# Condition factor of *Goniopsis cruentata* (Crustacea, Brachyura, Grapsidae) from Mundaú/Manguaba estuarine complex, Alagoas, Brazil

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**ABSTRACT.** The condition factor is a parameter which acts as a general indicator of the "well-being" of a species, and it can be obtained through the analysis of width *vs.* weight relationships. The present work aims to investigate size *vs.* weight relationship and the condition factor of the crab *Goniopsis cruentata* (Latreille, 1803). The study area was the Mundaú/Manguaba estuarine complex, Maceió, state of Alagoas, Northeast Brazil. Samplings were monthly accomplished from August 2007 to July 2008. A total of 626 individuals were analyzed, being 309 males and 317 females. Males were larger and heavier than females, what is expected in many brachyuran. The growth was positive allometric to both males (b = 3.42) and females (b = 3.30), not obeying the "cube law". The condition factor of female was higher than that of male crabs, probably due to the gonad weight of females. It also varied seasonally for both sexes, being higher in the autumn and winter in males, and in the autumn and spring in females, and related to the molt and period of spawning intensification.

**KEYWORDS.** Crab, growth, sexual dimorphism, mangrove forest, Northeast Brazil.

**RESUMO. Fator de condição de *Goniopsis cruentata* (Crustacea, Brachyura, Grapsidae) do complexo estuarino Mundaú/Manguaba, Alagoas, Brasil.** O fator de condição é um parâmetro que age como um indicador geral do "bem-estar" de uma espécie e pode ser obtido através da análise da relação largura-peso. O presente trabalho visa investigar a relação tamanho *vs.* peso e o fator de condição do caranguejo *Goniopsis cruentata* (Latreille, 1803). A área de estudo foi o complexo estuarino Mundaú/Manguaba, Maceió, estado de Alagoas, Nordeste do Brasil. As amostragens foram realizadas mensalmente de agosto de 2007 a julho de 2008. Um total de 626 indivíduos foi analisado, sendo 309 machos e 317 fêmeas. Os machos foram maiores e mais pesados que as fêmeas, o que é esperado em muitas espécies de braquiúros. O crescimento foi alométrico positivo tanto para machos (b = 3,42) quanto para fêmeas (b = 3,30), não obedecendo a "regra do cubo". O fator de condição da fêmea foi maior do que o dos machos, provavelmente devido ao peso das gônadas das fêmeas. O fator de condição também variou sazonalmente para ambos os sexos, sendo mais elevado no outono e no inverno nos machos, e no outono e primavera nas fêmeas, e estando relacionado à muda e ao período intenso de desova.

**PALAVRAS-CHAVE.** Caranguejo, crescimento, dimorfismo sexual, manguezal, Nordeste do Brasil.

The condition factor is a parameter which acts as an indicator of fatness, general "well-being" of a species and the environment suitability, being correlated to external (availability of food, latitudinal gradient), and internal factors (gonad cycle, rate of feeding and growth, and degree of parasitism) (Le Cren, 1951; Santos, 1978). Since the condition factor is an indicator of the health of an individual, its study is important to evaluate recent nutritional conditions and/or the use of resources in cyclic activities, as reproduction, which allows inferring relationships with environmental conditions and behavioral aspects of the species (Vazzoler, 1996). The condition factor may vary among seasons, gonad cycle and annual differences in environmental conditions (Froese, 2006). It results from different size *vs.* weight relationships obtained in each case.

The equation that best fits the size *vs.* weight relationship is the power function ($y = ax^b$), the same typically used in allometric studies in brachyurans (Le Cren, 1951; Atar & Seçer, 2003; Branco & Fracasso, 2004). The constant *a* represents the degree of fattening (condition factor), the coefficient *b* means the weight gain, *y* is the dependent variable, the weight, and *x* the independent variable, the size (Pinheiro & Fiscarelli, 2009).

The coefficient *b* expresses how size and weight are related to each other. According to Froese (2006), if $b = 3$, then small specimens have the same form and condition as large specimens; when $b > 3$, large specimens may presents ontogenetic changes in body shape with size, which is rare, or they are fatter than small specimens, which is not uncommon; in the case of $b < 3$, large specimens may have changed their body shape to become more elongated or small specimens are in better nutritional condition. These types of weight increase are termed isometric, positive and negative allometric, respectively (Hartnoll, 1982). In the case of isometry, the organism maintains the same shape along its development, meeting the cube law (Le Cren, 1951), but it rarely occurs (Froese, 2006).

