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Morphometric characters of the Mediterranean green crab (*Carcinus aestuarii* Nardo, 1847) (Decapoda, Brachyura), in Homa Lagoon, Turkey

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Abstract: Determining the length-length and length-weight relationships and having access to the formulas on the relationships would enable researchers to indirectly estimate the approximate sizes of the organisms when consumed as prey items by examining one of the appendages found in the gut contents. In order to determine some morphometric characters of the Mediterranean green crab (*Carcinus aestuarii* Nardo, 1847) inhabiting Homa Lagoon, İzmir Bay, Turkey, crab samples were collected using trammel nets, fyke nets, beach seines, and fence traps in monthly intervals between June 2006 and May 2007. A total of 608 male and 559 female specimens were collected during the sampling period. The largest (in terms of carapace length: CL) female and male were 39.59 mm and 51.63 mm, respectively. Morphometric equations for the conversions of length and weight were constructed separately for males, females, and the combined sexes. The equations for carapace width (CW) and right chela width (RChW) for males were found to be $RChW = 0.373997 \times CW - 3.90059$, $r^2 = 0.85$. The relationship between carapace width (CW) and wet weight (WW) was determined to be $LnCW = 0.3377 LnW + 2.6942$, $r^2 = 0.98$ for males, $LnCW = 0.3424 LnW + 2.6929$, $r^2 = 0.99$ for females, and $LnCW = 0.3361 LnW + 2.7019$, $r^2 = 0.99$ for both sexes combined. Males were generally bigger than females. The average values of the carapace width for males and females were 44.58 ± 7.34 mm and 29.10 ± 7.07 mm, respectively. The CW/CL ratio for both sexes combined ranged from 1.22 to 1.26.

Key words: *Carcinus aestuarii*, Mediterranean green crab, morphometric characters, Homa Lagoon, eastern Mediterranean

Homa Lagünü (Türkiye) Akdeniz yeşil yengeci'nin, *Carcinus aestuarii* Nardo, 1847 (Decapoda, Brachyura) morfometrik karakterleri

Özet: Boy-boy ve boy-ağırlık ilişkilerini tespit etmek ve bu ilişkilere ait formüllere sahip olmak araştırmacılara mide içeriğinde yer alan birkaç ekstremiteden organizmaların tahmini boyutlarını hesaplayabilme olanağı sağlayabilecektir. Homa Lagünü'nde (İzmir Körfezi, Türkiye) yaşayan Akdeniz yeşil yengecin (*Carcinus aestuarii* Nardo, 1847) bazı morfometrik özelliklerinin tespit edilmesi amacıyla, Haziran 2006-Mayıs 2007 tarihleri arasında uzatma ağı, pinter, tül ıgırıp ve tuzak kullanılarak aylık örnekleme şeklinde yengeç örnekleri toplanmıştır. Örnekleme periyodu boyunca toplam 608 erkek ve 559 dişi birey toplanmıştır. En büyük (karapas uzunluğu olarak) dişi ve erkek bireyler sırasıyla 39,59 mm ve 51,63 mm olarak tespit edilmiştir. Boy ağırlık dönüşümleri için morfometrik eşitlikler erkek, dişi ve her

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iki cinsiyeti kapsayacak şekilde ayrı ayrı hesaplanmıştır. Erkek bireyler için, karapas genişliği (CW) ile sağ kela genişliği (RChW) arasındaki eşitlik $RChW = 0,373997 \times CW - 3,90059$, $r^2 = 0,85$ olarak bulunmuştur. Karapas genişliği (CW) ile ağırlık (W) ilişkileri erkekler için $LnCW = 0,3377 LnW + 2,6942$, $r^2 = 0,98$; dişiler için $LnCW = 0,3424 LnW + 2,6929$, $r^2 = 0,99$ ve her iki cinsiyet için de $LnCW = 0,3361 LnW + 2,7019$, $r^2 = 0,99$ olarak tespit edilmiştir. Erkekler genel olarak dişilerden daha büyüktür. Erkekler ve dişiler için ortalama karapas genişlikleri sırasıyla $44,58 \pm 7,34$ mm ve $29,10 \pm 7,07$ mm'dir. Her iki cinsiyet için CW/CL oranları 1,22 ile 1,26 arasında değişim göstermektedir.

