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Width/length–weight relationships and condition factor of seven decapod crustaceans in a Brazilian tropical estuary

Gustavo F. de Carvalho-Souza [a,b,c,*], Diego V. Medeiros [c], Rodrigo de A. Silva [d], Enrique González-Ortegón [a]

[a] *Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC), Campus Universitario Río San Pedro, 11519, Puerto Real, Cádiz, Spain*
[b] *University of Cadiz, Campus de Excelencia Internacional del Mar (CEI·MAR), E-11510 Puerto Real, Cádiz, Spain*
[c] *Programa de Pós-Graduação em Conservação e Manejo da Biodiversidade, Universidade Católica do Salvador (UCSal), Campus de Pituaçu, Av. Prof. Pinto de Aguiar, Pituaçu, 41.740-090, Salvador, BA, Brazil*
[d] *RAS Consultoria Ambiental, Rua Dr. Alberto Pondé, 387, Candeal, Salvador, BA, Brazil*

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ABSTRACT

The analysis of body relationships and condition factors are useful tools in studies of marine populations, and they have been widely used in fishery research and management. In this study, width–weight (WWR) and length–weight (LWR) relationships and Fulton's condition factors were analyzed for six commercially important decapod crustacean species from the Paraguaçu River estuary (Todos os Santos Bay), eastern Brazil, namely *Callinectes danae*, *C. exasperatus*, *C. marginatus*, *C. ornatus*, *Goniopsis cruentata* and *Ucides cordatus*, and one non-indigenous species, *Charybdis helleri*. In total 5,704 individuals were measured and weighed during five years (2012–2017). The three allometric growth types for the crustacean species were observed, being most frequently the negative allometric growth. The analysis of covariance (ANCOVA) revealed significant differences between the sexes and climatic seasons in WWR/LWRs for the four species of the genus *Callinectes*, *C. helleri, G. cruentata* and *U. cordatus*, except for females and males of *C. danae* in WWR. The means for condition factor were generally higher for females than for males during the dry period, and in general, indicating good conditions for crustacean species. This study provided morpho-biometric parameters information will contribute stock management of traditional artisanal fisheries, and enable future comparative studies of populations of the same species.

1. Introduction

Morpho-biometric parameters are important indicators because they provide information on estimates of population growth, wellbeing of a species and others life history traits (Froese et al., 2011). Fisheries management has moved toward a more holistic approach and the estimates of basic parameters, such as length–weight (LWR), width–weight (WWR) relationships and Fulton's condition factor constitute a key element in fisheries stock assessments and research (Le Cren, 1951; Ricker, 1975; Froese, 2006).

The LWR and WWR are useful for determining stock biomass, analyzing ontogenetic changes and allow the assessment of spatial and seasonal variations (Froese, 2006; Bello et al., 2015; Johnston and Yeoh, 2020). In fact, condition factor assessment can provide important information about an individual's nutritional status and health by showing their feeding condition and adaptation to the environment (Ricker, 1975; Fassatoui et al., 2021).

The relationship between these metrics generates information contributing to the development of size-structured population dynamics models and morphometric interspecific and intrapopulational comparisons, which could reveal the existence of biogeographical relationships (Punt et al., 2013; Torres et al., 2017; Jones et al., 2019). This is particularly relevant for stocks or species with limited data (data-poor) where new researches are essential to improve species-specific estimates and enhance the accuracy of online databases, such as Sealifebase (Palomares and Pauly, 2022).

Portunid crabs (Crustacea: Decapoda: Brachyura) are important estuarine macro-invertebrates of tropical benthic communities. Its members play significant roles as key trophic link between primary consumers and higher trophic levels and represent important food resources for us and many other marine species such as swimming crabs (*Callinectes* Stimpson, 1860). For

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* Corresponding author at: Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC), Campus Universitario Río San Pedro, 11519, Puerto Real, Cádiz, Spain.
E-mail addresses: gustavofcsouza@gmail.com (G.F. de Carvalho-Souza), e.gonzalez.ortegon@csic.es (E. González-Ortegón).

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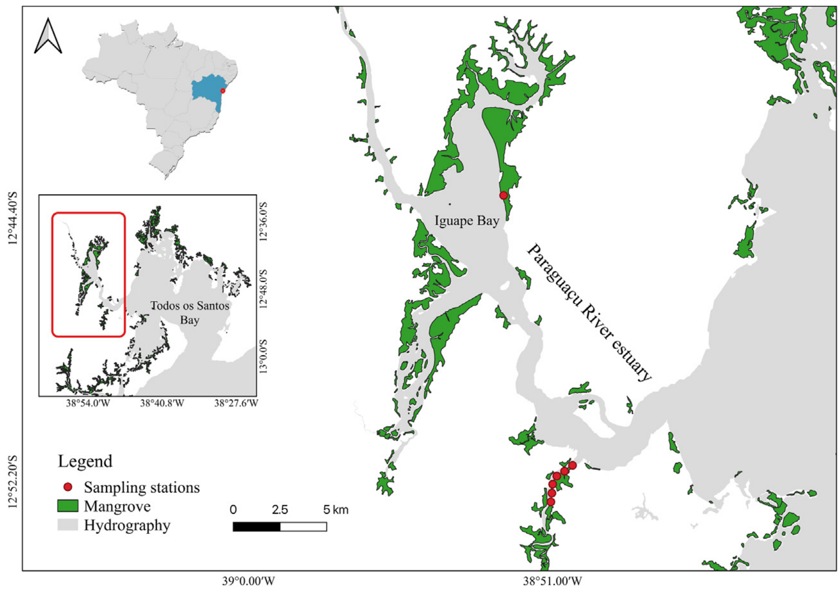

Fig. 1. Map of the lower Paraguaçu study area (Todos os Santos Bay, Bahia, Brazil), showing the location of the crustacean sampling stations (red circles).

instance, *Callinectes danae* Smith, 1869 is one of the most common and abundant species along the Brazilian coast (Severino-Rodrigues et al., 2001). The mangrove crabs *Goniopsis cruentata* (Latreille, 1803) and *Ucides cordatus* (Linnaeus, 1763) are also important fishery resources for traditional communities and fundamental species in nutrient cycling of the benthic mangrove macrofauna (Kristensen, 2008; Góes et al., 2010; Santos et al., 2013).

This paper describes the width–weight and length–weight relationships and condition factor of six commercially important decapod crustacean species, namely *C. danae*, *C. exasperatus* (Gerstaecker, 1856), *C. marginatus* (Milne-Edwards, 1861), *C. ornatus* Ordway, 1863, *G. cruentata* and *U. cordatus*, and one non-indigenous species, *Charybdis hellerii* (Milne-Edwards, 1867) from the Paraguaçu River estuary (Todos os Santos Bay), eastern Brazil.

2. Material and methods

Sampling was carried out semi-annualy (climatic seasons: dry and rainy) between August 2012 and April 2017, at seven stations along the Paraguaçu River estuary (Todos os Santos Bay), eastern Brazil (Fig. 1). The infralittoral crustaceans were sampled using two set of five rectangular multiple-entrance traps using fresh fish meat as bait, immersed in water for ∼16-hr each set (starting during twilight). For the intertidal crustaceans, a plot area of 10 × 10 m and sampling with duration of 30 min/station was delimited, where the specimens of *Ucides cordatus* were captured manually by hands. The individuals of *Goniopsis cruentata* were randomly collected with a fishing rod baited with pieces of other locally abundant small crustacean, *Aratus pisonii*. Local fishermen assisted all samplings. The collections were previously authorized by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) nº 150/2012–765/2016.

All individuals were identified to species and sexed based on the external morphology and species body relationships (when existent) were checked using Sealifebase (Palomares and Pauly, 2022). Carapace total width (CW, mm) and length (CL, mm), were measured with a digital caliper (precision: 0.1 mm) and weight (W, g) with a scale (precision: 0.1 g).

Prior to regression models, log–log plots of the length- and width–weight pairs were performed to detect and exclude outliers for each species (Froese, 2006). Width–weight (WWR) and length–weight (LWR) relationships were calculated for both sexes, climatic seasons and pooling (males and females) applying the logarithm-transformed linear model expressed as the following equation:

$$\log \text{W} = \log a + b \log \text{L}$$

where, "a" representing the intercept of the regression line and "b" the slope of the relationship. Relationships were not carried out in males of *C. exasperatus* and females of *C. marginatus* and *C. ornatus* by season due to their small sample sizes.