The cube law states that when the humid weight (HW) of an animal is related with its size, a tridimensional variable is compared to a linear one. The weight is three-dimensional because it depends of the length, width and height, while the carapace width (CW) is one-dimensional. Due to this, in the relation HW *vs.* CW, the value of *b* is isometric when equal to tree, as well as allometric, when *b* differs from three (Le Cren, 1951; Froese, 2006; Ahmad Dar *et al.*, 2012).

The width-weight relationships are important topics for the study of species with commercial value (Le Cren, 1951; Froese, 2006; Mohapatra *et al.*, 2010), since they allow the measurement of the condition factor. It has been commonly applied to fish (Le Cren, 1951; RAKITIN *et al.*, 1999; DUTIL *et al.*, 2003; FROESE, 2006), and crustacean species (RODRÍGUEZ, 1987; BRANCO & THIVES, 1991; ATAR & SEÇER, 2003; BRANCO & FRACASSO, 2004; MIYASAKA *et al.*, 2007; PINHEIRO & FISCARELLI, 2009; MOHAPATRA *et al.*, 2010).

*Goniopsis cruentata* (Latreille, 1803) (Brachyura, Grapsidae) is a mangrove crab typically found in mangrove forests, wandering on the substratum above the tide level, burrows of other crabs, crevices and climbing in mangrove trees, practically occupying all microhabitats in the mangrove ecosystem (COBO & FRANSOZO, 2003). According to MELO (1996), *G. cruentata* distribution ranges from Bermudas to Brazil (Western Atlantic) (MELO, 1996), and from Senegal to Angola (Eastern Atlantic), also occurring in the Panama Pacific coast (ABELE & KIM, 1989). This species has socio-economic importance, especially in the Northeast of Brazil (SILVA & OSHIRO, 2002), being used in the regional culinary. Some papers were accomplished with this species, dealing on aspects as fecundity (COBO & FRANSOZO, 2000; SILVA & OSHIRO, 2002; MOURA & COELHO, 2003), reproductive period (COBO & FRANSOZO, 2000, 2003), sexual maturity (MOURA & COELHO, 2004; COBO & FRANSOZO, 2005), histology of the gonads (GARCIA & SILVA, 2006, 2009; SOUZA & SILVA, 2009), population ecology (MOURA *et al.*, 2000; SOUSA *et al.*, 2000; SANTOS *et al.*, 2001; SANTOS & BOTELHO, 2002; BOTELHO *et al.*, 2004), relative growth (COBO & FRANSOZO, 1998), and ionic regulation (ZANDERS, 1978), for example. However, no study was accomplished dealing on the condition factor of this species.

The present work aims to investigate size *vs.* weight relationship and the condition factor of the crab *Goniopsis cruentata*, as well as sexual and seasonal variations of this parameter.

## MATERIALS AND METHODS

**Sampling area**. The study was conducted in the Mundaú/Manguaba estuarine complex, City of Maceió, state of Alagoas, Northeast Brazil (35°42'30" – 35°57'00"W and 9°35'00" – 9°45'00"S). The area shows tropical climate, with an annual mean temperature of 25°C and an annual mean rainfall of 1,504 mm³ (data provided by the Secretaria Executiva para o Meio Ambiente e Recursos Hidrológicos e Naturais – SEMARHN, state of Alagoas). Two periods are observed at the region, according to the rainfall and temperature: the rainy period, from March to August, and the dry period, from September to February. The salinity of the area is a parameter of high variability, both seasonal and spatially, varying from 0.16 to 28 (CALADO & SOUSA, 2003; ARAÚJO & CALADO, 2008). The texture of the sediment of the area varies from muddy to muddy sand.

**Field and laboratory procedures**. Samplings were monthly accomplished from August 2007 to July 2008 by three collectors in four regions of a mangrove forest, to maximize the number of collected individuals, with a catch effort of 50 minutes for each region. Unfortunately, data were not collected in April due to logistic impossibilities: the motor-boat used to reach the sites was broken. These regions were chosen taking into account the accessibility and the abundance of the species. For the statistical analysis, the data were grouped, since apparently there was no difference among the sampling stations.

The crabs were manually captured in low tide. Mud balls were done with the mangrove soil and shoot on the visualized specimens to immobilize them, making their collection easier. The captured crabs were put into containers with alcohol 70% concentrated. The captured crabs were sexed by abdomen morphology: in the case of females, the abdomen is round shaped and in the males it is triangular shaped (SANTOS *et al.*, 2001). The carapace width (CW) and humid weight (HW) were obtained in both sexes with a caliper (0.05 mm) and a precision balance (0.01 g), respectively. The individuals with regenerating limbs and in molt were discarded to avoid bias. After the analysis, the ovigerous females were separated for fecundity studies.

