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Linear-weight relationship of the species Carcinus aestuarii Nardo, 1847 (Decapoda: Brachyura: Carcinidae) along the Bulgarian Black Sea coast

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Abstract. Aim of the present study was to establish the growth of the decapod crustacean *Carcinus aestuarii* Nardo, 1847, for the Bulgarian Black Sea area. Biometric measurements of specimens sampled by diving and trawling were compared. Averaged values for carapace length (in cm) of the specimens collected by diving and trawling are relatively similar (4.25±0.856, against 4.92±0.064). Data for carapace mean width varied from 5.56±1.11 to 6.34±0.873 cm. Weight ranged from 8.5 to 167.86 g. Minimal values for size and weight were observed in the specimens collected by diving, and the maximum in the trawl discards. Positive allometric growth was observed in most cases, except for the total pool of discards and, in particular, for male individuals. Further detailed investigations on a monthly and seasonal basis are required to understand the complexity of factors influencing the populations of *Carcinus aestuarii* and its response to environmental changes.

Key words: Mediterranean green crab, length/width-weight ratio, Crustacea, the Black Sea.

Introduction

The Mediterranean green crab, *Carcinus aestuarii* Nardo, 1847, and the North Atlantic shore crab *Carcinus maenas* (Linnaeus, 1758) are among the 100 world's worst invaders (Leignel et al., 2014), but for the Mediterranean and the Black Sea, *Carcinus aestuarii* is native (Mori et al., 1990; Behrens Yamada & Hauck, 2001; Uzunova, 2016). In the historical sources, for the Bulgarian coastal area, this species was reported under the name *C. meanas* (Chichkoff, 1912; Bulgurkov, 1939; Valkanov, 1955), or *Carcinus mediterraneus* (Marinov, 1990).

Despite its high tolerance to oxygen deficiency and ecological plasticity (Leignel et al., 2014), *C. aestuarii* was highly influenced by the deterioration of the Black Sea ecosystem in the 90-es of the past century and was even reported as endangered for Romanian waters (Micu & Micu, 2006). Nowadays, a recovery of its population is observed, but the bottom trawling, where it is found as non-fish bycatch (discards), has become a new challenge for it. For this reason, the study of biological characters is very important for the control and conservation of their populations.

Studies on the biology of this decapod species for the Eastern and Southern Black Sea area, and neighboring Aegean Sea area were done by Kasapoglu & Duzgunes (2013), Özcan et al. (2009), Aydin (2013, 2018), but for the Bulgarian Black Sea sector, contemporary information on the distribution and biology of *C. aestuarii* is lacking.

Therefore, the present work aims to provide information about basic morpho-biometric parameters, such as length–weight, width–weight relationships, and Fulton's condition factor for the *Carcinus estuarii* populations from the Bulgarian Black Sea area. These parameters provide valu-

able information about the growth, welfare, and adaptation to environmental conditions of studied populations (Ricker, 1975; Fassatoui & Romdhane, 2021).

Materials and methods

Samples from *C. aestuarii* were collected along the Bulgarian Black Sea coast (from Cape Kaliakra to the North to Resovo to the South) (Fig. 1). Part of the samples (115 individuals) were taken from the bycatch of the bottom trawling activity of the fishery at depth between 15-37 m in the period 2020-2025. The other part (93 individuals) was collected by hand in the nearshore coastal area (1-10 m) by snorkeling and diving in the period of 2016-2025 (Fig. 1). Materials were transported frozen or preserved in 70% alcohol, or in 3.7% formalin. In laboratory conditions, biometric measurements of carapace length (CL) and carapace width (CW) in centimeters with a digital caliper (with accuracy to 0.01 cm) were taken. Wet weight (W) was measured in grams with an accuracy of 0.01 g (Kern balance). Carapace length (CL) was measured from the edge of the frontal region near the eye to the base of the carapace back wall. Carapace width (CW) was measured in the largest body part between the tips of the last couple of spines.

For statistical calculations of size-weight relationships and condition factor, Microsoft Excel statistical functions were used.

Length-weight relationships were estimated using the $W=aL^b$ equation, where W is the weight in grams, L is carapace length (CL in cm) or width (CW in cm), a (slope), and b (intercept) are equation parameters calculated by the least squares method (Ricker, 1973).

The significance of regression for the calculated data was assessed using ANOVA analyses and Pauly's t-test ($p<0.005$) (Bagenal, 1978; Pauly, 1984).

Calculation of Fulton's coefficient of condition factor (Kn) was by $Kn=100W/L^3$, where L is carapace length (CL in cm)/width (CW in cm) and W (g) (Le Cren, 1951; Bagenal, 1978; Sparre & Venema, 1992).