Sex-ratio of each species was calculated as the total number of males divided by the total number of females observed during each sampling and was used to analyzed from the ratio tends to be of 1:1 female to male in the total population by Chi-square test as: $= \sum (\text{O}-\text{E})^2/\text{E}$, where O was the observed frequency of females or males and E was the expected frequency of females or males. The analysis of covariance (ANCOVA) was used to determine if there were significant differences of the slope (b) coefficients in the width/length–weight relationships between the sexes and seasons of crustacean species.

Fulton's condition factor (K) was estimated from the relationship $\text{K} = 100\ \text{W}/\text{WL}^{\text{b}}$ to assess the crustacean condition, where W = the weight of each crustacean, WL = the carapace width or length, and b is the allometric growth coefficient computed for each sex's WWR/LWR (Le Cren, 1951; Ricker, 1975). We checked the underlying assumptions of the normality and homoscedasticity using a Shapiro–Wilk's normality test and the Levene median test, respectively. After, Kruskal–Wallis tests (non-parametric ANOVA) were applied to compare the K results against their factors (sex and climatic season) followed by the post hoc Dunn's comparisons (with Bonferroni correction). All analyses were performed using R software version 4.2.1 (R Core Team, 2022).

3. Results

A total of 5704 specimens belonging to the seven crustacean species *Callinectes danae* (3529), *Goniopsis cruentata* (806), *Ucides cordatus* (592), *Callinectes ornatus* (243), *Charybdis helleri* (215), *Callinectes exasperatus* (165) and *Callinectes marginatus* (140) from the Paraguaçu River estuary (Todos os Santos Bay, Brazil) were

Table 1
Parameter estimates of the width and length–weight relationship for each species of decapod crustacean in the Paraguaçu River estuary: N (sample size) and ranges of carapace width (CW), carapace length (CL), and weight (W) for male, female and pooled sexes, and sex-ratio with Chi-square (x^2) values and significant level (– not significant; *** p < 0, 0.001; ** p = 0.001–0.01; * p = 0.01–0.05).

Species	Sex	N	Carapace width (mm)		Carapace length (mm)		Weight (g)		Sex-ratio	
			Min–Max	Mean ± SD	Min–Max	Mean ± SD	Min–Max	Mean ± SD	F:M	χ^2
Callinectes danae	F	1834	50.9–109.0	80.79 ± 10.03	23.0–55.1	38.33 ± 4.84	9.9–84.0	33.36 ± 12.04	1:0.92	5.47*
	M	1695	40.4–126.2	88.76 ± 15.93	22.0–59.2	40.85 ± 6.72	8.0–128.1	48.01 ± 23.75		
	Pooled	3529	40.4–126.2	84.71 ± 13.70	22.0–59.2	39.87 ± 6.10	8.0–128.1	40.99 ± 20.05		
Callinectes exasperatus	F	141	56.1–122.0	91.15 ± 10.10	29.3–69.2	49.97 ± 6.01	15.2–145.0	75.00 ± 23.42	1:0.17	82.96***
	M	24	56.3–106.5	82.96 ± 13.69	28.0–63.1	45.75 ± 8.80	14.2–133.2	70.50 ± 36.19		
	Pooled	165	56.3–122.0	89.90 ± 11.02	28.0–69.2	49.36 ± 6.63	14.2–145.0	75.35 ± 25.61		
Callinectes marginatus	F	25	54.0–80.1	68.96 ± 6.65	26.6–40.1	34.32 ± 3.80	12.5–47.0	24.8 ± 8.09	1:4.6	57.85***
	M	115	53.0–103.0	75.33 ± 9.97	25.4–50.0	36.82 ± 4.51	11.0–107.0	37.9 ± 16.30		
	Pooled	140	53.0–103.0	74.19 ± 9.75	25.4–50.0	36.37 ± 4.48	11.1–107.0	35.56 ± 15.95		
Callinectes ornatus	F	33	50.0–103.6	71.42 ± 12.94	25.0–55.5	34.58 ± 6.95	11.0–80.0	25.85 ± 15.61	1:6:36	128.9***
	M	210	37.9–108.1	77.51 ± 11.35	22.0–48.2	36.88 ± 5.03	7.2–66.0	32.77 ± 12.62		
	Pooled	243	37.9–108.1	77.26 ± 11.23	22.0–55.5	36.57 ± 5.37	7.2–80.0	31.83 ± 13.25		
Charybdis hellerii	F	51	26.1–70.0	49.78 ± 8.80	16.0–46.4	33.29 ± 5.86	4.1–67.7	21.92 ± 10.31	1:3.21	59.39***
	M	164	32.3–75.2	56.60 ± 9.02	21.0–52.8	38.46 ± 5.99	4.2–79.2	36.21 ± 16.41		
	Pooled	215	26.1–75.2	54.98 ± 9.41	16.0–52.8	37.2 ± 6.34	4.2–79.2	32.82 ± 16.34		
Goniopsis cruentata	F	369	21.0–45.5	34.13 ± 4.48	17.4–41.3	29.05 ± 4.04	7.0–50.4	23.54 ± 8.80	1:1.18	5.73*
	M	437	19.0–52.1	35.54 ± 5.97	16.0–41.3	30.13 ± 5.37	5.1–66.2	27.06 ± 12.02		
	Pooled	806	19.0–52.1	34.89 ± 5.38	16.0–41.3	29.64 ± 4.83	5.1–66.2	25.45 ± 10.81		
Ucides cordatus	F	157	39.1–70.6	52.51 ± 6.53	25.6–54.0	39.06 ± 5.47	29.0–165.2	69.02 ± 28.58	1:2.54	112.4***
	M	425	38.2–74.4	56.80 ± 6.80	24.1–56.5	41.16 ± 5.72	35.3–210.0	91.28 ± 34.89		
	Pooled	592	38.2–74.4	55.59 ± 6.99	24.1–56.5	40.57 ± 5.73	29.0–210.0	85.01 ± 34.69		

captured to estimate the width–weight and length–weight relationships and Fulton's condition factor. All species were observed in the dry and wet seasons every year between 2012 and 2017, and *C. danae* had the highest abundance (Table 1). Among these seven species, five showed ovigerous females: *C. danae* (10.41% of total of females); *C. exasperatus* (9.92%); *C. hellerii* (37.25%); *G. cruentata* (14.90%) and *U. cordatus* (6.36%). The sample sizes (N), mean, SD, minimum, and maximum carapace widths (CW), carapace lengths (CL) and weights (W), and sex-ratio (proportion of females to males, Chi-square values and significance level) of measured individuals for each species (pooled and both sexes) are summarized in Table 1 and Figure S1.

Linear regressions fitted to estimate the WWR and LWR were highly significant for all crustacean species ($P < 0.001$) and the coefficient of determination (r^2) ranging from 0.80 to 0.97 (Table 2 and Figure S2).

In regards to WWR, the estimated coefficient b ranged from 2.52 to 3.40 (females of *G. cruentata* in the rainy period, and males of *C. exasperatus*, respectively). In this case, based on the b-value of WWR, the growth type of *C. exasperatus* was clearly positive allometric ($b > 3$), and the rest of species was negative allometric ($b < 3$). That is, although, in *C. marginatus* females, b-value was 3.03 (isometric growth), the confident interval was between 2.28 and 3.78.

In relation to LWR, the estimated coefficient b ranged from 2.51 to 3.19 (*G. cruentata* and *C. marginatus*, respectively). Based on the b-value of LWR, the growth type of some category in the species *C. danae*, *C. exasperatus* and *C. marginatus* was positive allometric ($b > 3$), although only males of the species *C. danae* showed a confidence interval slightly above 3. The other species (*C. ornatus, C. hellerii, G. cruentata* and *U. cordatus*) showed a negative allometric growth ($b < 3$). No significant differences were found for both b coefficients when compared to the threshold of 3 ($P > 0.05$).

Both size and weight differed between the sexes, with males showing larger carapace (CW and CL) and weight (W) than females, except for *C. exasperatus*. The value of coefficient b of the CW-W and CL-W relationships in males and females, in dry and wet seasons showed statistically significant differences for all species, with the exception of the CW-W relationship of the species *C. danae* (Table 3).