**Data analyses**. All statistical analyses were performed at 5%. The normality of the data was verified through a Shapiro-Wilk test, and the variances, through a Bartlett test. A Student $t$ test was applied to compare the CW and HW between sexes (ZAR, 1996).

The relationship of weight in function of size in *G. cruentata* was determined for the total number of individuals of each sex through the allometric equation $HW = aCW^{b}$, where HW is the humid weight, CW is the carapace width, $b$ is the slope, and $a$ the intercept (PINHEIRO & FISCARELLI, 2009). The fit was evaluated by the coefficient of determination ($r^2$). The residues were analyzed by visual inspection, to remove outliers. The data was log-transformed and a linear function was applied. An analysis of covariance (ANCOVA) was used to compare the slopes and intercepts of the lines between sexes, to verify the possibility of grouping males and females by the same equation. The type of weight increase was defined by the coefficient b (isometric, $b = 3$; positively allometric, $b > 3$; and negatively allometric, $b < 3$). To evaluate if $b$ differs significantly from 3, a $t$ test was applied. It meets the "cube law" to size *vs.* weight relationship (LE CREN, 1951).

The total condition factor was calculated for each sex by the formula $a = HW/CW^{b}$ (LE CREN, 1951; PINHEIRO & FISCARELLI, 2009), where HW is the humid weight, CW is the carapace width, $b$ is the slope, and $a$ is the condition factor. This formula was also applied by months and seasons of the year (Summer = January to March; Autumn = April to June; Winter = July to September; and Spring = October to December) for each sex.

Since the data was heterocedastic, the Mann-

Whitney-Wilcoxon test was applied to compare the total condition factor between males and females, and the non-parametric test of Kruskal-Wallis compared the condition factor of each sex between seasons of the year, followed by Dunn's *a posteriori* test, when significant differences were found ($\alpha = 0.05$) (Zar, 1996).

## RESULTS

A total of 626 individuals of *Goniopsis cruentata* were analyzed, being 309 males and 317 females. The males were larger ($p = 0.04$; $t = 2.04$) and heavier ($p = 0.0002$; $t = 3.85$) than the females (Tab. I).

The slopes and intercepts of the regression lines (Fig. 1) differed between sexes ($p = 0.0001$), showing sexual dimorphism in the growth of weight in function of width of *G. cruentata.* This relationship was positive allometric to both males ($b = 3.42$; $t > 1.96$) and females ($b = 3.30$; $t > 1.96$) (Fig. 1; Tab. II).

The minimum, maximum and mean values of condition factor of the total males and females are presented in the Tab. III. The condition factor of the females was higher than that of males ($U = 926.5$; $p = 0.0001$). Comparing months, the condition factor varied for both males and females (Fig. 2). Regarding seasons, it also varies for both sexes (Fig. 3), being higher in the autumn and winter in males ($H = 87.79$; $p = 0.0001$), and in the autumn and spring in females ($H = 36.55$; $p = 0.0001$).

## DISCUSSION

Both size and weight differed between the sexes in the present population, with males being larger and heavier than females, what is expected for the species (Botelho *et al.*, 2004), and in many brachyuran (Branco & Thives, 1991; Baptista *et al.*, 2003; Baptista-Metri *et al.*, 2005; Pinheiro & Hattori, 2006; Pinheiro & Fiscarelli, 2009). Therefore, this species shows differential growth rate between sexes. Males, as their reproductive effort, direct energy to body increase, which allows copulation, and a greater probability of leaving descendents. It may also be related to the chelae waving as the courtship behavior of *Goniopsis cruentata*, observed by Hartnoll (1969) – larger males may be seen as best partners by females. On the other hand, females invest a larger portion of energy into the development of the gonads and the production of eggs (Kotiaho & Simmons, 2003), leading to a differential growth rate between both sexes (Wenner, 1972; Díaz & Conde, 1989). Individuals that invest more energy into reproduction may have less energy to invest into their somatic growth (Ferkau & Fischer, 2006). Hence, females cannot attain greater sizes than males do. The investment in the production of gametes and yolked eggs, and in the parental care is called costs of reproduction (Reznick, 1985; Fernández *et al.*, 2000; Ferkau & Fischer, 2006), in which there is a "trade off" among different components of the organism life history (Reznick, 1985).