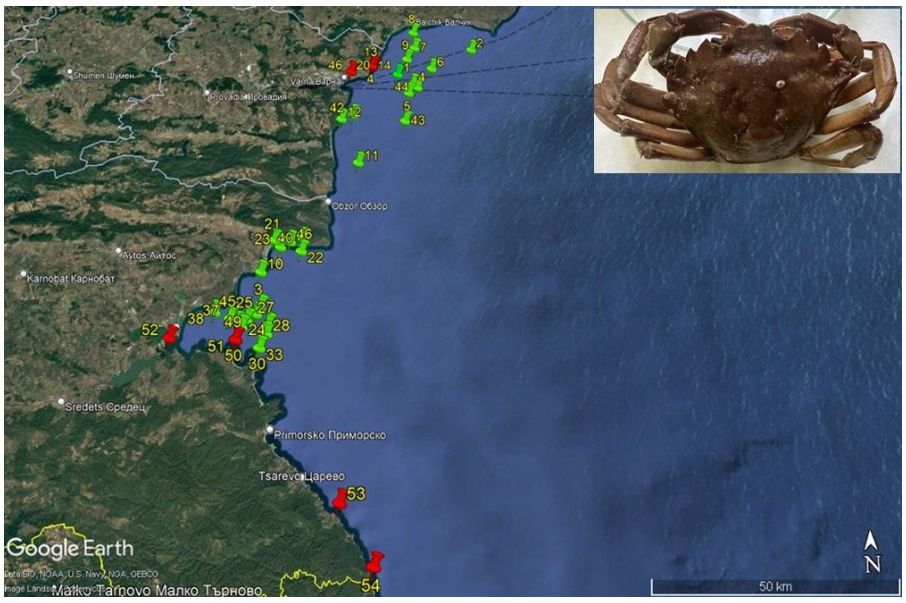


Fig. 1. Map showing the location of collecting sites of Mediterranean green crab *Carcinus aestuarii* Nardo, 1847 (the incorporated photo) along the Bulgarian Black Sea coast. **Note:** The green map pins point to crab samples collected by trawling. The red map pins point to hand collecting by snorkeling and diving.

Results and Discussion

A total of 208 *C. aestuarii* individuals were collected during the investigated period, 115 of them being male individuals and 93 females. Ovigerous females were observed only in the discard and consisted of 18% of the total female individuals. Results of measurements of body size are presented in Table 1. The variations of observed body size were as follows: CL ranged between 2.43 and 6.35 cm and CW from 3.341 to 8.56 cm,

female individuals being smaller. The averaged values of gender combined pools collected by diving specimens (1-10 m of depth) and trawling (15-37 m) areas of the Western Black Sea are relatively close, but differ in the size of female individuals from the 1-10 m area, which are significantly smaller than the ones in discards. The male size of discarded specimens (max 6.35 cm) is bigger than the average (5.39 cm). The crabs with minimal values of CL are concentrated near the shoreline, and in the trawling discards are found mainly specimens over 3 cm. Mean size of male individuals of discards specimens (5.39 cm) is close to the established for the Eastern part of the Black Sea, where it is 5.02 cm, respectively for female individuals – 4.63 cm for the Bulgarian part against 4.8 cm (see Aydın, 2013, 2018) for the Turkish one. Mean carapace width of investigated *C. aestuarii* populations expressed a difference of nearly 1 cm in favor of the discard pool. CW minimum was observed in female individuals from the nearshore area, and the maximum was detected in male individuals of the trawling area (Table 1). Our findings for trawling's area fall in the frame observed by Aydın (2013, 2018) for the Turkish coastal region, namely average value of CW - 6.35 cm for all, but the average CW for females of Bulgarian sector was smaller (5.92 cm) than 6.09 cm for female individuals of Turkish area and the CW in discards male individuals were bigger (mean=7.23 cm) than 6.61 cm respectively.

More pronounced differences are observed in the weight (W). The mean weight of the discards pool is 1.3-fold higher than that of the nearshore pool. The mean W for the Southern Black Sea coastal area estimated by Aydın (2013) correlates with that of our discards' samples (67.23 g). The differences in the male average weight are much bigger in favor of discarding males (1.6-fold), reaching 167.86 g for particular individuals. In the Turkish region, the weight of the specimens ranged between 0.76-172.00 g, and in our data, the minimum was 8.64 g and the maximum was 167.86 g.

