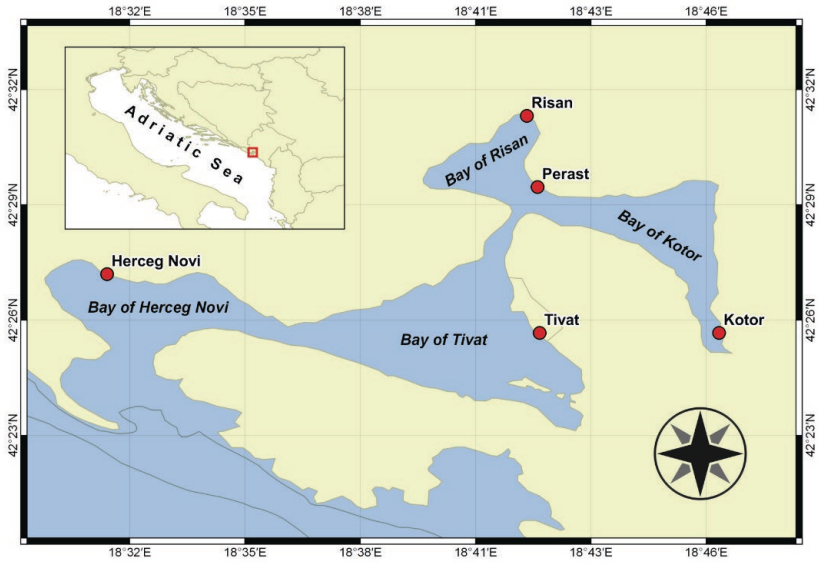

Fig. 1. Study area

(16 and 7, respectively). Samples were stored on ice immediately after capture and transferred to the laboratory for further analysis. For each individual, the following parameters were measured: carapace length CL, from postorbital edge to posterior margin of the carapace and total length TL, from the tip of the rostrum to the end of the telson, body weight, weight of mature ovaries (stages of maturity III and IV). Length measurements were obtained with callipers with an accuracy of 0.1 mm, while the body weight and the gonad weight were measured using a digital balance to the nearest 0.01 g. Sex was determined macroscopically according to the presence of the petasma in males and the thelycum in females. The sex ratio was expressed as males/females. Results were tested using the χ^2 –test. The Kolmogorov-Smirnov test as well as the Mann-Whitney test was used to find some differences between male and female size frequency distribution. Length-weight relationships were determined separately for males and females using the general formula $W = aL^b$, where W is weight in g, L is carapace length in mm and *a* and *b* are the coefficients of the functional regression between W and CL. The hypothesis of isometric growth was tested using the Student's *t*-test.

The macroscopic stage of gonad development in females was determined using a five-stage ovary scale proposed by Rodriguez (1985). The reproduction period was considered the period of the year during which females with mature ovaries (maturity stages III and IV) can be found in the samples. Females with mature ovaries were used to determine the gonadosomatic index (GSI) which is expressed as the ratio of the gonad weight to the body weight of a female (Lumare *et al*., 2011): GSI = (gonad weight (g)/body weight (g))*100.

Fulton's condition factor was determined by using the formula $K = (W/L^3)*100$, where K is the condition factor, W is weight in g and L is carapace length in mm (Rodriguez, 1987). One-way ANOVA was used to compare the differences between sexes.

RESULTS

A total of 456 Caramote prawn specimens were analysed, 228 female and 228 male. Carapace length of the total sample ranged between 29 mm and 65 mm. The length frequency distribution showed different patterns for males and females (Fig. 2). The mean size (CL ± sd) of males was 36.6 mm ± 3.27 (range 29-45 mm), while the mean size of females was 46.1 mm ± 5.48 (range 35-65 mm). The mean size of females was significantly larger than the mean size of males ($P < 0.05$). Size frequency distribution significantly differed between sexes (Kolmogorov-Smirnov test, $z = 0.72807$, p-value=0 and Mann-Whitney test, $U = 2916$, p-value < 0.00001). Males dominated the length intervals between 29 and 39 mm, while females were the most abundant in classes larger than 42 mm. Females were larger and mainly adult individuals. Among males, only 8 individuals had CL ranging from 29 mm to 30 mm, and they were considered juveniles. Regarding the TL, the largest females and males were 230 mm and 173 mm, respectively.

