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RESEARCH ARTICLE

Some Biological Characteristics of the Invasive Moon Crab *Matuta victor* (Fabricius, 1781) (Crustacea: Decapoda: Matutidae) in Karataş Coasts (Adana, Türkiye)

Canan Türeli[1]*, Tamer Leba[2]

[1]*Department of Basic Sciences, Faculty of Fisheries, Cukurova University, 01130 Adana, Türkiye https://orcid.org/0000-0002-8682-8081
[2]Maritime and Inland Waters Services Branch Office, Adana Metropolitan Municipality, Adana, Türkiye https://orcid.org/0000-0003-2896-7371

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Abstract: In this study, some biological characteristics of the invasive moon crab, *Matuta victor*, which has recently entered the waters of the northeastern Mediterranean, Türkiye, were investigated for the first time. The study was carried out seasonally on sandy bottoms at 0.5-3 m depths along Karataş (Adana, Türkiye) coasts between 2020 -2021. A total of 364 crabs were obtained, 93 females (27 ovigerous), 270 males and one juvenile. The carapace width of female crabs ranged between 27.49-49.30 mm with a mean of 41.55±4.01 mm. The carapace width of male crabs ranged between 21.28-66.70 mm with a mean of 49.15±8.97 mm. Mean carapace length measurements in females and males were 26.83±2.52 mm and 32.71±5.85 mm, and the mean total weights were 8.18±1.99 g and 16.27±7.30 g, respectively. The male:female ratio was 2.16:1. Morphometric relationships indicated negative allometric growth for females, males, and both sexes. Ovigerous females were obtained in all seasons except the winter. The female crabs with carapace widths that ranged between 35.31-48.84 mm and a mean of 41.97±3.29 mm had a mean fecundity of 36822.04±29745.9 eggs.

Anahtar kelimeler:

İstilacı tür
Matuta victor
Oransal büyüme
Morfometrik ilişkiler
Yumurta verimliliği
Akdeniz

Karataş Sahillerindeki (Adana, Türkiye) İstilaci Tür Ay Yengeci *Matuta victor* (Fabricius, 1781) (Crustacea: Decapoda: Matutidae)'un Bazı Biyolojik Özellikleri

Öz: Bu çalışmada kuzeydoğu Akdeniz'e son zamanlarda giriş yapmış istilacı Ay Yengeci *Matuta victor*'un bulunurluğu ve bazı biyolojik özellikleri ilk kez incelenmiştir. Çalışma Karataş (Adana) sahillerinde, 2020-2021 yılları arasında mevsimsel olarak 0,5-3 m derinliklerdeki kumlu zeminde gerçekleştirilmiştir. Çalışmada 93 dişi (27'si yumurtalı) 270'i erkek ve 1 tanesi juvenil olmak üzere toplam 364 birey elde edilmiştir. Dişi bireylerde 27,49-49,30 mm arasında değişen karapas genişliği ortalama 41,55±4,01 mm olarak hesaplanmıştır. Erkek bireylerde 21,28-66,70 mm aralığında değişen karapas genişliğinin ortalaması 49,15±8,97 mm olarak ölçülmüştür. Ortalama karapas uzunluk ölçümleri dişilerde ve erkeklerde sırasıyla; 26,83±2,52 mm ve 32,71±5,85 mm; ortalama total ağırlıkları ise 8,18±1,99 g ve 16,27±7,30 gr bulunmuştur. Erkek:dişi oranı 2,16:1 olarak hesaplanmıştır. Dişi, erkek ve tüm bireylerde hesaplanan morfometrik ilişkiler incelendiğinde negatif allometrik büyüme saptanmıştır. Kış ayları dışında diğer mevsimlerde yumurtalı dişiler elde edilmiştir. Karapas genişlikleri 35,31-48,84 mm ve ortalama 41,97±3,29 mm olan yumurtalı dişilerin, yumurta verimlilikleri ortalama 36822,04±29745,9 yumurta olarak hesaplanmıştır.

Introduction

With the opening of the Suez Canal, many organisms of Indo-Pacific origin migrated into the Mediterranean. From 1980 onwards, the coastal communities of the Levantine coast differed significantly from communities elsewhere in the Mediterranean due to populations of species migrating through the Suez Canal. The Suez Canal is the most important transit route for Decapods and Stomatopods alien to the Mediterranean, but the relative importance of vectors/pathways varies between countries. Almost all of the alien species recorded on the Levantine coast are found to be introduced via the Suez Canal, while ship transportation and aquaculture are major introduction pathways on the coasts of Italy, France, and Spain (Galil et al., 2015). The number of alien species has doubled since 1970 (Katsanevakis et al., 2014). In the Mediterranean Sea, 900 alien species were detected in December 2020