Anahtar sözcükler: *Carcinus aestuarii*, Akdeniz yeşil yengeci, morfometrik karakterler, Homa Lagünü, doğu Akdeniz

Introduction

The Mediterranean green crab (*Carcinus aestuarii* Nardo, 1847) is 1 of the 2 species of the genus *Carcinus* Leach, 1814. Until the end of the 20th century, this species was only known to inhabit estuarine and lagoonal waters of the Mediterranean and Black Seas (Mori et al., 1990; Behrens Yamada and Hauck, 2001), but there have also been some recent records from Japan (Sakai, 1986; Furota et al., 1999). In the last 2 centuries, specimens of the genus *Carcinus* have been accidentally introduced into several regions outside their native range as a result of maritime commerce and ballast transport: *Carcinus maenas* (Linnaeus, 1758) to the east and west coasts of North America, Australia, Tasmania, and South Africa; and *C. aestuarii* to Japan (Almacá, 1962; Geller et al., 1997; Behrens Yamada and Hauck, 2001; Carlton and Cohen, 2003).

The presence of *C. aestuarii* in the Turkish seas was reviewed by Kocataş and Katağan (2003). In addition to the results presented in that study, *C. aestuarii* was reported to be found in the Turkish straits system by Balkıs (2003), in the Gallipoli peninsula by Yurdabak (2004), off the coast of Sinop by Bilgin and Çelik (2004), in İzmir Bay by Çınar et al. (2006), along the Turkish Mediterranean coast by Özcan (2007), and in the Dardanelles by Çelik et al. (2007).

Carcinus aestuarii has little economic value in Turkey, but it is used as an additional fish food for sea bream (*Sparus aurata* Linnaeus, 1758) pools in the Homa Lagoon. There is very little information on the biology of *C. aestuarii* in Turkey, however, and the objective of the present study was to define the length-length and length-weight relationships in *C. aestuarii*.

Determining the length-length and length-weight relationships in this kind of organism is important.

Having information about the relationships between the variables presented here would enable researchers to estimate the approximate size of a consumed *C. aestuarii* merely by reference to one of the appendages in the gut contents.

Materials and methods

In order to determine some morphometric characters of the Mediterranean green crab (*C. aestuarii*) inhabiting the Homa Lagoon, İzmir Bay, Turkey, a total of 1167 crab specimens were collected using trammel nets, fyke nets, beach seines, and fence traps, in monthly intervals between June 2006 and May 2007 (Figure 1).

All of the sampled specimens were preserved in a 4% formalin solution. Using observations of characteristic abdomen shapes (triangular in males and circular in females) and the appearance of the first 2 pairs of pleopods (modified to gonopods in males), the specimens were sorted into 2 groups based on sex. Immature specimens were also measured and included in the analysis. In total, 11 different morphometric characters were taken into consideration: wet weight (WW), carapace width (CW), carapace length (CL), carapace depth (CD), right chela length (RChL), right chela width (RChW), right propod length (RPL), left chela length (LChL), left chela width (LChW), left propod length (LPL), and optical groove width (OW). All of the morphometric characters were measured using digital calipers (0.01 mm of precision). In order to provide linear relationships between body size and the weight of the specimens, the wet weight (WW) of each specimen was taken using a digital balance with a precision of 0.01 g. The specimens were not blotted with filter paper before being weighed and only undamaged specimens were included.