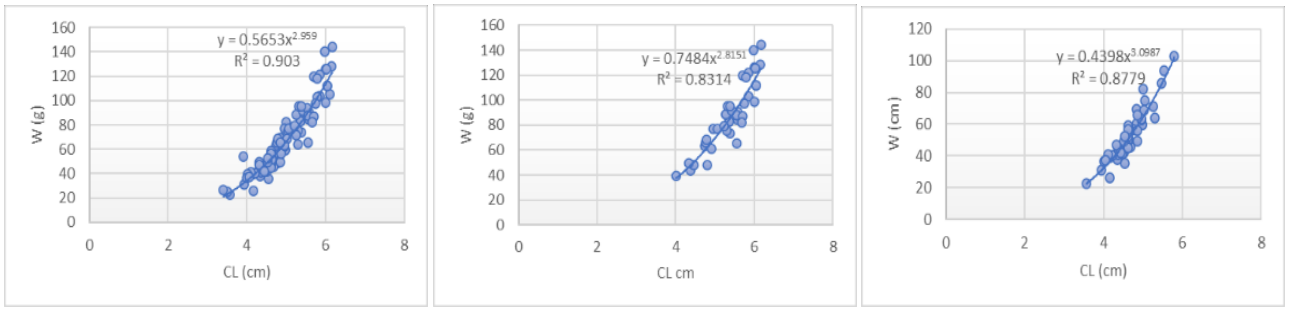
Table 1. Carapace length (CL), carapace width (CW) and weight (W), Max = the greatest value; Min = the least value; N = number of individuals; W = weight; Standard error (SE) of the mean, established for the population of *C. aestuarii* from the Bulgarian Black Sea area.

	N	**CL (cm)**		**CW (cm)**		**W (g)**	
		Mean±SE	**Min-Max**	**Mean±SE**	**Min- Max**	**Mean±SE**	**Min-Max**
Near shore combined	93	4.25±0.856	2.43-6.03	5.56±1.11	3.341-7.78	48.43±2.918	8.45-124
Near shore ♂	67	4.46±1.049	2.7-6.02	5.87±1.347	3.55-7.78	55.74±3.67	8.45-124
Near shore ♀	26	3.779±0.97	2.43-4.4	4.93±1.247	3.341-5.62	31.27±2.36	8.56-57.14
Discards combined	115	4.92±0.064	3.39-6.35	6.34±0.873	4.57-8.56	67.23±3.028	8.64-167.86
Discards ♀	67	4.63±0.059	3.51-6.10	5.92±0.804	4.57-8.06	52.34±2.35	8.64-105.54
Discards ♂	48	5.39±0.1	3.4-6.35	7.023±1.26	4.59-8.56	90.78±5.028	26.76-167.86

Values for b, derived through regression analyses (Fig. 2), applied to the pool of discarded specimens from Bulgarian waters, show similarity with findings of Aydin (2013, 2018). The same author established b=2.95, similar to our findings for the discards pool 2.959 and for the male group (b=2.8151), indicating negative allometric growth (Pauly's t-test, $p<0.05$). Only female individuals from this group demonstrated positive allometric growth.

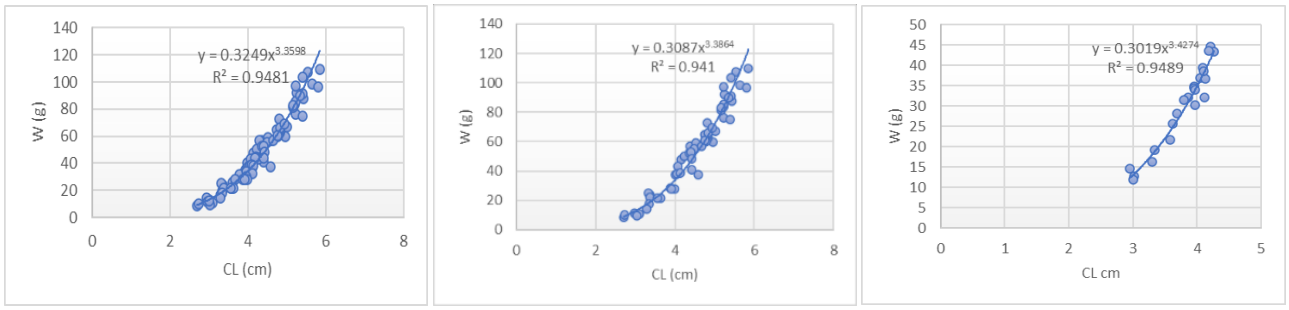
Results of regression analyses show CL-W positive allometric growth of the nearshore pool for all groups (Fig. 3).

The width-weight (CW/W) ratio of *C. aestuarii* carapace expresses negative allometric growth for males and positive for the total of discards pool and females in particular, while for nearshore specimens, these values are only positive (Fig. 4 and Fig. 5).