The Fulton's condition factor K varied between 0.0019 (*C. exasperatus* — males) and 0.1911 (*G. cruentata* — males) in WWR, and between 0.0181 (*C. hellerii* — females) and 0.7502 (*U. cordatus* — males) in LWR. The analysis of K revealed significant differences among all factors, sex and climatic season for several species (Fig. 2).

The Fulton's condition factor K with WWR, presented significant differences in both factors (sex and climatic season) for the species *C. danae* (Kruskal–Wallis, P value between < 0.0001 and <0.05) and *G. cruentata* ($P < 0.0001$) Significant sex differences of K were also found for *C. exasperatus* using width carapace measurements ($P < 0.0001$), as well as *C. marginatus* ($P = 0.001$), *C. hellerii* ($P < 0.0001$) and *U. cordatus* ($P = 0.0009$). On the other hand, the K results for *C. ornatus* presented a significant difference between seasons ($P = 0.0009$).

The Fulton's condition factor K with LWR measurements presented also significant differences for sex and climatic season for the species *C. danae* ($P < 0.0001$ and <0.05, respectively) and *G. cruentata* ($P < 0.0001$). The K values for *U. cordatus* ($P < 0.0001$), *C. ornatus* ($P < 0.0001$), *C. hellerii* ($P = 0.02$), *C. exasperatus* ($P < 0.0001$) and *C. marginatus* ($P < 0.0001$) revealed a significant difference only between sexes when the carapace length was used.

4. Discussion

Information of the variation in size among populations of a species is useful to understand the effect of abiotic (e.g. dry or wet seasons) and biotic interaction on the growth pattern of a species. Detection of these effects on morpho-biometric traits are very useful to provide a baseline for management strategies, particularly in species susceptible to fishing pressure such as crabs. However, there is an important lack of morphological trait of many species, even in their native areas. The present study provides a detailed estimate of WWR and LWRs and condition factor for males, females and pooled sex of seven decapod crustaceans from the Paraguaçu River estuary (Todos os Santos Bay), eastern Brazil.

Table 2
Relationship values of the carapace width/length–weight for male, female and pooled sexes: a, intercept; b, slope; CI, confidence intervals; r^2 coefficient of determination; TG, types of growth (I, isometry; A+, positive allometry; A-, negative allometry).

Species	Sex/Season	CW x W Regression parameters				CL x W Regression parameters			
		a (95% CL)	b (95% CL)	r^2	TG	a (95% CL)	b (95% CL)	r^2	TG
Callinectes danae	F	0.0001 (0.0001–0.0002)	2.74 (2.694–2.795)	0.873	A-	0.0015 (0.0013–0.0018)	2.71 (2.670–2.768)	0.879	A-
	M	0.0001 (0.0001–0.0002)	2.77 (2.737–2.808)	0.931	A-	0.0005 (0.0004–0.0006)	3.05 (3.013–3.094)	0.928	I
	F/Dry	0.0002 (0.0001–0.0002)	2.71 (2.646–2.784)	0.845	A-	0.0016 (0.0012–0.0020)	2.70 (2.643–2.775)	0.855	A-
	M/Dry	0.0001 (0.0001–0.0002)	2.73 (2.687–2.773)	0.947	A-	0.0005 (0.0004–0.0006)	3.04 (2.994–3.105)	0.931	I
	F/Rainy	0.0001 (0.0001–0.0002)	2.78 (2.708–2.857)	0.907	A-	0.0014 (0.0011–0.0018)	2.74 (2.677–2.821)	0.911	A-
	M/Rainy	0.0003 (0.0003–0.0005)	2.81 (2.760–2.876)	0.916	A-	0.0005 (0.0004–0.0006)	3.06 (3.007–3.124)	0.926	I
	Pooled	0.0002 (0.0002–0.0003)	2.67 (2.645–2.709)	0.885	A-	0.0008 (0.0007–0.0009)	2.89 (2.861–2.934)	0.871	A-
Callinectes exasperatus	F	0.0001 (0.00005–0.0005)	2.86 (2.607–3.128)	0.889	A-	0.0024 (0.0009–0.006)	2.63 (2.402–2.872)	0.896	A-
	M	0.00001 (0.000001–0.0001)	3.40 (3.00–4.00)	0.901	A+	0.0005 (0.0001–0.0024)	3.03 (2.651–3.412)	0.921	I
	F/Dry	0.0001 (0.00004–0.0006)	2.88 (2.574–3.195)	0.805	A-	0.0022 (0.0007–0.0062)	2.66 (2.394–2.930)	0.826	A-
	M/Dry	–	–	–	–	–	–	–	-
	F/Rainy	0.0001 (0.00001–0.0011)	2.92 (2.430–3.422)	0.866	A-	0.0029 (0.0004–0.0208)	2.58 (2.08–3.086)	0.811	A-
	M/Rainy	–	–	–	–	–	–	–	-
	Pooled	0.0001 (0.00002–0.0003)	2.91 (2.740–3.281)	0.846	A-	0.0021 (0.001–0.0045)	2.67 (2.479–2.864)	0.820	A-
Callinectes marginatus	F	0.00006 (0.00002–0.0014)	3.03 (2.284–3.782)	0.842	I	0.0013 (0.0001–0.011)	2.76 (2.170–3.364)	0.891	A-
	M	0.0001 (0.00004–0.0002)	2.94 (2.746–3.151)	0.879	A-	0.0004 (0.0002–0.0009)	3.13 (2.931–3.334)	0.892	A+
	F/Dry	–	–	–	–	–	–	–	-
	M/Dry	0.00003 (0.0003–0.0003)	2.95 (2.686–3.215)	0.877	A-	0.0005 (0.0001–0.0012)	3.09 (2.829–3.353)	0.889	I
	F/Rainy	–	–	–	–	–	–	–	-
	M/Rainy	0.0001 (0.00003–0.0007)	2.84 (2.507–3.185)	0.866	A-	0.0004 (0.0001–0.0014)	3.15 (2.807–3.498)	0.884	A+
	Pooled	0.00006 (0.00002–0.0001)	3.06 (2.862–3.272)	0.863	I	0.0003 (0.0001–0.0007)	3.19 (2.988–3.408)	0.867	A+
Callinectes ornatus	F	0.0001 (0.00004–0.0006)	2.76 (2.462–3.069)	0.914	A-	0.002 (0.001–0.0061)	2.57 (2.328–2.821)	0.934	A-
	M	0.0001 (0.00009–0.0003)	2.75 (2.599–2.907)	0.855	A-	0.001 (0.0008–0.0025)	2.76 (2.607–2.915)	0.856	A-
	F/Dry	–	–	–	–	–	–	–	-
	M/Dry	0.0002 (0.00009–0.0005)	2.72 (2.530–2.917)	0.857	A-	0.001 (0.0005–0.0028)	2.80 (2.582–3.026)	0.828	A-
	F/Rainy	–	–	–	–	–	–	–	-
	M/Rainy	0.0003 (0.0001–0.0012)	2.59 (2.311–2.875)	0.808	A-	0.0021 (0.0008–0.0052)	2.65 (2.394–2.918)	0.837	A-
	Pooled	0.0009 (0.00009–0.0003)	2.76 (2.635–2.903)	0.872	A-	0.0014 (0.0009–0.0023)	2.75 (2.622–2.890)	0.871	A-
Charybdis hellerii	F	0.0007 (0.0002–0.0023)	2.61 (2.391–2.841)	0.896	A-	0.002 (0.001–0.0062)	2.55 (2.304–2.808)	0.892	A-
	M	0.0003 (0.0001–0.0007)	2.84 (2.643–3.044)	0.828	A-	0.0006 (0.0003–0.0013)	2.95 (2.771–3.136)	0.862	A-
	F/Dry	0.004 (0.0006–0.0326)	2.61 (2.308–2.929)	0.887	A-	0.002 (0.0008–0.0048)	2.60 (2.359–2.850)	0.931	A-
	M/Dry	0.0002 (0.00008–0.0008)	2.91 (2.644–3.208)	0.831	A-	0.0007 (0.0003–0.0018)	2.92 (2.679–3.171)	0.866	A-
	F/Rainy	0.0008 (0.0002–0.0031)	2.59 (2.264–2.921)	0.950	A-	0.003 (0.0006–0.0174)	2.52 (2.046–3.010)	0.893	A-
	M/Rainy	0.0005 (0.0001–0.0016)	2.74 (2.453–3.032)	0.823	A-	0.0005 (0.0002–0.0016)	2.99 (2.715–3.280)	0.854	A-
	Pooled	0.0002 (0.0001–0.0005)	2.87 (2.720–3.031)	0.861	A-	0.0008 (0.0005–0.0014)	2.89 (2.754–3.039)	0.882	A-
Goniopsis cruentata	F	0.0017 (0.001–0.002)	2.68 (2.585–2.780)	0.887	A-	0.003 (0.002–0.004)	2.58 (2.497–2.672)	0.901	A-
	M	0.001 (0.001–0.002)	2.66 (2.591–2.734)	0.925	A-	0.004 (0.003–0.005)	2.53 (2.483–2.586)	0.955	A-
	F/Dry	0.0007 (0.0004–0.001)	2.91 (2.764–3.063)	0.883	A-	0.004 (0.003–0.007)	2.51 (2.388–2.642)	0.887	A-
	M/Dry	0.001 (0.001–0.002)	2.73 (2.628–2.840)	0.924	A-	0.004 (0.003–0.006)	2.52 (2.449–2.610)	0.947	A-
	F/Rainy	0.002 (0.001 - 0.004)	2.52 (2.393–2.655)	0.893	A-	0.003 (0.002–0.004)	2.61 (2.492–2.731)	0.915	A-
	M/Rainy	0.001 (0.001–0.003)	2.57 (2.492–2.661)	0.941	A-	0.004 (0.003–0.005)	2.51 (2.464–2.580)	0.970	A-
	Pooled	0.001 (0.001–0.002)	2.67 (2.616–2.730)	0.913	A-	0.004 (0.003–0.004)	2.55 (2.512–2.604)	0.936	A-
Ucides cordatus	F	0.0007 (0.0003–0.001)	2.86 (2.646–3.082)	0.801	A-	0.004 (0.002–0.006)	2.62 (2.503–2.754)	0.912	A-
	M	0.0007 (0.0004–0.001)	2.89 (2.758–3.034)	0.800	A-	0.007 (0.004–0.0104)	2.52 (2.428–2.627)	0.855	A-
	F/Dry	0.0007 (0.0002–0.002)	2.88 (2.567–3.205)	0.803	A-	0.003 (0.001–0.006)	2.70 (2.534–2.866)	0.930	A-
	M/Dry	0.0005 (0.0002–0.001)	2.96 (2.777–3.143)	0.813	A-	0.191 (0.110–0.330)	2.53 (2.381–2.694)	0.814	A-
	F/Rainy	0.0009 (0.0003–0.002)	2.80 (2.516–3.085)	0.816	A-	0.006 (0.003–0.0124)	2.51 (2.330–2.697)	0.895	A-
	M/Rainy	0.0006 (0.0003–0.0014)	2.89 (2.700–3.092)	0.817	A-	0.007 (0.004–0.011)	2.51 (2.396–2.634)	0.901	A-
	Pooled	0.0005 (0.0003–0.0009)	2.94 (2.829–3.054)	0.816	A-	0.004 (0.003–0.006)	2.62 (2.543–2.716)	0.857	A-