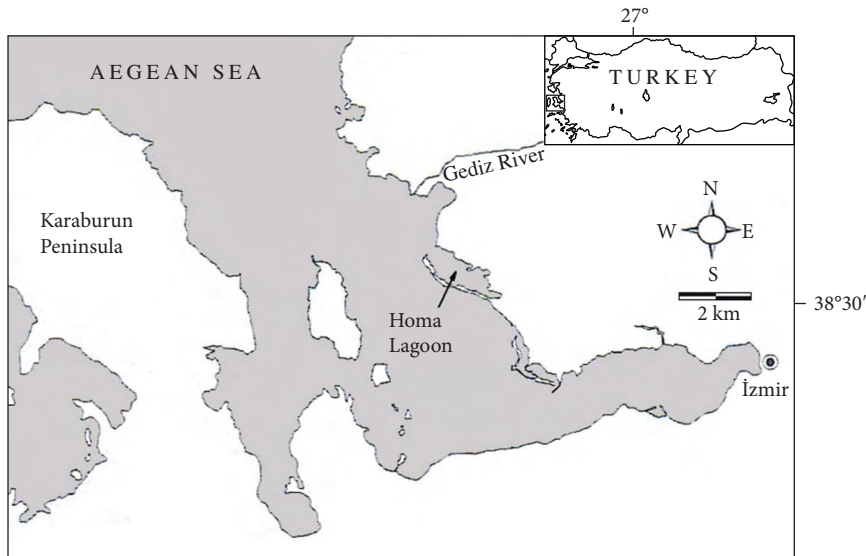


Figure 1. Geographical position of Homa Lagoon, İzmir Bay, Turkey.

The logarithmic form of the exponential curve was used to estimate the weight-length relationships (Ricker, 1973; Ricker, 1975):

$\log W = \log a + b \log L$ where W is the wet weight (g), L the carapace length (cm), a the intercept, and b the slope. The parameters a and b in the W - L and L - L relationships were estimated by linear regression analysis (least-squares method) on log-transformed data and the association degree between variables (W and L) was calculated by the determination correlation coefficient (r^2).

Results and discussion

A total of 608 males and 559 females of *C. aestuarii* were measured. The distribution of specimens according to sexes and sampling dates is presented in Figure 2. In general, the number of males sampled in each month during the study was higher than that of females, except for the period between October and December 2006. During this period an acute increase in the activity of females was observed, probably due to a migration from the estuary to the sea, where they were caught in the fence traps. At this time, many ovigerous females were caught and will be studied later.

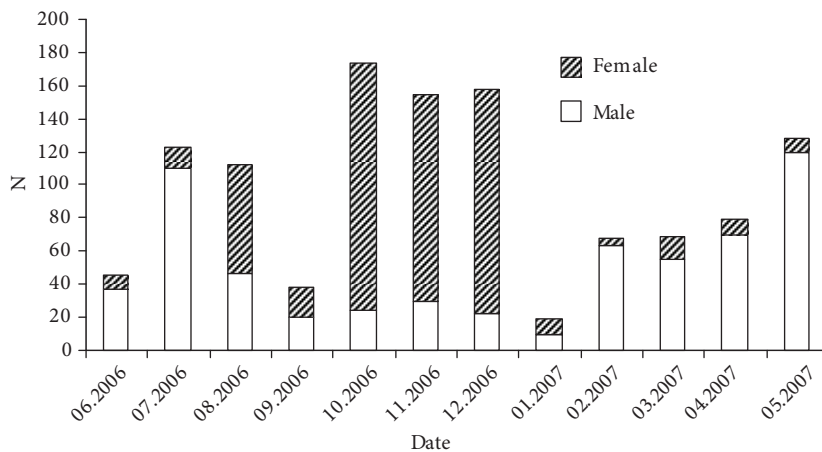


Figure 2. Numbers of sampled crab specimens (N) of *Carcinus aestuarii* Nardo, 1847 collected per month. In these columns white represents males, diagonal shading represents females.