*Corresponding author: cantur@cu.edu.tr

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(Zenetos and Galanidi, 2020). In Turkish seas, 79 of 539 alien species were reported to be Crustacean species. The majority of the alien species along the Turkish coasts are species introduced from the Red Sea (58%) (Çınar et al., 2021). Many Lessepsian species have already crossed the Levantine coast, some of them spreading towards the western Mediterranean. Alien species content is increasing in the Levantine upper continental shelf biota (Galil, 2012). While some Penaeid and Portunid species establish economic populations that contribute to the Levantine fisheries, some species are represented by single individuals (Galil and Mendelson, 2013). Approximately 60% of the alien Brachyuran crab species distributed in the world have been reported from the Mediterranean Sea. This makes the Mediterranean Sea the richest sea in terms of invasive crabs (Brockerhoff and McLay, 2011, Moussa et al., 2016). Regarding alien invasive crab species, 39 species of the Red Sea/Indo-Pacific origin belonging to 19 families have been reported in the Mediterranean (Levitt et al., 2014; Corsini-Foka and Kondylatos, 2015; Galil et al., 2015). In Turkish waters, 15 of the 86 Brachyuran crab species, mostly found in the Aegean and Levantine seas, were reported to be foreign species (foreign/native ratio= 21%) (Bakir et al., 2014)

The natural distribution area of the moon crab (*Matuta victor*) is the Indo-West Pacific, including the Suez Canal, Red Sea, Gulf of Oman, East African coasts, Madagascar, Bay of Bengal, Andaman Sea, Pakistan, India, Malaysia, Indonesia, South China Sea, Japan, Australia and the Mediterranean Sea (Galil and Mendelson, 2013). It is also found off the coasts of the Philippines, Fiji (Ng, 1998), Taiwan (Ng and Huang, 1997; Ng et al., 2002), and southern Thailand (Fazrul et al., 2015). It is an aggressive, omnivorous species and was first reported from Haifa Bay (Israel) in the eastern Mediterranean Sea in 2012 (Galil and Mendelson, 2013). Afterward, the first reports were made from the Lebanese coast of Batroun in 2013, from the coasts of Tyr and Saida in 2014 (Crocetta and Bariche, 2015), from the Mediterranean coast of Syria in 2017 (Zeini and Hasan, 2017), and most recently from the island of Rhodes in 2018 (Kondylatos et al., 2018).

On the coasts of our country, reports were made from the Gulf of Antalya in 2015 (Gökoğlu et al., 2016), Iz Tuzu coast, Muğla (Ateş et al., 2017), and Yumurtalık Cove İskenderun Bay (Yeşilyurt et al., 2019). *M. victor* (Matutidae) is the only known species of the genus *Matuta* in the Mediterranean (Kondylatos et al., 2018).

In its natural habitat, the ecology of Matutid crabs is little known. This active, voracious and omnivorous predator exhibiting intraspecific feeding competition is known for its reproductive flexibility and high egg productivity (Perez, 1990; Innocenti et al., 2017). These are characteristics of a successful disperser species, but the potential impacts of this disperser species are not yet known (Hänfling et al., 2011; Innocenti et al., 2017). Some of the invasive species can establish large populations in the Levantine basin, becoming more dominant than their endemic distribution range. Since brachyuran crabs have an important role in regulating prey populations, the possibility that *M. victor* establishing large populations on the Levantine beaches should not be ruled out. The diet of moon crabs consists mainly of crustaceans and molluscs. Small crabs feed on small soft-shelled species, while larger crabs feed on sessile crustacean invertebrates such as Anomuran crabs, Bivalves, and Gastropods or slow-moving species (Perez and Bellwood, 1988). *M. victor* is an entrant to the Mediterranean and it is thought that it may settle and establish populations in the eastern Mediterranean due to suitable conditions. In this study, we determined the status, abundance, and some biological characteristics (morphometric characteristics, length-weight relationship, fecundity, etc.) of *M. victor* collected from Karataş, Adana, Türkiye. This is the first detailed bio-ecological study on this alien species on the Mediterranean coast of Türkiye. This study also aims to collect data that will help to determine the potential impacts of *M.victor* and to contribute to future plans for its management.

Material and Methods

The coast of Karataş, where the study was conducted, is located in the northwest of the Iskenderun Bay (Fig. 1). Sampling was carried out seasonally between 2020-2021 in Akyatan Beach, Karataş district (Adana), in shallow areas with sandy bottom at depths of 0.5-3 m, using a hand grab and a beach seine with a wing length of 10 m and a mesh size of 1 mm (Figure 1).

The samples obtained were kept in freezers and brought to the laboratory. The crabs were then identified according to Galil and Clark (1994), Ateş et al. (2017), and Behera et al. (2018) (Figure 2).