The overall sex ratio (males/females) was found to be 1:1. The monthly sex ratio varied from 1:0 to 1.93:1. The highest value was in October ($\chi^2 = 4.455$, p-value = 0.035) while the lowest value was in December when males were not present in the sample (Fig. 3). Females outnumbered males only in May ($\chi^2 = 8.758$, p-value = 0.003) and November. The latter should be taken with caution, due to the small number of individuals in the sample during the winter months.

Length-weight relationships were determined separately for males and females (Fig. 4). The *b* values indicate that specimens of *M. kerathurus* show negative allometric growth in both sexes (t-test, $P<0.05$).

In the present study, Fulton's condition factor value was estimated as 0.0478 ± 0.0043 for males, 0.0426 ± 0.0041 for females and 0.045 ± 0.005 for the whole sample. Mean values of the condition factor were higher for males than for females (one-way ANOVA, $p < 0.05$) (Fig. 5). Analysing the condition factor, CF of males increased until October when it reached the maximum value of 0.049 ± 0.003. CF values of females followed that pattern until August after which there was a rapid decrease in September (0.0399 ± 0.0035). The maximum value of CF for females (0.045 ± 0.0023) was also observed in October.

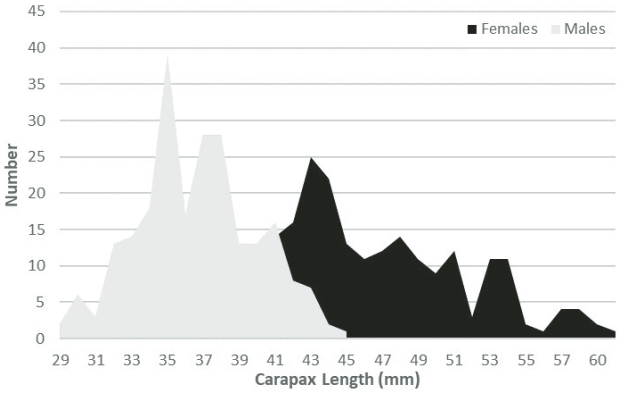

Fig. 2. Size frequency distribution of *Melicertus kerathurus* in Boka Kotorska Bay

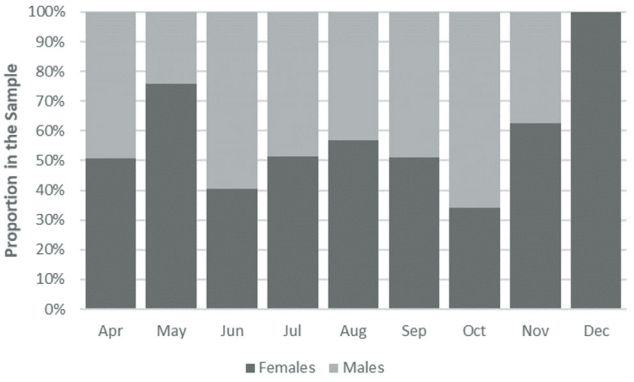

Fig. 3. Monthly variation of sex ratio of the *Melicertus kerathurus* in the Boka Kotorska Bay (south-eastern Adriatic Sea)

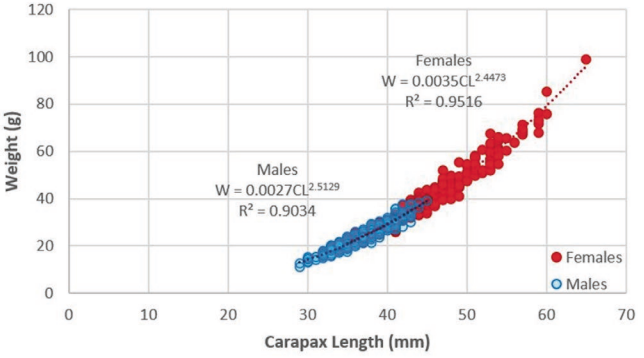

Fig. 4. Length-weight relationship for males and females of *Melicertus kerathurus* in Boka Kotorska Bay (south-eastern Adriatic Sea)