Sexual dimorphism in the seven species studied (except for *C. exasperatus*) can also be seen in other populations (Pinheiro and Fiscarelli, 2009; Araújo et al., 2012) more clearly in the width–weight and length–weight relationships, as the species *C. danae, C. exasperatus* and *C. marginatus*. Within the brachyuran crabs, males are usually larger and heavier than females (Hartnoll, 2006; Navarro-Ojeda et al., 2022). This is due to the greater reproductive effort in males, directing their energy towards body increase, which gives them a greater probability of copulate and consequently leaving offspring (Pinheiro and Fransozo, 1999; Mantelatto and Martinelli, 1999). On the other hand, females invest a greater portion of energy in the development of the gonads and in the production of eggs (Kotiaho and Simmons, 2003), leading them not to reach larger sizes than males.

The sex ratios observed in this study were skewed toward males in some species and females in others, with the exception of *C. danae* and *G. cruentata* which were more balanced. The mechanisms underlying these variations have been reported to be ecological differences and human-induced activities between the sexes appear to be the major explanation for sex ratio bias in crustaceans (Ewers-Saucedo, 2019; Ogburn, 2019). In particular fishing mortality, catchability, longevity, seasonal migrations or behavioral characteristics in response to fluctuating environmental conditions (e.g. temperature and salinity), can lead to skewed sex ratios of crabs in estuaries.

The estimations for the b allometric coefficient b varied within the range of values (2.5 to 3.5) indicated for healthy marine populations (Carlander, 1969; Froese, 2006). Mostly, the studied species showed a negative allometric growth, and these data were consistent with those found in previous estimates on these commercially important crustaceans (Table 4 and references therein). The species *C. exasperatus* and *C. marginatus* had the largest coefficients, notably superior from the other species analyzed ($p < 0.05$).

Table 3
Analysis of covariance (ANCOVA) results showing comparisons of slopes b and intercepts a between sexes and climatic season for each species of decapod crustacean in the Paraguaçu River estuary. Significant values (P value < 0.05, in bold) and degree of freedom (F value) are presented for each species.

Species		CW x W Regression parameters				CL x W Regression parameters			
		slope b		intercept a		slope b		intercept a	
		F value	P value	F value	P value	F value	P value	F value	P value
Callinectes danae	Sex	49.09	**<0.0001**	15572.1	**<0.0001**	734.78	**<0.0001**	11981.30	**<0.0001**
	Season	2.8307	0.0925	16494.42	**<0.0001**	111.42	**<0.0001**	10833.69	**<0.0001**
Callinectes exasperatus	Sex	637.70	**<0.0001**	298.82	**<0.0001**	752.55	**<0.0001**	268.80	**<0.0001**
	Season	625.40	**<0.0001**	287.29	**<0.0001**	744.91	**<0.0001**	261.54	**<0.0001**
Callinectes marginatus	Sex	862.37	**<0.0001**	479.95	**<0.0001**	995.75	**<0.0001**	497.99	**<0.0001**
	Season	854.46	**<0.0001**	453.90	**<0.0001**	876.61	**<0.0001**	416.75	**<0.0001**
Callinectes ornatus	Sex	1564.31	**<0.0001**	835.73	**<0.0001**	1608.79	**<0.0001**	723.91	**<0.0001**
	Season	1513.61	**<0.0001**	794.94	**<0.0001**	1412.08	**<0.0001**	633.71	**<0.0001**
Charybdis hellerii	Sex	1203.97	**<0.0001**	628.11	**<0.0001**	1320.48	**<0.0001**	651.37	**<0.0001**
	Season	1387.03	**<0.0001**	671.56	**<0.0001**	1623.56	**<0.0001**	732.58	**<0.0001**
Goniopsis cruentata	Sex	8361.73	**<0.0001**	3757.30	**<0.0001**	11903.32	**<0.0001**	4849.99	**<0.0001**
	Season	8666.67	**<0.0001**	3895.08	**<0.0001**	12318.05	**<0.0001**	5023.24	**<0.0001**
Ucides cordatus	Sex	2382.26	**<0.0001**	960.08	**<0.0001**	3990.74	**<0.0001**	1222.68	**<0.0001**
	Season	2867.99	**<0.0001**	1156.00	**<0.0001**	3597.84	**<0.0001**	1098.08	**<0.0001**