Biometric characters; total weight (TW), carapace width (CW), and carapace length (CL) were measured. The total weight (TW) of each specimen was measured using a precision balance sensitive to 0.1 g, and carapace measurements were made with the help of a digital caliper sensitive to 0.1 mm.

Carapace width-carapace length and total weight-carapace width relationships were determined using regression analysis in SPSS 13 package program. The morphometric relationship was calculated for females, males, and both sexes using the formula $Y=aX^b$ (Ricker, 1975).

The allometric coefficient was determined from the b value in the linear regression equation. Accordingly, b=3 is considered as isometric growth, b<3 as negative allometric growth and b>3 as positive allometric growth (Zar, 2010).

Egg mass from ovigerous females was weighed and stored to determine egg production. Eggs were preserved in Bouin's solution (picric acid 75cc, formaldehyde 40% 25cc, glacial acetic acid 5cc). For egg counting, 3 subsamples of 1-10 mg were taken from each specimen. The subsamples were weighed on a balance, placed on a glass slide and wetted with 30% glycerin before counting using a stereo microscope (Olympus, SZX16). Egg productivity was determined according to Türeli (1999).

Figure 1. Sampling Area

A B C

Figure 2. *M. victor* A: Dorsal View, B: Ventral View (male and female), C: Ovigerous Female (with Orange Eggs) (Original)

Fecundity (Egg Productivity) = (total egg weight x number of sub-sample eggs) / sub-sample egg weight

The fecundity of each female crab was calculated using the mean egg count from three subsamples.

Statistical equality of the morphometric relationship between sexes was tested using One Way ANOVA at a significance level of $p \leq 0.05$. Sex ratios were calculated using the Chi-Square (x^2) test against an expected frequency of 1:1 (Zar, 1999). All statistical analyses were performed using SPSS for Windows (Version 13).

Results

In the present study, a total of 364 *M. victor* specimens, including 66 adult females, 27 ovigerous females, 270 males, and 1 juvenile were captured. The mean ± standard deviation and min-max values are given in Table 1.

The differences between carapace width, carapace length, and total weight of male and female crabs were found to be statistically significant ($p<0.05$). The distribution of carapace widths of all specimens was 21.28-66.70 mm and the mean carapace width was 40.77±9.41 mm.

During this study, most crabs (n: 146) were caught in spring season. This was followed by the fall (n: 90) and the winter (n: 73) seasons. The least number of crabs were caught in summer (n: 55). During the whole sampling period, male crabs were caught in higher numbers in each season. It was determined that 25% of *M. victor* specimens were female and 75% were male. When the capture rates of male and female crabs were analyzed, this difference was found to be statistically significant ($p<0.05$). The calculated male to female sex ratio was 2.9:1. The highest female ratio was in the fall (43%) and the lowest was in the spring (8%). The highest male ratio was observed in the spring with a ratio of 11.16:1. The difference in the male to female ratio in the spring and the autumn was significant ($p<0.05$).

The linear relationship between carapace length (CL) and carapace width (CW) was CW= 7.0698 + 1.2864 CL (R^2 = 0.67) in females, CW= 1.6713 + 1.4514 CL (R^2 = 0.89) in males, and CW= 3.1327 +1.4125 CL (R^2 = 0.89) in both males and females (Figure 3). The relationship between carapace width and the total weight was TW= 0.0017 CW 2.2862 (R^2 = 0.55) in females, TW= 0.0004 CW 2.7187 (R^2 = 0.88) in males, and TW= 0.0003 CW 2.7767 (R^2 = 0.87) in total (Figure 4).

Table 1. Mean length and weight values calculated from specimens of *M. victor* (mean±std. deviation, min.-max.)

Sex	Number of Sp.	Total Weight (g)	Carapace Length (mm)	Carapace Width (mm)
Female	66	8.18±1.99 (2.84-13.75)	26.83±2.52 (16.16-33.20)	41.55±4.01 (27.49-49.30)
Ovigerous Female	27	9.77±2.53 (5.58-15.11)	27.15±2.12 (22.9-31.82)	42,09±3,17 (35.31-48.84)
Male	270	16.27±7.30 (1.62-41.40)	32.71±5.85 (15.37±46.63)	49.15±8.97 (21.28-66.70)
Juvenile	1	2.4	19.27	26.95
Total	364	14.39±7.45 (1.62-41.40)	31.19±5.79 (15.37-46.63)	40.77±9.41 (21.28-66.70)