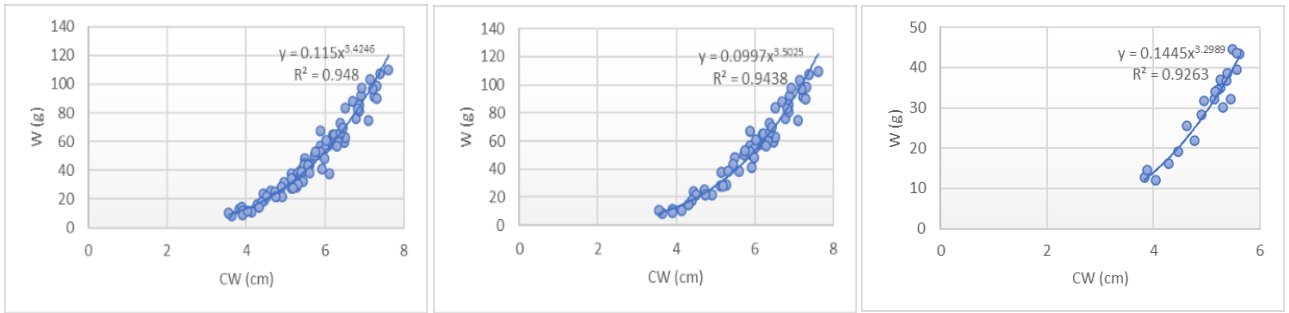
a b c

Fig. 2. CL-W ratio of *C. aestuarii* from the Bulgarian Black Sea area: a - total discards pool, b - males, and c - females.



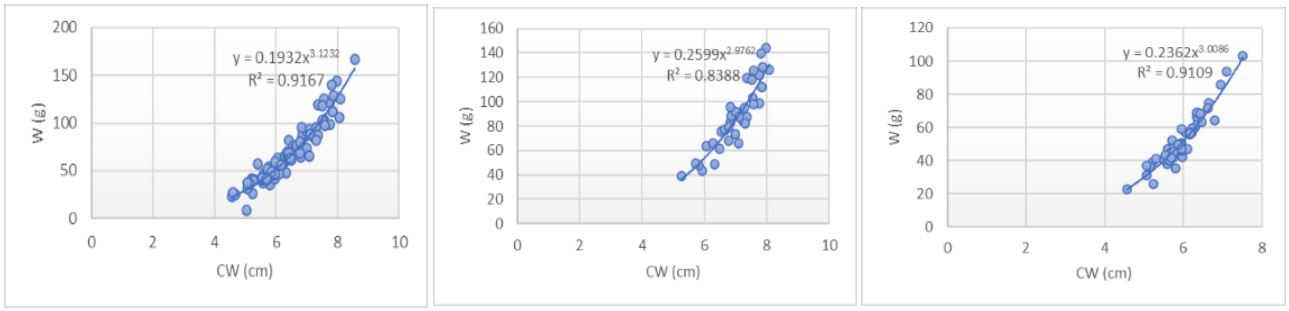
a b c

Fig. 3. CL-W ratio of *C. aestuarii* from the Bulgarian Black Sea area: a - total collected by hand pool, b - males, and c - females.



a b c

Fig. 4. CW-W ratio of *C. aestuarii* from the Bulgarian Black Sea area: a - total collected by hand pool, b - males, and c - females.



a b c

Fig. 5. CW-W ratio of *C. aestuarii* from the Bulgarian Black Sea area: a - total discards pool, b - males, and c - females.

Fulton's coefficient was calculated by regions and by sex and presented in Table 2. Our findings are very similar to those of Aydin (2018). For the total pool, he reported K=54.82, and in the nearshore area we found 54.74 against 52.194 for the trawling region. K for females is 53.88 in Aydin (2018) and in our study is 52.84 for near shore specimens and 50.52 for discards individuals. Male specimens exhibited similar values for the Bulgarian Black Sea area – 55.06 for the nearshore area and 54.721 for the trawling area. Aydin's (2018) results – 55.73 are closer to our nearshore results.

Table 2. Condition factor (K) of Fulton for carapace length (CL).

	Range	**Mean**	**Standard error**
Nearshore pool combined	29.96 -116.29	54.74	1.122
Males	33.36 - 65.322	55.06	1.055
Females	33.36 - 68.324	50.83	1.330
Trawl pool combined	14.23 - 65.36	52.19	0.724
Males	38.2 – 65.0	54.72	1.095
Females	14.23 – 65.37	50.522	0.908

Conclusions

As a result of this initial study of relationships length/width – weight of *C. aestuarii* from the Bulgarian Black Sea region was established that in the 1-10 m area, the size and weight of specimens are relatively smaller, compared to those between 15-37 m, probably due to different sampling strategies and better environmental conditions for youngsters' growth in the coastal area. Fulton's coefficient shows relatively similar values, being a little higher in the near-shore area. Data could be a basis for further monitoring of *C. aestuarii* populations and, respectively, of ecological changes, affecting its growth and development along the Bulgarian Black Sea.

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