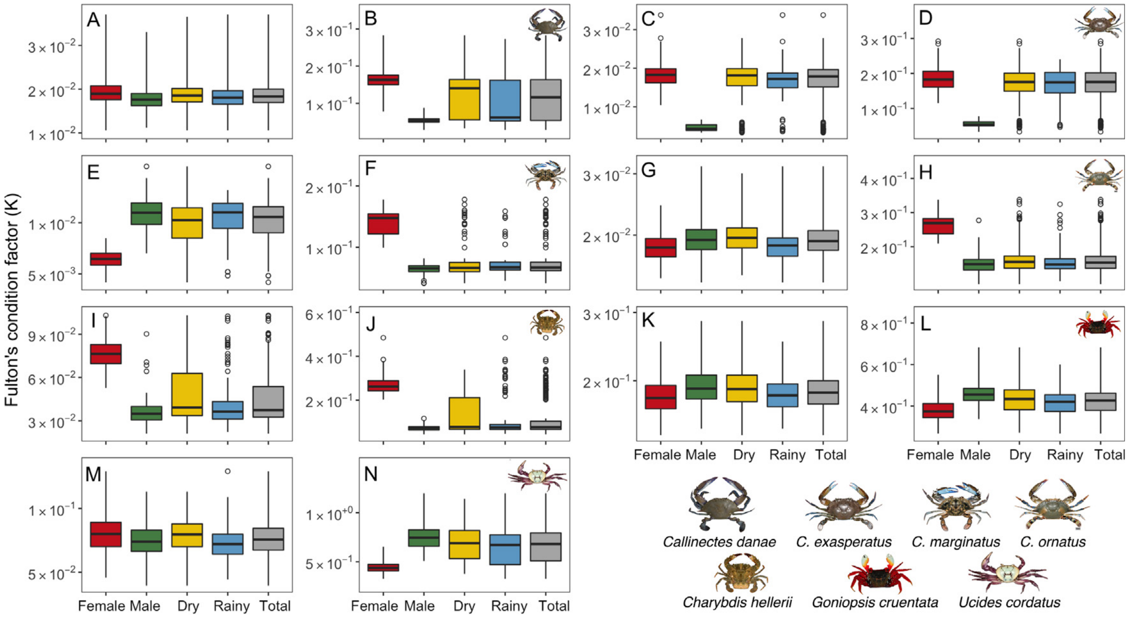

Fig. 2. Fulton's condition factor (K) by sex, climatic season and pooled data (Total) for each crustacean species from Paraguaçu River estuary, Brazil, using carapace width and carapace length, respectively: (A–B) *Callinectes danae*; (C–D) *C. exasperatus*; (E–F) *C. marginatus*; (G–H) *C. ornatus*, (I–J) *Charybdis hellerii*; (K–L) *Goniopsis cruentata* and; (M–N) *Ucides cordatus*. Plots show the median (line drawn), quartiles (box portion), minimum and maximum data value (end of whiskers) and outliers (open circles).

The WWR and LWR indicated that the portunids may occasionally display different patterns of allometric growth, coinciding with those previously observed, such as *C. danae* and *C. ornatus* in northeastern and northern Brazil (Shinozaki-Mendes and Lessa, 2017; Oliveira et al., 2022), *G. cruentata* (Santos et al., 2013; Reis et al., 2015) and *U. cordatus* (Araújo and Calado, 2008; Pinheiro and Fiscarelli, 2009; Araújo et al., 2012; Leite et al., 2014), but differing from those found in other parts of Brazil (Table 4 and references therein). The different spatial patterns across populations may reflect changes in life histories for the same species (Araújo and Lira, 2012). Overall, variations in allometric coefficients can be related to numerous direct and indirect factors, including biotic factors, e.g. physiological features, growth phase, sex, sexual maturity, stomach fullness, length frequency, food availability, nutrition (Le Cren, 1951; Froese et al., 2011), abiotic conditions, e.g. climatic seasons, temperature, salinity, pH, dissolved oxygen (Hartnoll, 1985) or human pressures, e.g. fishing, coastal urbanization (Branco and Fracasso, 2004; Rudershausen et al., 2021).

The K values varied according to both factors, with females generally having higher condition factor values, as well as during the breeding season (Fig. 2). There are several bioecological processes that are often recognized as influencing the condition of crustaceans. Adverse environmental conditions, poor feeding sources, parasite infections, spawning activity and seasonality have all been reported to influence temporal and/or spatial variation in condition factors between or within different stocks (Froese, 2006; Hartnoll, 2006; Hines et al., 2008). Lira et al. (2012) analyzing the seasonal variations in condition factor suggest that the size is an important feature that influences the condition factor between species. According to Pinheiro and Fiscarelli (2009) studying *U. cordatus*, the improved feeding conditions in the autumn compared to the earlier months (summer), lead to crabs of both sexes to present higher K values.

Table 4

Review of width/length–weight relationships (intercept a and slope b) of crustaceans studied in the present work.

Species	Width–weight relationship		Length–weight relationship		Locality	Reference
	Range a	Range b	Range a	Range b		
Callinectes danae			0.001–0.0019	2.65–2.82	Mundaú Lagoon, Alagoas, Brazil	Pereira-Barros and Travassos (1975)
			0.0738–0.0889	2.80–2.89	Itacorubi mangrove, Santa Catarina, Brazil	Branco and Thives (1991)
	0.0715	2.91			Conceição Lagoon, Santa Catarina, Brazil	Branco and Masunari (1992)
	0.162–0.184	2.81–2.89	0.840–0.872	2.75–2.82	Ciénaga Grande de Santa Marta, Colombia	Escobar M.R. Giraldo (1993)
	0.0001	3.00–3.01			Shangri-lá Beach, Paraná, Brazil	Baptista-Metri et al. (2005)
	0.0087–0.085	2.84–2.85			Babitonga Bay, Santa Catarina, Brazil	Pereira et al. (2009)
	0.00006–0.0001	2.87–2.99			Guanabara Bay, Rio de Janeiro, Brazil	Golodne et al. (2010)
			0.0007–0.0001	2.87–2.98	Margarita Island, Venezuela	Castillo et al. (2011)
	0.00008–0.0012	3.02–3.12			Santa Cruz Channel, Pernambuco, Brazil	Araújo and Lira (2012)
	0.00009–0.0001	2.93–3.06			Santos-São Vicente estuary, São Paulo, Brazil	Scalco (2012)
	0.0702	3.11			Iguape and Cananéia Estuarine-Lagoon Complex, São Paulo, Brazil	Severino-Rodrigues et al. (2012)
	0.0871	2.83			Santa Cruz Channel, Pernambuco, Brazil	Shinozaki-Mendes and Lessa (2017)
			0.00035	2.67–2.68	Margarita Island, Venezuela	Eslava et al. (2019)
	0.0001	2.79	0.0006–0.0011	2.85–3.03	Caeté, Pirabas and Salinas estuaries, northern Brazil	Oliveira et al. (2022)
	0.0001–0.0006	2.67–2.81	0.0005–0.0016	2.70–3.06	Paraguaçu River estuary, Bahia, Brazil	Present study
Callinectes exasperatus	0.00001–0.0001	2.86–3.4	0.0005–0.0029	2.58–3.03	Paraguaçu River estuary, Bahia, Brazil	Present study
Callinectes marginatus	0.00003–0.0001	2.84–3.06	0.0003–0.0013	2.76–3.19	Paraguaçu River estuary, Bahia, Brazil	Present study
Callinectes ornatus	0.20–1.07	2.09–2.15			Mullet Bay, Bermuda	Haefner (1990)
	0.51–0.65	2.95–3.17			Matinhos region, Paraná, Brazil	Branco and Lunardon-Branco (1993)
	0.06	2.98–3.14			Ría Celestún, Yucatan, Mexico	Andrade Hernández (1999)
	0.000000005	3.09–3.12			Shangri-lá Beach, Paraná, Brazil	Baptista et al. (2003)
	0.0466–0.0498	3.10–3.16			Armação do Itapocoroy, Santa Catarina, Brazil	Branco and Fracasso (2004)
	0.00003–0.00004	3.10–3.15			Guanabara Bay, Rio de Janeiro, Brazil	Golodne et al. (2010)
			0.00001	3.31–3.38	Sucre, northern Venezuela	Moreno et al. (2011)
	0.00005–0.00007	2.96–3.05			Northern Rio de Janeiro, Brazil	Tudesco et al. (2012)
	0.0004–0.0006	3.04–3.17			São Francisco River, Northeast, Brazil	Santos et al. (2016)
	0.0003	2.55	0.0008	2.84	Caeté, Pirabas and Salinas estuaries, northern Brazil	Oliveira et al. (2022)
	0.00006–0.0001	2.89–3.17	0.0003–0.0016	2.67–3.18	Pirambu, Sergipe, Brazil	Santos et al. (2022)
	0.0001–0.0009	2.59–2.76	0.001–0.0021	2.57–2.80	Paraguaçu River estuary, Bahia, Brazil	Present study
Charybdis hellerii	0.0001–0.0002	2.94–3.22			Ubatuba Bay, São Paulo, Brazil	Mantellato and Garcia (2001)
	0.0002–0.004	2.59–2.91	0.0005–0.003	2.52–2.99	Paraguaçu River estuary, Bahia, Brazil	Present study

(*continued on next page*)

Table 4 (*continued*).