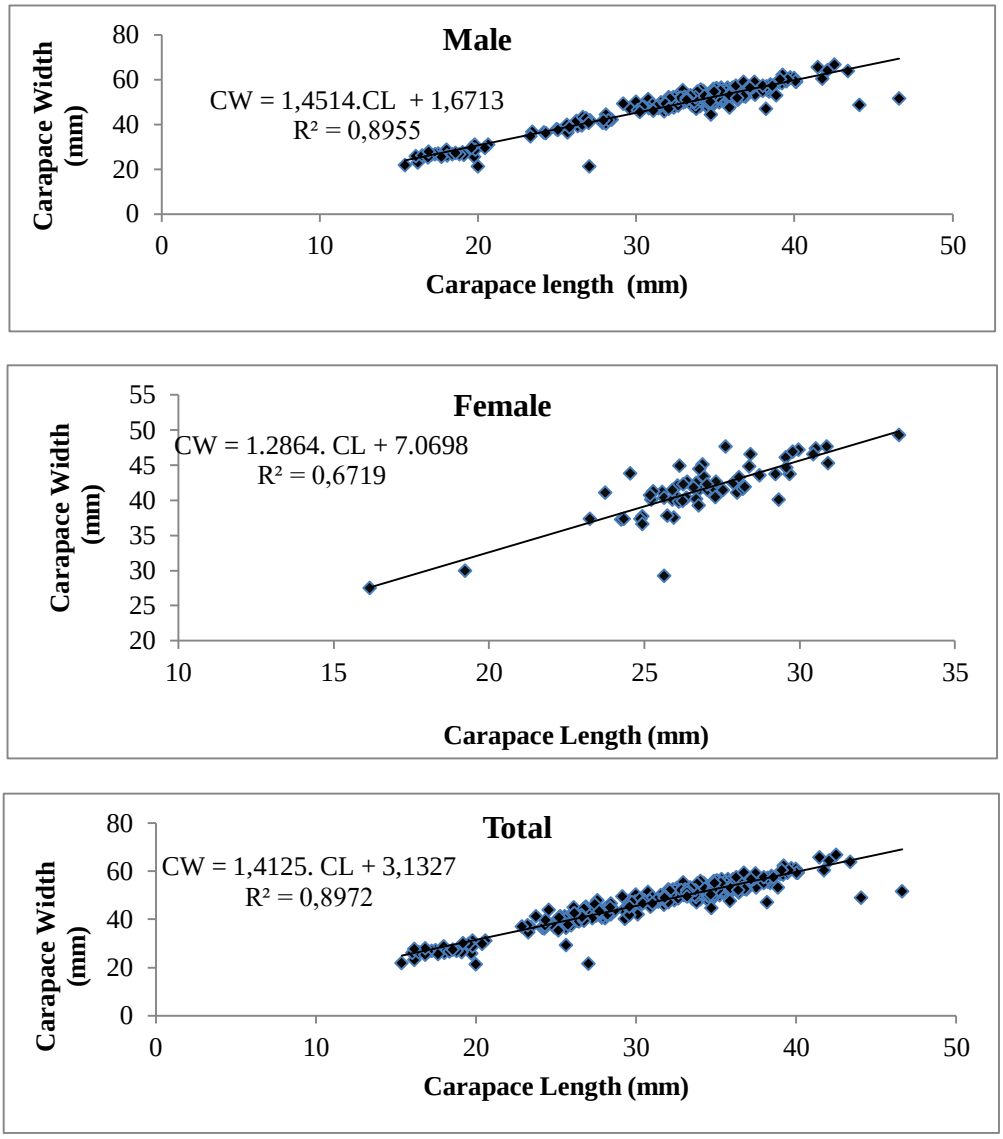
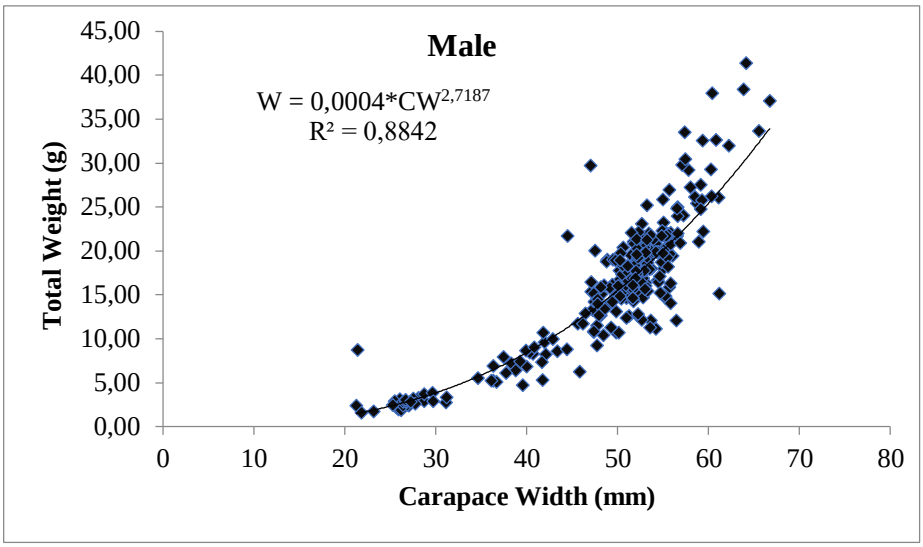
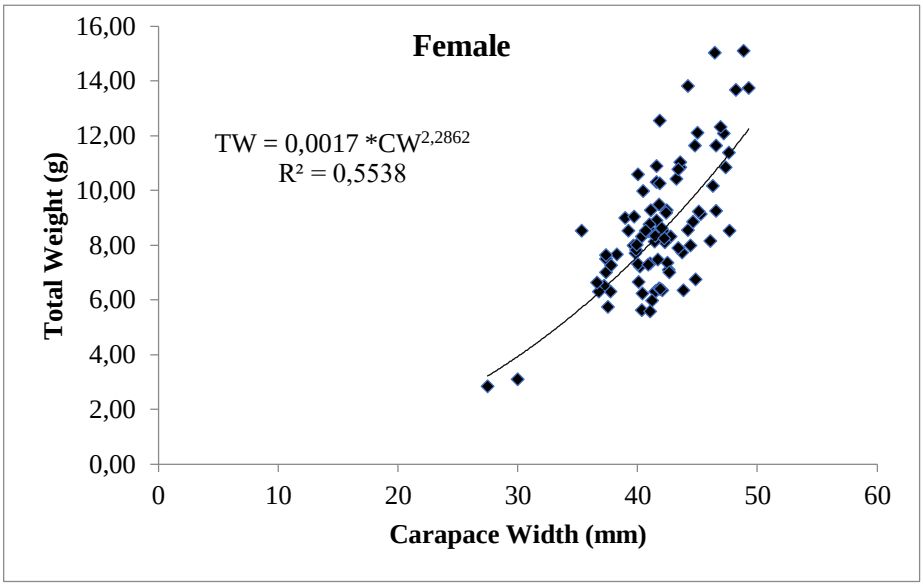