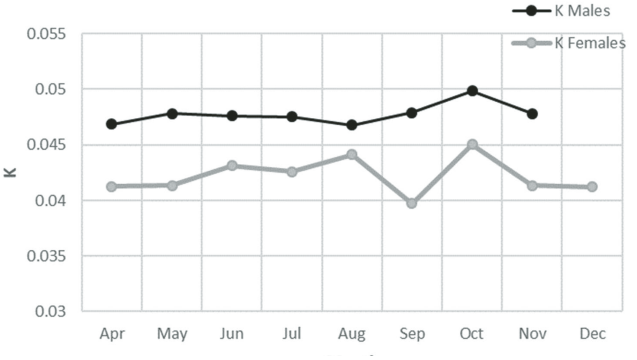

Fig. 5. Monthly variation of condition factor of males and females of *Melicertus kerathurus* in Boka Kotorska Bay (south-eastern Adriatic Sea)

Females with mature ovaries (maturity stages III and IV) were found throughout the whole sampling period but with the highest percentages in June, July, and August with a peak in June (83.67%) (Fig. 6). In those three months, mature females comprised 82.88 % of the female population. After August the number of mature females decreased. In December, mature females were represented by only two individuals, but as was previously mentioned, the winter samples had only a small number of individuals. The average size of mature females was 46.40 mm CL (corresponding to TL = 174.92 mm, W = 43.44 g). The smallest size of mature female was estimated at CL = 37 mm (TL = 145 mm, W = 21.31 g) while the largest size was 65 mm CL (TL = 230 mm, W = 98.98 g).

GSI values of maturity stage III varied between 0.7 and 3.74 and the values of stage IV varied between 0.53 and 5.41. The average GSI value for the three months was 2.17. Monthly variation of the mean GSI values for females are shown in the Figure 7 and showed that GSI rapidly increased after May through the August and showed the peak in June. A slight decrease was shown in October. Another increase was observed in November.

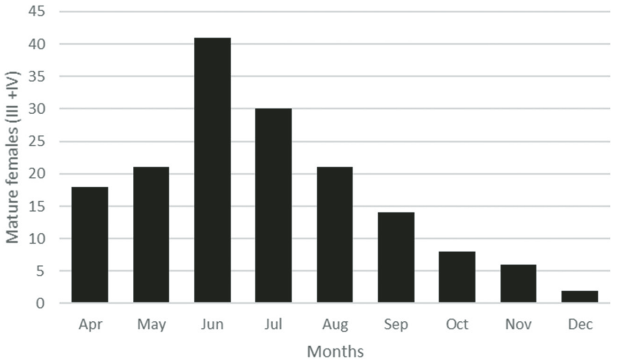

Fig. 6. Number of mature females (III +IV) of *Melicertus kerathurus* in the Boka Kotorska Bay

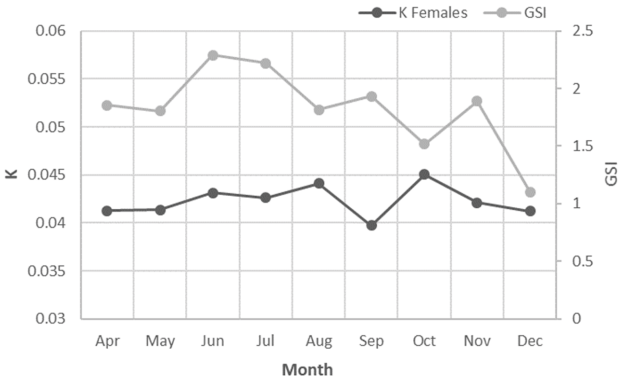

Fig. 7. Monthly variation of mean GSI and condition factor of females of *Melicertus kerathurus* at stage III and IV maturity in Boka Kotorska Bay

DISCUSSION

Analysis of the monthly variation of GSI with maturity stage data suggests that the spawning period of *M. kerathurus* in the Boka Kotorska Bay is from April-May to August with a peak in June. The data in this study agree with periods of spawning reported in other parts of the Adriatic Sea. Lumare *et al*. (2011) reported that the main reproductive period of *M. kerathurus* in the south-eastern coast of Italy is from the end of May to about mid-August, with the peak in June and July. In the southwest Adriatic Sea, Casciaro *et al*. (2015) found the presence of mature individuals especially in summer while post-spawning and recovering specimens occurred during winter. These data from the Adriatic Sea are consistent with data reported for the Thermaikos Gulf (North Aegean Sea) (Kevrekidis & Thessalou-Legaki, 2013), Izmir Bay (Aegean Sea) (Turkmen & Yilmazyerli, 2006), and Amvrakikos Gulf (western Greece) (Conides *et al*., 2008).