Size-frequency (CL and CW) distributions showed a size-predominance of males over females, with mean male size exceeding that of females (Figure 3). The differences between the three main morphometric characters (CL, CW, and WW) of sexes are presented in a box-and-whisker plot (Figure 4). From this diagram it is clear that all of the measured values showed differences between the sexes. As a result of the analysis of variance (ANOVA), the computed differences between the CL, CW, and WW values were found to be nonsignificant between males and females ($P = 0.8426$ for WWM-WWF; $P =$

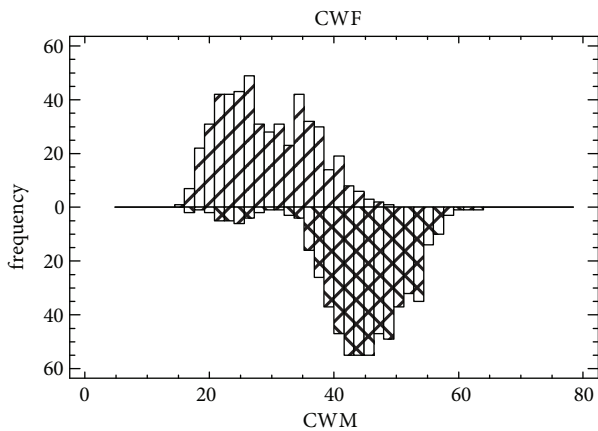


Figure 3. *Carcinus aestuarii* Nardo, 1847 from Homa Lagoon, İzmir Bay, Turkey. Frequency diagram of the carapace width of females (CWF) and the carapace width of males (CWM).

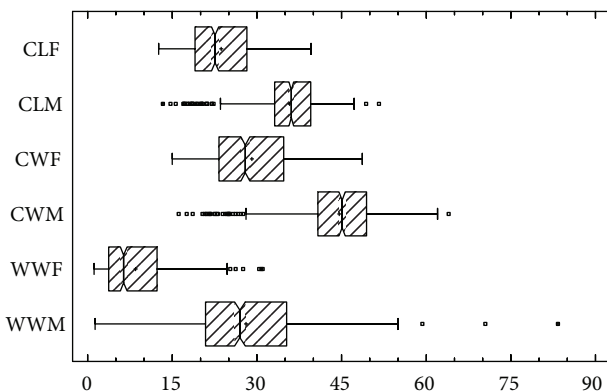


Figure 4. *Carcinus aestuarii* Nardo, 1847 from Homa Lagoon, İzmir Bay, Turkey. Box-and-whisker diagram of carapace length (mm) of females (CLF) and males (CLM), carapace width (mm) of females (CWF) and males (CWM), and wet weight (g) of females (WWF) and males (WWM).

0.2295 for CWM-CWF; $P = 0.4502$ for CLM-CLF).

The CW/CL ratio is an important character that helps with the identification between the 2 species of *Carcinus* when used together with the shape of the adult male pleopods. The CW/CL ratio is always smaller than 1.30 in *C. aestuarii* specimens, while it was found to be between 1.304 and 1.348 in the *C. maenas* specimens (Behrens Yamada and Hauck, 2001). The CW/CL ratios of males, females, and of both sexes combined are summarized in a box-and-whisker plot where all of these values mainly ranged from 1.20 to 1.26 (Figure 5).

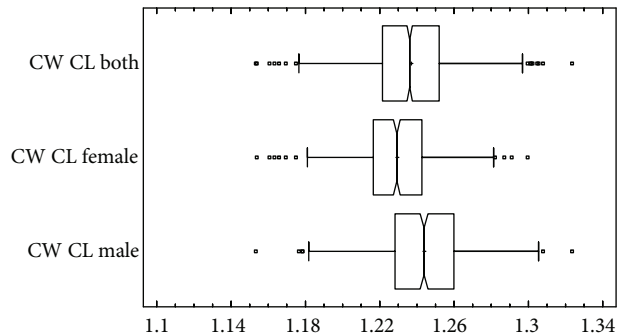


Figure 5. *Carcinus aestuarii* Nardo, 1847 from Homa Lagoon, İzmir Bay, Turkey. The ratios of carapace width (CW) to carapace length (CL) in males, females, and both sexes combined.