Figure 3. Relationship between the carapace length (CL) and carapace width (CW)





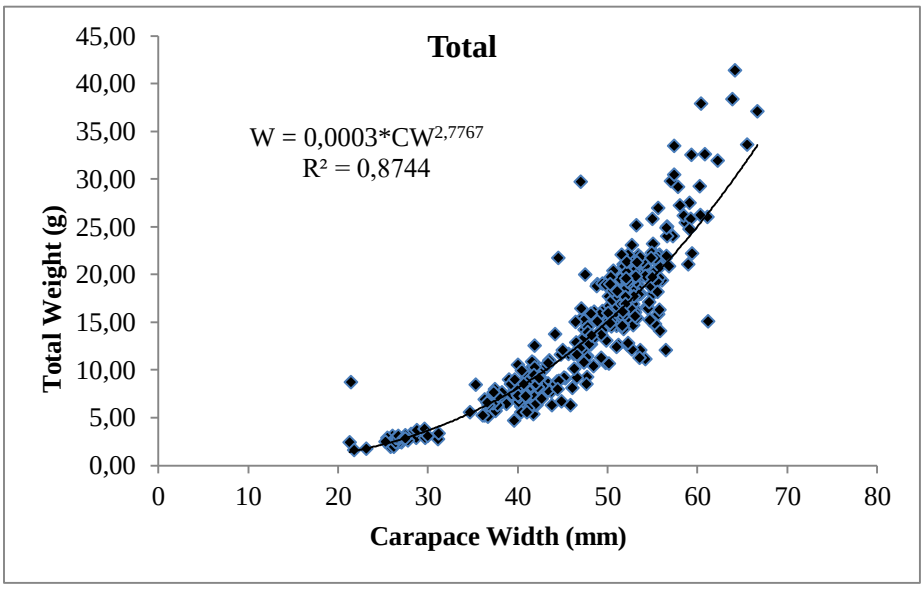


Figure 4. Relationships between the carapace width (CW) and total weight (TW)

A negative allometric growth was observed for both sexes and all specimens since b values were less than 3. A strong relationship was observed between proportional growth (carapace width - carapace length; weight - carapace width) in *M. victor* females, males, and all crabs (R^2 ranged between 0.67 to 0.89).

Carapace width was used to determine the length-frequency distribution (Figure 5) . In males, 120 crabs were observed in the 56.0-60.9 mm range, followed by 64 specimens in the 46.0-50.9 mm range. The highest number of *M. victor* females was in the 46.0-50.9 mm range with 47 crabs range. While 28 females were found in the 51.0-55.9 mm length range, only one female was found in the 36.0-40.9 mm range. With respect to all crabs collected in this study, the maximum number of crabs was found in the 56.0-60.9 mm range, and the minimum number of specimens was in the of 71.0-75.9 mm range (Figure 5).