Species	Width–weight relationship		Length–weight relationship		Locality	Reference
	Range a	Range b	Range a	Range b		
Goniopsis cruentata	0.1738–0.3981	3.24–3.30			Mundaú/Manguaba estuarine complex, Alagoas, Brazil	Lira et al. (2012)
	0.0005–0.0006	2.94–2.99			Caravelas River estuary, Bahia, Brazil	Santos et al. (2013)
	0.4991–1.2046	2.31–2.93			Dura Beach, Ubatuba, São Paulo, Brazil	Reis et al. (2015)
	0.0007–0.002	2.52–2.91	0.003–0.004	2.51–2.61	Paraguaçu River estuary, Bahia, Brazil	Present study
Ucides cordatus			0.9827–1.1624	2.46–2.62	Itacorubi mangrove, Santa Catarina, Brazil	Branco (1993)
	0.0002–0.0016	2.64–3.08	0.0006–0.0038	2.58–3.07	Formoso and Ilhetas River estuary, Pernambuco, Brazil	Botelho et al. (1999)
	0.0005–0.0007	2.87–2.93			Mundaú/Manguaba estuarine complex, Alagoas, Brazil	Araújo and Calado (2008)
	0.0004–0.0007	2.88–2.99			Barra de Icapara, São Paulo, Brazil	Pinheiro and Fiscarelli (2009)
	0.0004	2.97–3.00			Vitoria Bay, Espírito Santo, Brazil	Góes et al. (2010)
	0.0003–0.0012	2.83–3.03			Ariquindá and Mamucabas River, Pernambuco, Brazil	Araújo et al. (2012)
	0.047–7.4557	2.40–2.70			Amapá, Calçoene and Oiapoque, northern Brazil	Amaral et al. (2014)
	0.0006–0.0007	2.89–2.95			Jaguaribe River mangrove, Ceará, Brazil	Leite et al. (2014)
	0.0004–0.005	2.99–3.00			Joanes River estuary, Bahia, Brazil	Moraes et al. (2015)
			0.0017–0.054	1.87–2.63	Maranhão Island, northern Brazil	Rocha and Lima (2020)
	0.001–0.0021	2.59–2.79			Babitonga Bay, Santa Catarina, Brazil	Pescinelli et al. (2021)
	0.0005–0.0009	2.80–2.96	0.003–0.191	2.51–2.70	Paraguaçu River estuary, Bahia, Brazil	Present study

Condition factor of females and males in WWR and LWR may change throughout climatic seasons as result of its lifestyle and ontogenetic changes of crustaceans (Boothby and Avault, 1971). For instance, species of the genus *Callinectes* Stimpson, 1860 perform a reproductive migration from estuarine oligo/mesohaline regions of estuary to the lower estuary and the adjacent coastal ocean looking for more saline zones, which can trigger the gonadal development and facilitate larval dispersal (Branco and Masunari, 1992; Hines et al., 2008; Shinozaki-Mendes and Lessa, 2017).

Females of the invasive species *C. hellerii* in the Paraguaçú river estuary showed a lower regression coefficient compared to males, due to their larger and heavier gonads and a high number of ovigerous females sampled, which resulted in a greater condition factor (especially in dry season) as observed for other brachyurans (Table 4 references). In *G. cruentata*, the variation of the condition factor showed a slight difference, with males being larger than females, contrasting with the results obtained by other studies (Lira et al., 2012). There was no clear pattern of the condition factor in WWR and LWR among males and females of *Ucides cordatus*, but it increased in the dry season, which was the reproductive period of this species, and were in agreement with results obtained from other geographical areas (Pinheiro and Fiscarelli, 2009; Araújo et al., 2012).

Based on results obtained and previously reported, the condition factor of crustaceans of both sexes can be connected to reproductive season, which proves to be an important indicator in understanding reproductive behavior and managing these economically exploited species. The width–weight and length–weight relationships, and condition factors obtained in this study could be useful in biomass dynamics modeling of estuarine crustaceans which are one of the main targets of local artisanal fishing activity and whose population dynamics and structure is poorly studied especially in the eastern Brazilian region.

5. Conclusions

The present study reported the width–weight and length–weight parameters, and their condition factors of seven crustacean species from the eastern Brazil. The growth types for these crustacean species of the Paraguaçu River estuary were estimated, and mainly the species showed a negative allometric growth for WWR and for LWR ($b < 3$). The assessment of the condition factor showed that in general females were higher than males during the dry period, indicating good conditions for crustacean species. These morphometric relationships have prompt applicability for supplying basic knowledge needed in stock assessments and management frameworks of traditional artisanal fisheries.

CRediT authorship contribution statement

Gustavo F. de Carvalho-Souza: Conceptualization, Methodology, Sample collection, Formal analysis, Writing – original draft. **Diego V. Medeiros:** Methodology, Sample collection, Writing – review & editing. **Rodrigo de A. Silva:** Methodology, Sample collection, Writing – review & editing. **Enrique González-Ortegón:** Conceptualization, Methodology, Supervision, Formal analysis, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.rsma.2023.102880.

References

Amaral, K.D.S., Vieira, I.M., Osório, F.M., Rocha, J.D.M., Lima, J.F., 2014. Bioecology of the crab ucides cordatus (Crustacea, Decapoda) in mangroves influenced by the Amazon river Brazil. Acta Amaz. 44 (2), 213–222. http://dx.doi.org/10.1590/S0044-59672014000200007.

Andrade Hernández, M., 1999. Pautas para el manejo y ordenamiento de una pesquería multiespecífica de crustáceos en un área natural protegida: El caso de la Ría Celestún, Yucatán. In: Pronatura PenÍnsula de Yucatán AC. Informe Final SNIB-CONABIO, N° M126. México, D.F..

Araújo, M.S.L.C., Calado, T.C.S., 2008. Bioecologia do caranguejo-uçá Ucides cordatus (Linnaeus) no complexo estuarino lagunar Mundáu/Manguaba (CELMM) Alagoas, Brasil. Revista Da GestÃo Costeira Integrada 8 (2), 169–181. http://dx.doi.org/10.5894/rgci141.

Araújo, M.S.L.C., Castiglioni, D.S., Coelho, P.A., 2012. Width-weight relationship and condition factor of ucides cordatus (Crustacea, Decapoda, Ucididae) at tropical Mangroves of northeast Brazil. Iheringia, SÉrie Zool. 102 (3), 277–284. http://dx.doi.org/10.1590/S0073-47212012000300005.

Araújo, M., Lira, J., 2012. Condition factor and carapace width versus wet weight relationship in the swimming crab Callinectes danae Smith 1869 (Decapoda: Portunidae) at the Santa Cruz channel, Pernambuco state, Brazil. Nauplius 20, 41–50, https://www.scielo.br/j/nau/a/cbbXRmDhpYcZvdcrSVDMkcN/?lang=en.

Baptista, C., Pinheiro, M.A.A., Blankesteiyn, A., Borzone, C.A., 2003. Estrutura populacional de Callinectes ornatus Ordway (Crustacea, Portunidae) no Balneário Shangri-lá, Pontal do Paraná, Paraná, Brasil. Revista Brasileira de Zool. 20 (4), 661–664. http://dx.doi.org/10.1590/S0101-81752003000400018.

Baptista-Metri, C., Pinheiro, M.A.A., Blankesteiyn, A., Borzone, C.A., 2005. Biologia populacional e reproductiva de Callinectes danae Smith (Decapoda: Portunidae) no Balneário Shangrí-lá, Pontal do Paraná, Paraná, Brasil. Revista Brasileira de Zool. 22, 446–453. http://dx.doi.org/10.1590/S0101-81752005000200022.

Bello, G., Zupa, R., Corriero, A., 2015. Ontogenetic change in the body length–mass relationship concomitant to the onset of vitellogenesis in female blackmouth catshark Galeus melastomus (Chondrichthyes: Scyliorhinidae). Ital. J. Zool. 82 (3), 358–365. http://dx.doi.org/10.1080/11250003.2015.1027308.

Boothby, R.N., Avault, Jr., J.W., 1971. Food habits, length-weight relationship, and condition factor of the red drum (Sciaenops ocellata) in southeastern Louisiana. Trans. Am. Fish. Soc. 100 (2), 290–295.