The GSI values of females varied between 0.53 and 5.41. The maximum mean GSI value was in June while the minimum was observed in December. In the Adriatic Sea, similar results were reported by Lumare *et al*. (2011), Lumare & Scordella (2001) as well as Bolognini (2016). Besides one peak in June, we noticed another one in November. According to Turkmen & Yilmazyerli (2006), this species can spawn 2 or 3 times during the reproductive season, with intervals of 2 months. This agrees with Lumare *et al*. (2011), who claimed that this species may reproduce at least twice in the wild which is earlier confirmed by the study of Lumare & Lumare (2009).

Turkmen & Yilmazyerli (2006) pointed out that females grow to a larger size than males which is in accordance with our results. The mean size of females was significantly larger than that of males. Conides *et al*. (2008) stated that in most cases, the sex ratio is rarely close or equal to the 1:1 ratio which is the case with the overall sex ratio in this study. The same author claimed that males usually outnumbered females. In this study, females were less abundant than males in almost the entire sampling period, except in May. Males were predominant in smaller size classes (from 29 to 39 mm) while the larger length groups were only composed of females (from 42 mm CL). Jaziri *et al*. (2015) explained this by the early onset of sexual maturity in males which reduces energy investment in growth and results in smaller body sizes.

The carapace length-weight relationship indicated strong allometry in both sexes, with females larger and heavier than males. The CL-W relationship for males is represented by $W = 0.0027\ CL^{2.5159}$, while for females it is $W = 0.0035\ CL^{2.4473}$. The *b* values indicate that specimens of *M. kerathurus* show negative allometric growth in both sexes (t-test, $P<0.05$). Similar growth was observed in the central Adriatic Sea (Bolognini, 2016) as well as in its northern part (Marčeta & Sanda, 2021). Negative allometric growth was also reported for Italian waters (south-west coast of Sicily) (Cannizzaro *et al*., 2003), Gulluk bay (Aegean Sea) (Turkmen *et al*., 2007), Amvrakikos Gulf (Ionian Sea) (Conides *et al*., 2006) and in the Gulf of Tunis (Jaziri *et al*, 2015) while in other Mediterranean areas a positive allometric growth for females was reported (Turkmen & Yilmazyerli, 2006; Ben Meriem, 1995; Klaoudatos *et al*., 1984). Various factors may be responsible for the differences in the *b* value of the length-weight relationships among seasons and years, such as temperature, salinity, food, time of year, and stage of maturity (Pauly, 1984). In addition, differences in the *b* value could be also attributed to differences in sampling, sample size, or length ranges. According to Hartnoll (1982) penaeid shrimps show a size dimorphism. This situation is in accordance with our data

and those reported for this species in the Mediterranean (Turkmen & Yilmazyerli, 2006; Kapiris & Conides, 2009; Kevrekidis & Thessalou-Legaki, 2011; Jaziri *et al*., 2015).

From the study carried out by Manaşirli & Avşar (2008) the negative relationship that exists in this study between GSI and CF values in females could be explained by shrimp needing a good state of nourishment before every spawning period, and consuming their reserves through the reproductive period. Jaziri *et al*. (2015) reported that lower values of CF were recorded before spawning, suggesting that energy investment was mainly devoted to gonad growth. The same authors claimed that the maturity pattern was almost independent of body conditions because no clear relationship was recorded between females' GSI and Le Cren relative CF. In this study, males have higher condition factor values than females. According to Gopalakrishnan *et al*. (2014) the same situation was reported for the wild population of *Penaeus monodon*.

CONCLUSIONS

The present study provides new information regarding the reproductive period of the Caramote prawn on the southeast coast of the Adriatic Sea. The monthly distribution of mature females, GSI, and condition factor showed that the reproductive period of the Caramote prawn in Boka Kotorska Bay is from April-May to August with a peak in June. The minimum landing size for this species in Montenegro is 100 mm in total length. In this study, all specimens were larger (118-230 mm TL). All of this information contributes to the sustainable exploitation of this species, which is a valuable and commercially very important species. The migratory movement of juveniles, size at first maturity, and other reproductive aspects must be considered for future investigation.

Received September 29, 2022

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