Ovigerous females (OF) were obtained in all seasons except in the winter. The highest number of ovigerous females was in the fall with 15 specimens, followed by the summer with 9 females. The lowest number of ovigerous females were caught in the spring (n= 3). In terms of developmental stages, eggs in the early developmental stage, indicated by the typical orange-color, were represented by the highest numbers. Eggs in the developing stage were brown in colour and those in the final development stage were black (Figure 6). The carapace widths of females with orange-colored eggs ranged between 36.78-46.27 mm, those with brown eggs ranged between 38.99-48.84 mm, and those with black eggs ranged between 35.31-44.23 mm.

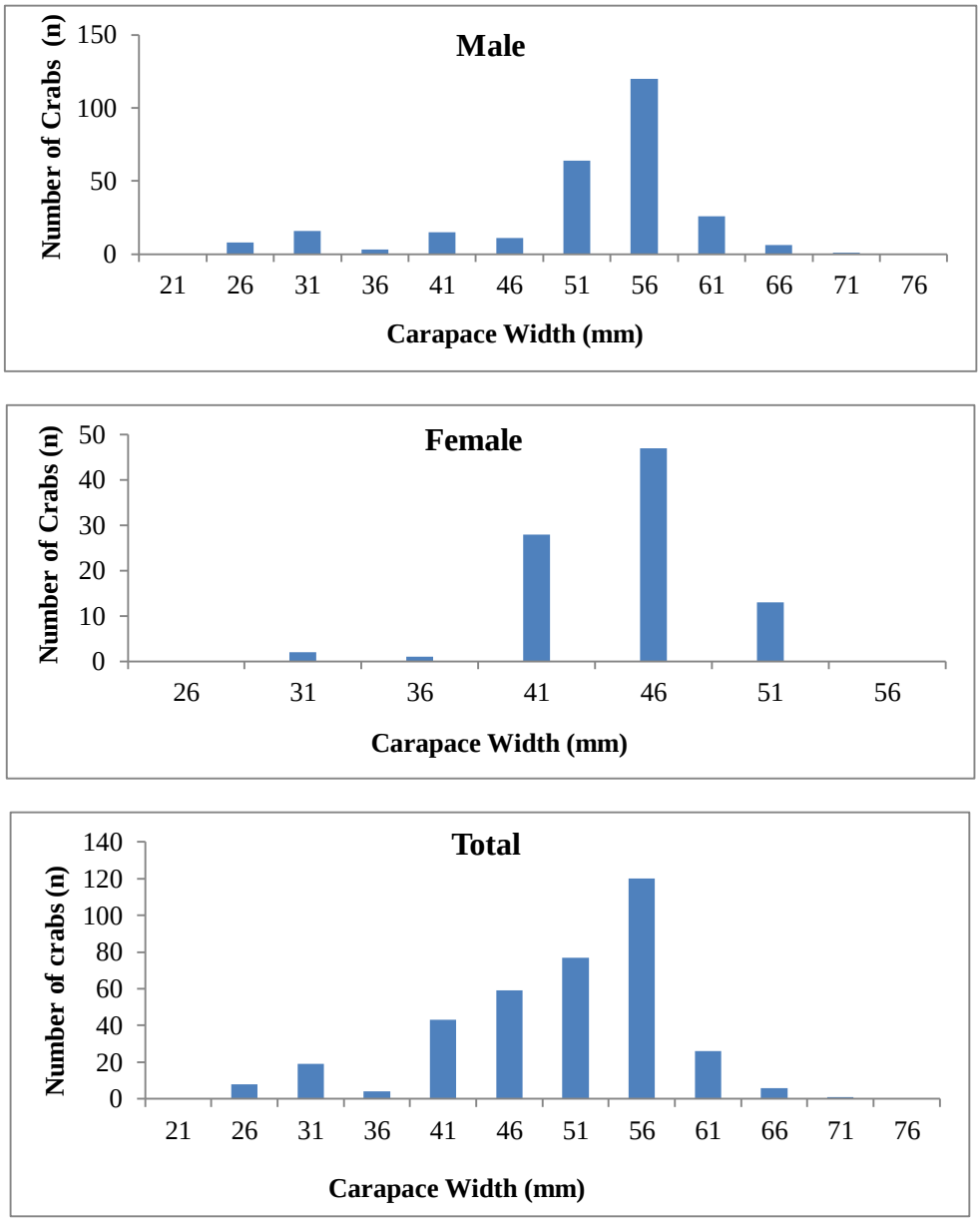


Figure 5. Length-frequency (CW) distribution of *M. victor* a) males, b) female, and c) males and females