Botelho, E.R.O., Dias, A.F., Ivo, C.T., 1999. Estudo sobre a biologia do caranguejo-uçá, Ucides cordatus (Linnaeus, 1763), capturado nos estuários dos Rios Formoso (Rio Formoso) e Ilhetas (Tamandaré), no Estado de Pernambuco. Boletim TÉcnico CientÍfico Do CEPENE 7, 117–145.

Branco, J.O., 1993. Aspectos bioecológicos do caranguejo Ucides cordatus (Linnaeus 1763) (Crustacea, Decapoda) do manguezal do Itacorubi, Santa Catarina, BR. Arquivos de Biol. E Tecnol. 36 (1), 133–148.

Branco, J.O., Fracasso, H.A.A., 2004. Biologia populacional de Callinectes ornatus (Ordway) na Armação do Itapocoroy, Penha, SC. Revista Brasileira de Zool. Curitiba 21 (1), 91–96. http://dx.doi.org/10.1590/S0101-81752004000100016.

Branco, J.O., Lunardon-Branco, M.J., 1993. Aspectos da biologia de Callinectes ornatus Ordway, 1863 (Decapoda, Portunidae) da região de Matinhos, Paraná, Brasil. Arquivos de Biol. E Tecnol. 36 (3), 489–496.

Branco, J.O., Masunari, S., 1992. Crescimento de Callinectes danae (Decapoda: Portunidae) da lagoa da Conceição, Florianápolis, Santa Catarina, Brasil. Revista Brasileira de Zool. 9 (1–2), 53–66. http://dx.doi.org/10.1590/S0101-81751992000100008.

Branco, J.O., Thives, A., 1991. Relação peso/largura, fator de condição e tamanho de primeira maturação de Callinectes danae Smith 1869 (Crustacea, Portunidae) no manguezal do Itacorubi, SC, Brasil. Arquivos de Biol. E Tecnol. 34, 415–424.

Carlander, K.D., 1969. Handbook of Freshwater Fishery Biology. The Iowa State University Press Ames, IA. 1, 752.

Castillo, J., Eslava, N., Gonzalez, L.W., 2011. Crecimiento del cangrejo Callinectes danae (Decapoda: Portunidae) de la Isla de Margarita, Venezuela. Revista BiologÍa Trop. 59 (4), 1525–1535. http://dx.doi.org/10.15517/RBT.V59I4.3417.

Escobar M.R. Giraldo, J.O., 1993. Evaluación de la Captura de Jaibas (Género Callinectes) Con Nasas Y Otras Artes, En la CiÉnaga Grande de Santa Marta, Caribe Colombiano. Universidad del Magdalena, Santa Marta, p. 187.

Eslava, N., González, L.W., Guevara, F., Quijada, I., 2019. Parámetros poblacionales del cangrejo Callinectes danae (Decapoda: Portunidae) de La Isleta, isla de Margarita, Venezuela. Revista CientÍfica. FVC-Luz. 29 (3), 221–230, https://produccioncientificaluz.org/index.php/cientifica/article/view/32414.

Ewers-Saucedo, C., 2019. Evaluating reasons for biased sex ratios in Crustacea. Inverteb. Reprod. Dev. 22, 2–230. http://dx.doi.org/10.1080/07924259.2019.1588792.

Fassatoui, C., Hatira, S., Romdhane, M.S., 2021. Size-weight relationships and condition factor of the invasive Atlantic blue crab Callinectes sapidus Rathbun, 1896 (Decapoda: Brachyura: Portunidae) from northern Tunisia: A preliminary investigation. J. Crustacean Biol. 41 (3), ruab039. http://dx.doi.org/10.1093/jcbiol/ruab039.

Froese, R., 2006. Cube law, condition factor and weight–length relationships: History, meta-analysis and recommendations. J. Appl. Ichthyol. 22, 241–253. http://dx.doi.org/10.1111/j.1439-0426.2006.00805.x.

Froese, R., Tsikliras, A.C., Stergiou, K.I., 2011. Editorial note on weight-length relations of fishes. Acta Ichthyol. Et Piscatoria 41, 261–263. http://dx.doi.org/10.3750/AIP2011.41.4.01.

Góes, P., Branco, J.O., Pinheiro, M.A.A., Barbieri, E., Costa, D., Fernandes, L.L., 2010. Bioecology of the uçá-crab, Ucides cordatus (Linnaeus, 1763), in Vitória Bay, Espírito Santo State, Brazil. Braz. J. Oceanogr. 58 (2), 153–163.

Golodne, P.M., Matos, M.C.O., Vianna, M., 2010. On the population structure of Callinectes danae and Callinectes ornatus (Decapoda, Portunidae), in Guanabara Bay, Rio de Janeiro State, Brazil. AtlÂntica (Rio Grande) 32 (2), 151–161. http://dx.doi.org/10.5088/atlantica.v32i2.2457.

Haefner, Jr., P.A., 1990. Morphometry and size at maturity of Callinectes ornatus (Brachyura, Portunidae) in Bermuda. Bull. Mar. Sci. 46 (2), 264–286.

Hartnoll, R.G., 1985. Growth, sexual maturity and reproductive output. In: Wenner, A.M. (Ed.), Factors in Adult Growth. Balkema, Rotterdam, The Netherlands, pp. 101–128.

Hartnoll, R.G., 2006. Reproductive investment in Brachyura. Hydrobiologia 557, 31–40. http://dx.doi.org/10.1007/s10750-005-9305-6.

Hines, A.H., Johnson, E.G., Young, A.C., Aguilar, R., Kramer, M.A., Goodison, M., Zmora, O., Zohar, Y., 2008. Release strategies for estuarine species with complex migratory life cycles: Stock enhancement of Chesapeake blue crabs. Rev. Fish. Sci. 16 (1–3), 175–185. http://dx.doi.org/10.1080/10641260701678090.

Johnston, D.J., Yeoh, D.E., 2020. Carapace width-weight relationships of blue swimmer crab Portunus armatus (A.) (Crustacea: Brachyura: Portunidae) in southwestern Australia: influences of sex, decadal change, environment, and season. J. Crustacean Biol. 40 (5), 526–533. http://dx.doi.org/10.1093/jcbiol/ruaa046.

Jones, J.B., Pierce, G.J., Saborido-Rey, F., Brickle, P., Kuepper, F.C., Zhanna N. Shcherbich, Z.N., Arkhipkin, A.I., 2019. Size-dependent change in body shape and its possible ecological role in the Patagonian squid (Doryteuthis gahi) in the southwest Atlantic. Mar. Biol. 166, 54. http://dx.doi.org/10.1007/s00227-019-3501-9.

Kotiaho, J.S., Simmons, L.W., 2003. Longevity cost of reproduction for males but no longevity cost of mating or courtship for females in the male-dimorphic dung beetle Onthophagus binodis. J. Insect Physiol. 49, 817–822.

Kristensen, E., 2008. Mangrove crabs as ecosystem engineers; With emphasis on sediment processes. J. Sea Res. 59, 30–43. http://dx.doi.org/10.1016/j.seares.2007.05.004.

Le Cren, E.D., 1951. The length–weight relationship and seasonal cycle in Gonad weight and condition in the perch (Perca fluviatilis). J. Anim. Ecol. 20 (2), 201–219.

Leite, M.M.L., Ogawa, C.Y., Rezende, C.F., Silva, J.R.F., 2014. Temporal variation in the weight-size relationship of the mangrove crab ucides cordatus L. (Decapoda: Ucididae) in relation to its life cycle phases. Animal Biol. 64, 333–342. http://dx.doi.org/10.1163/15707563-00002451.

Lira, J.J.P.R., Calado, T.C.S., Araújo, M.S.L.C., 2012. Condition factor of Goniopsis cruentata (Crustacea, Brachyura, Grapsidae) from Mundaú/Manguaba estuarine complex, Alagoas Brazil. Iheringia, SÉrie Zoologia 102 (3), http://dx.doi.org/10.1590/S0073-47212012005000001.

Mantelatto, F.L.M., Martinelli, J.M., 1999. Carapace width-weight relationships of Callinectes ornatus (Brachyura, Portunidae) from Ubatuba, bay Brazil. Iheringia, SÉrie Zool. 87, 111–116.