Regression analyses between CW, CL, and WW for males, females, and both sexes combined are presented in Figure 6, which shows a high positive linear relationship between these variables. Determination correlation coefficient values (r^2) in male specimens were the highest CL (0.9918) in relation to WW (Figure 6). Regression analyses gave better results in females where correlation coefficient values were 0.9935 and 0.9901 in the equations of CL to WW and CW to WW, respectively (Figure 6).

The length-weight and other relations of morphometric characters presented here will enable biologists to accurately estimate the wet weight and size for *C. aestuarii* based on a single measured value of the carapace of the specimen. The 9 morphometric

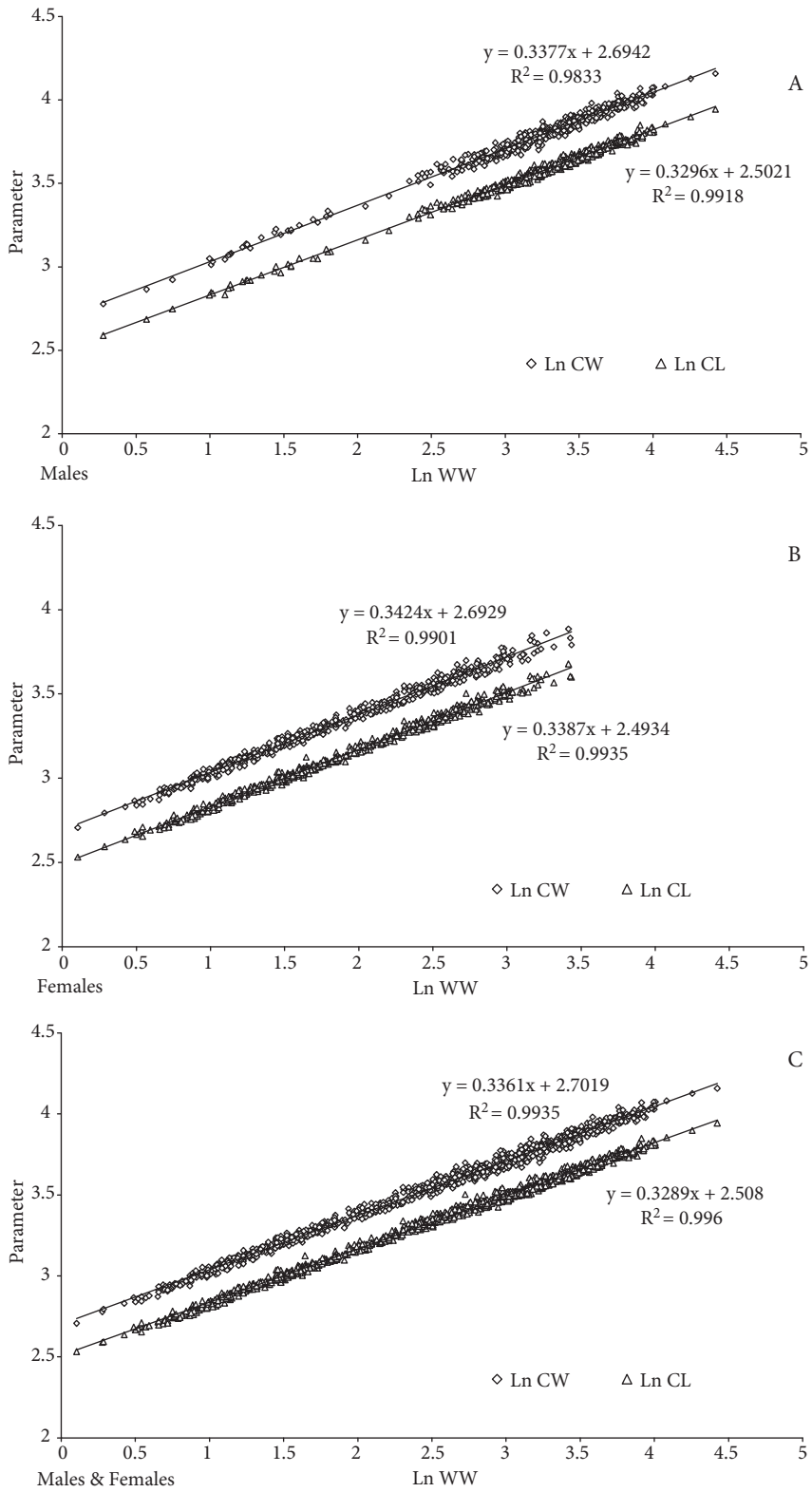


Figure 6. *Carcinus aestuarii* Nardo, 1847 from Homa Lagoon, İzmir Bay, Turkey. Scatter plot diagrams between carapace width (CW) and wet weight (WW), and carapace length (CL) and wet weight (WW) for (A) males, (B) females, and (C) males and females combined.

Table. Conversion formulas of morphometric characters of *Carcinus aestuarii* Nardo, 1847 from Homa Lagoon, İzmir Bay, Turkey.

Morphometric Characters	MALES		FEMALES	
	Formula (cm)	r ²	Formula (cm)	r ²
Carapace length (CL)	$0.7753 \times CW + 1.2469$	0.9860	$0.8034 \times CW + 0.2781$	0.9948
Carapace depth (CD)	$0.4311 \times CW + 1.1107$	0.9652	$0.4569 \times CW + 0.3673$	0.9323
Right chela length (RChL)	$0.7455 \times CW - 5.7072$	0.9437	$0.5899 \times CW - 2.6260$	0.9347
Right chela width (RChW)	$0.3740 \times CW - 3.9006$	0.8480	$0.2747 \times CW - 2.0856$	0.8700
Right propod length (RPL)	$0.4885 \times CW - 4.2433$	0.9261	$0.3667 \times CW - 1.6310$	0.9065
Left chela length (LChL)	$0.6518 \times CW - 3.8962$	0.9426	$0.5346 \times CW - 1.8730$	0.9361
Left chela width (LChW)	$0.2797 \times CW - 2.5002$	0.8809	$0.2101 \times CW - 1.0628$	0.9146