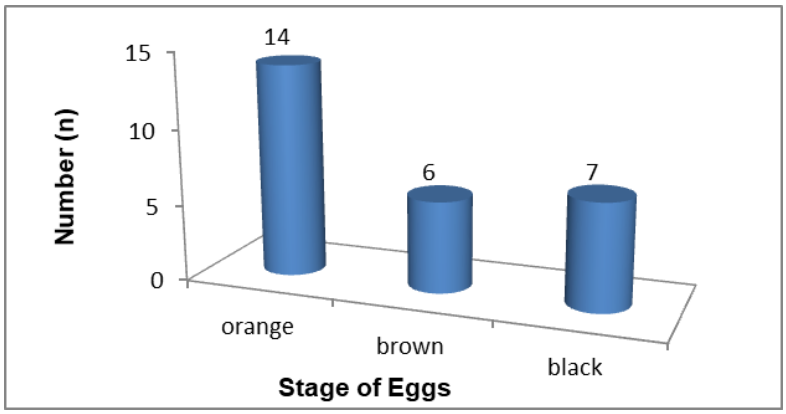


Figure 6. Developmental stages of eggs as indicated by their coloration.

Fecundities were calculated for 21 individuals with proper egg mass out of a total of 27 ovigerous females. Carapace lengths of ovigerous females ranged between 22.9 and 31.82 mm with a mean of 27.01±2.22 mm, carapace widths between 35.31-48.84 mm with a mean of 41.97±3.29 mm (Figure 7), total weights between 6.32 -15.11 g with a mean of 10.01±2.46 g, and egg weights between 0.13-2.37 g with a mean of 0.97±0.66 g. The mean egg productivity was 36822.04±29745.9. The highest number of eggs was 123419.27 from an individual with 48.84 mm in CW and 15.11 g in weight, and the lowest number of eggs was 5334 from an individual with 43.39 mm in CW and 10.78 g in weight.

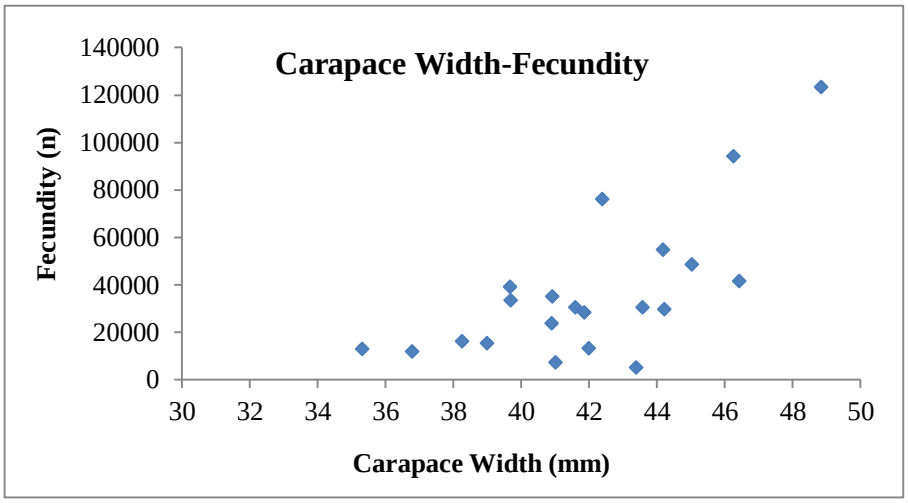


Figure 7. Relationship between the carapace width (CW) and fecundity.

Discussion

In its natural habitat, the ecology of Matutid crabs is poorly known and data presented in this study contributes to the existing literature. With respect to *M. victor* densities in the wild, different results were reported. In Haifa Bay (Israel) near Kiryat Yam in the fall of 2013, 0.1-1 crab/m^2 were reported and the majority of crabs were caught from depths of less than 0.3 m. Near Na'aman Lagoon, Zevulun Plain Beach in 2013, a large number of crabs were caught corresponding to a density of 27 crabs/m^2 whereas in May 2017 in Kiryat Yam, the density was reported to be 2 crabs/m^2 (Innocenti et al., 2017). Others reported considerably lower number of crabs. For example, Zeini and Hasan (2017) captured a total of 11 specimens, including one female, at a depth of 8-10 m with a sandy bottom off the Mediterranean coast of Syria. Kondylatos et al. (2018) reported *M. victor* from the island of Rhodes in the Gulf of Zefyros in the Mediterranean. They caught a single male by snorkeling at a depth of 1.5-2 m on a sandy bottom. Galil and Mendelson, (2013) captured an adult male with a carapace length of 3.25 cm from a depth of 10 m in Haifa Bay (Israel) and 1 adult female with a carapace length of 2.95 cm from a depth of 5 m in Kiryat Yam. Behera et al. (2018) caught 10 individuals of *M. victor* consisting of 5 males and 5 females off the coast of Gopalpur Odisha (India). They calculated the mean carapace width as 4.84±0.5 cm for males and 4.46±0.2 cm for females. Yeşilyurt et al. (2019) caught 4 males, 1 female, and 1 juvenile at a depth of 30-50 cm with a sandy bottom in Kokar locality, Yumurtalık Bay (Türkiye). The carapace width of male crabs ranged between 54.65 to 62.43 mm and was 44.47 mm in the