Mantellato, F., Garcia, R., 2001. Biological aspects of the nonindigenous portunid crab (Charybdis hellerii) in the western tropical south Atlantic. Bull. Mar. Sci. 68 (3), 469–477.

Moraes, E.E.B., Nunesmaia, B.J.B., Pinheiro, M.A.A., 2015. Population biology of 'uçá' crab, Ucides cordatus (Linnaeus, 1763) (Brachyura: Ucididae), in mangroves of the Joanes River, Bahia state, Brazil. Nauplius 23, 59–71. http://dx.doi.org/10.1590/S0104-64972015002309.

Moreno, C., Graziani, C., Nunez, J.G., Villaroel, E., 2011. Caracterización bioecológica y poblacional de tres comunidades de crustáceos decápodos en la costa Noroccidental del estado Sucre, Venezuela. Zootecnia Trop. 29 (1), 29–47, https://hdl.handle.net/1807/64526.

Navarro-Ojeda, N.A., Cuesta, J.A., González-Ortegón, E., 2022. Population structure of the stone crab Xantho poressa (Olivi, 1792) in a human-restricted access area. Reg. Stud. Mar. Sci. 53, 102375. http://dx.doi.org/10.1016/j.rsma.2022.102375.

Ogburn, M.B., 2019. The effects of sex-biased fisheries on Crustacean sex ratios and reproductive output. Invertebr. Reprod. Dev. 63 (3), 200–207. http://dx.doi.org/10.1080/07924259.2019.1612787.

Oliveira, R.R.S., Oliveira, D.B., Cordeiro, A.P.B., Cintra, I.H.A., Klautau, A.G.C.M., 2022. Carapace width/length-weight relationships for portunid crabs (genus Callinectes Stimpson, 1860) in northern Brazilian mangrove estuaries. Nauplius 30, http://dx.doi.org/10.1590/2358-2936e2022011.

Palomares, M.L.D., Pauly, D. (Eds.), 2022. SeaLifeBase. World Wide Web electronic publication, www.sealifebase.org, version (04/2022).

Pereira, M., Branco, J., Christoffersen, M., Freitas, F., Fracasso, H., Pinheiro, T., 2009. Population biology of Callinectes danae and Callinectes sapidus (Crustacea: Brachyura: Portunidae) in the south-western Atlantic. J. Mar. Biol. Assoc. United Kingdom 89 (7), 1341–1351. http://dx.doi.org/10.1017/S0025315409000605.

Pereira-Barros, J.B., Travassos, I., 1975. Informes Sobre a Pesca E Biologia Do Siri Tinga (Callinectes Danae) E GuajaÚ (Callinectes Bocourti), Na Lagoa MundaÚ, MaceiÓ, Alagoas. SuperintendÊncia Do Desenvolvimento Do Nordeste - SUDENE. Departamento de Recursos Pesqueiros, Recife, Brasil, p. 9.

Pescinelli, R.A., Freitas, Jr., F., Costa, R.C., Hilesheim, J.C., Dieh, F.L., Branco, J.O., 2021. Assessment of population biology, size-weight relationship, condition factor, and spatial distribution of the Mangrove crab ucides Cordatus (Crustacea: Ocypodidae) in southern Brazil. Acta Zool. 1–11. http://dx.doi.org/10.1111/azo.12412.

Pinheiro, M.A.A., Fiscarelli, A.G., 2009. Length-weight relationship and condition factor of the Mangrove crab ucides cordatus (Linnaeus, 1763) (Crustacea, Brachyura, Ucididae). Braz. Arch. Biol. Technol. 52 (2), 397–406. http://dx.doi.org/10.1590/S1516-89132009000200017.

Pinheiro, M.A.A., Fransozo, A., 1999. Reproductive behavior of the swimming crab Arenaeus cribarius (Lamarck, 1818) (Crustacea, Brachyura, Portunidae) in captivity. Bull. Mar. Sci. 64 (2), 243–253.

Punt, A.E., Huang, T., Maunder, M.N., 2013. Review of integrated size-structured models for stock assessment of hard-to-age Crustacean and Mollusc species. ICES J. Mar. Sci. 70 (1), 16–33. http://dx.doi.org/10.1093/icesjms/fss185.

R Core Team, 2022. R: A language and environment for statistical computing. In: R Foundation for Statistical Computing. Vienna, Austria, https://www.R-project.org/.

Reis, C.R.G., Taddei, F.G., Cobo, V.J., 2015. Growth and reproduction of the Mangrove crab Goniopsis Cruentata (Latreille, 1803) (Crustacea: Decapoda: Grapsidae) in southeastern Brazil. Anais Da Acad. Brasileira de CiÊncias 87, 699–711. http://dx.doi.org/10.1590/0001-3765201520130387.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Canada 191, 1–382.

Rocha, C.H.S., Lima, T.B., 2020. Biometric differences in ucides Cordatus (Linnaeus, 1763) (Crustacea; Brachyura; Ocypodidae) as an indicative of environmental stress. Revista Ibero Americana de CiÊncias Ambientais 11 (2), 228–235. http://dx.doi.org/10.6008/CBPC2179-6858.2020.002.0024.

Rudershausen, P.J., Merrell, J.H., Buckel, J.A., 2021. Factors influencing colonization and survival of Juvenile Blue Crabs Callinectes sapidus in southeastern U.S.. Tidal Creeks Divers. 13 (491), http://dx.doi.org/10.3390/d13100491.

Santos, M.C.F., Botelho, E.R.O., Corrêa, F.M., Almeida, L., da Silva, C.G.M., 2013. Aspectos populacionais do aratu Goniopsis cruentata (Latreille, 1803) (Decapoda, Grapsidae) no manguezal de Caravelas (Bahia – Brasil). Boletim TÉcnico E CientÍfico Do CEPENE 19 (1), 27–36.

Santos, M.D.C.F., Dagoberto, P.O.R.T., Fisch, F., Barbieri, E., Branco, J.O., 2016. Biologia populacional de Callinectes ornatus associada à pesca do camarão-sete-barbas, rio São Francisco (Alagoas e Sergipe, Brasil). Boletim Do Instituto de Pesca 42 (2), 449–456. http://dx.doi.org/10.20950/1678-2305.2016v42n2p449.

Scalco, A.C.S., 2012. Dinâmica Populacional e avaliação de estoques de Callinectes danae Smith, 1869 (Decapoda: Portunidae) no Estuário de Santos-São Vicente, SP, Brasil. In: DissertaçÃo (Mestrado Em Aquicultura E Pesca). Instituto de Pesca, p. 70.

Severino-Rodrigues, E., Fernandes-Musiello, J., Moura, A.A.S., Branco, G.M.P., Canéo, O.C., 2012. Biologia reprodutiva de fêmeas de Callinectes danae (Decapoda, Portunidae) no complexo estuarino-lagunar de Iguape e Cananéia (SP). Boletim Do Instituto de Pesca 38 (1), 31–41, https://www.pesca.agricultura.sp.gov.br/38_1_31-41.pdf.

Severino-Rodrigues, E., Pita, J.B., Graça-Lopes, R., 2001. Pesca artesanal de siris (Crustacea, Decapoda, Portunidae) na região estuarina de Santos e São Vicente (SP), Brasil. Boletim Do Instituto de Pesca 27, 7–19.

Shinozaki-Mendes, R.A., Lessa, R., 2017. Population dynamics of Callinectes Danae Smith, 1869 (Brachyura: Portunidae) in a tropical estuary. J. Crustacean Biol. 37 (6), 683–692. http://dx.doi.org/10.1093/jcbiol/rux078.

Torres, M.A., Vila, Y., Silva, L., Acosta, J.J., Ramos, F., Palomares, M.L.D., Sobrino, I., 2017. Length–weight relationships for 22 Crustaceans and cephalopods from the Gulf of Cadiz (SW Spain). Aquat. Living Resour. 30 (12), http://dx.doi.org/10.1051/alr/2017010.

Tudesco, C.C., Fernandes, L.P., Di Beneditto, A.P.M., 2012. Population structure of the crab Callinectes ornatus ordway, 1863 (Brachyura: Portunidae) bycatch in shrimp fishery in northern Rio de Janeiro state, Brazil. Biota Neotropica 12 (1), http://dx.doi.org/10.1590/S1676-06032012000100007.