Left propod length (LPL)	$0.4022 \times CW - 2.3698$	0.9196	$0.3226 \times CW - 1.0219$	0.9166
Optical groove width (OW)	$0.3332 \times CW + 2.0379$	0.9754	$0.3447 \times CW + 1.7824$	0.9859

characters and their parameters with relation to CW were calculated for 1167 specimens divided by sex (Table). Statistically well-supported relations were found for almost all of these measured characters. The highest coefficient value was the CL/CW ratio in females (0.9948) while the lowest was for RChW/CW in males (0.8480).

Weight-size relationships can provide useful information about the increase in weight of a population and this parameter could also be important for comparative studies between populations (Mori et al., 1990). For example, Can et al. (2007) reported a negative allometric growth pattern both in males and females of *C. aestuarii* (795 individuals) collected from the Çakalburnu Lagoon, in İzmir Bay. Those authors reported *b* values for the length-weight relationship ($\log WW = \log a + b \log CW$) in the *C. aestuarii* population of 2.30-2.92 for males and 2.66-2.81 for females. Similarly, the comparative *b* values for the populations of *C. aestuarii* in the present study were 2.91 for males and 2.89 for females.

Mori et al. (1990) studied *C. aestuarii* samples from the lagoon of San Teodoro, Italy, and reported an isometric growth in males and a slight allometric negative growth in females. Those authors noted that the slopes of the weight-size relationships differed between males and females of *C. aestuarii* (Mori et al., 1990). A similar difference was also observed between the weights of male and female specimens in the present study (Figure 4), but the difference was not statistically significant ($P = 0.8426$ for WWM-WWF). The minimum sizes of male and female specimens in our study were measured at 16.10 and 14.98 mm CW, respectively.

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