female specimen; the carapace length was 29.52 mm in the female and ranged between 35.56-40.01 mm in male crabs. The carapace width and the carapace length of the juvenile crab were 46.90 mm and 30.23 mm, respectively. Although the carapace widths of the individuals caught by Behera et al. (2018) from the shores of Gopalpur Odisha are similar to those in our study, the range of carapace widths of males in this study was larger than that reported in Yumurtalık Bay (Türkiye) (Yeşilyurt et al., 2019). The carapace width of the juvenile crab was considerably smaller than that of the single specimen reported from Yumurtalık Bay. Naderi and Mahigir (2022) reported 181 males and 129 females from the coasts of Gehrdo in the Oman Sea (Iran). The carapace width of male and female crabs ranged between 16.4-44.3 mm and 19.3-36.9 mm, respectively. The range of carapace width and weight values reported in the Oman Sea was lower compared to our results. These differences are thought to be due to the differences in the regional and bio-ecological conditions. The mean carapace width and weight were found to be higher in males than in females.

In this study, the ratio of male:female crabs was 2.9:1 and this is the first data on the sex distribution of the species for our region and Türkiye. Naderi et al. (2021) reported a sex ratio of 1.4:1 (M:F) from the coast of Gehrdo (Sea of Oman) which was lower than that reported in the present study. In this study, the majority of males were caught in the spring. Conversely, the lowest number of females (8) was found in the same season. Throughout the study period, the sex ratio of *M. victor* was different than 1:1. This difference in the sex ratio may be due to depth preferences of females for reproduction. Since there is limited information on the bio-ecology of this newly introduced species in our seas, further studies on the reproduction period should be carried out.

In the present study, the minimum and maximum number of eggs ranged between 5334- 123419.27. Naderi et al., 2021, reported a maximum of 43423 eggs (CW: 26.7 mm; TW: 6.25 g) and a minimum of 11635 eggs (CW: 28.55 mm; TW: 8.79 g) from the Arabian Sea. These authors also reported an inverse relationship between fecundity and carapace width and weight. On the contrary, our findings indicated that fecundity of *M. victor* increased as a factor of carapace width. It has been reported that ovigerous females were mostly caught in the spring and the summer (Naderi et al., 2021). The spawning season of the Genkai-nada Sea (Japan) moon crab was in July and September (Kobayashi, 2013). In our study, most ovigerous females were caught in the fall and summer.

In our study, the morphometric relationship and proportional growth of female, male and all specimens were calculated as negative allometric growth. In the study conducted in the Oman Sea, while males showed positive allometry in accordance with our study, females had negative allometry (Naderi and Mahigir, 2022). Reported b values for males and females were 3.11 and 2.75, respectively, and these values were lower than reported for *M. victor* in its natural distribution area in the Oman Sea. According to Gökçe et al. (2016), b values vary depending on many factors affecting growth in crustaceans such as salinity, temperature, nutrition, sex, maturity and season. It should be kept in mind that the species only provides information about the region studied during the study. Since the length-weight study of the species was not available, our findings could not be compared with the studies conducted in our country and in endemic distribution regions.

The species diversity of the Mediterranean is changing with the introduction of endemic and exotic species and a new Lessepsian or species of Indo-Pacific and Atlantic origin. *M. victor* is an entrant to the Mediterranean and it is expected that it will settle and establish populations in the eastern Mediterranean due to suitable environmental conditions. In this study, distribution and some biological characteristics of *M. victor* are reported for the first time. Ovigerous individuals were obtained in all seasons except winter and the majority of ovigerous females were caught in the fall. More comprehensive studies should be carried out to fully reveal the biological characteristics of *M. victor*, which has recently entered the coastal waters of our region and established populations.

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Conflicts of Interest

No potential conflict of interest was reported by the authors.

Author Contributions

The study was planned and designed by Canan Türeli and Tamer Leba. Tamer Leba performed to collected samples from the field and analysed them in the laboratory. All authors contributed to the writing of the final manuscript.

Ethics Approval

The material used in this article is invertebrate species therefore ethics committee approval is not required for this study.

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