Males were also heavier than females, what may be caused by the direct relation of the weight with size, as can be observed in many crabs (Kowalczuk & Masunari, 2000; Baptista *et al.*, 2003; Branco & Fracasso, 2004; Myiasaka *et al.*, 2007; Pinheiro & Fiscarelli, 2009) – since males attain greater sizes, they are heavier. Males being heavier may allow them to catch the female easily and to copulate more successfully. According to Pinheiro & Fiscarelli (2009), whom studied the crab *Ucides cordatus* (Linnaeus, 1763) (Ucididae), the higher weight of males can be attributed to the positive allometric growth of the chelae.

In both sexes the weight grew allometrically positive in relation to size ($b > 3$), not obeying the "cube law". Actually, this law is not commonly observed in

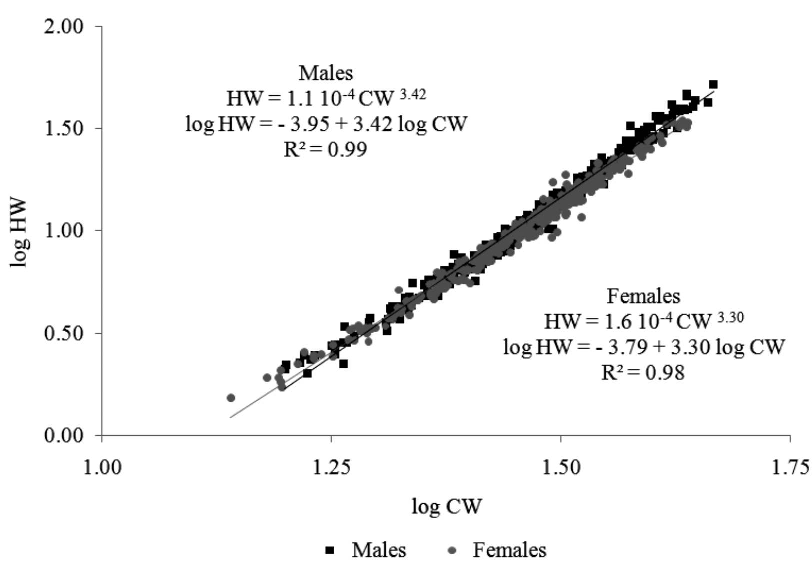


Fig. 1. Regression lines to the carapace width *vs.* humid weight relationship in male and female of *Goniopsis cruentata* (Latreille, 1803) crabs, with the potency equation and the determination coefficient r².

Tab I. Minimum, maximum and mean values of carapace width (mm) and weight (g) to both males and females of *Goniopsis cruentata* (Latreille, 1803) crabs (sd, standard deviation; *, significant differences between the sexes).

| | Carapace width (mm) | | Humid weight (g) | |
|---|---|---|---|---|
| | Males | Females | Males | Females |
| Minimum | 14.80 | 12.80 | 1.02 | 0.53 |
| Maximum | 45.35 | 42.45 | 51.05 | 33.72 |
| Mean ± sd | 28.93 ± 6.64* | 27.89 ± 6.09* | 13.49 ± 10.22* | 10.78 ± 7.05* |

Tab. II. Linear equation, $r^2$, and results of the ANCOVA for regression coefficients (b) in the relation CW *vs.* HW of *Goniopsis cruentata* (Latreille, 1803) crabs (*, significant differences between the regression lines for males and females).

| Sex | n | Linear equation | $r^2$ | ANCOVA b | *p* |
|---|---|---|---|---|---|
| Male | 309 | log HW = -4.0 + 3.24 log CW* | 0.99 | 14.05 | 0.0001 |
| Female | 317 | log HW = -3.7 + 3.30 log CW* | 0.98 | | |

Tab. III. Minimum, maximum and mean values of the condition factor to both males and females of *Goniopsis cruentata* (Latreille, 1803) crabs (sd, standard deviation; *, significant differences between the sexes).

| Sex | Condition factor | | |
|---|---|---|---|
| | Minimum | Maximum | Mean ± sd |
| Males | $0.72 \times 10^{-4}$ | $1.4 \times 10^{-4}$ | $1.1 \times 10^{-4} \pm 0.09 \times 10^{-4}$ * |
| Females | $1.0 \times 10^{-4}$ | $2.1 \times 10^{-4}$ | $1.6 \times 10^{-4} \pm 1.4 \times 10^{-4}$ * |

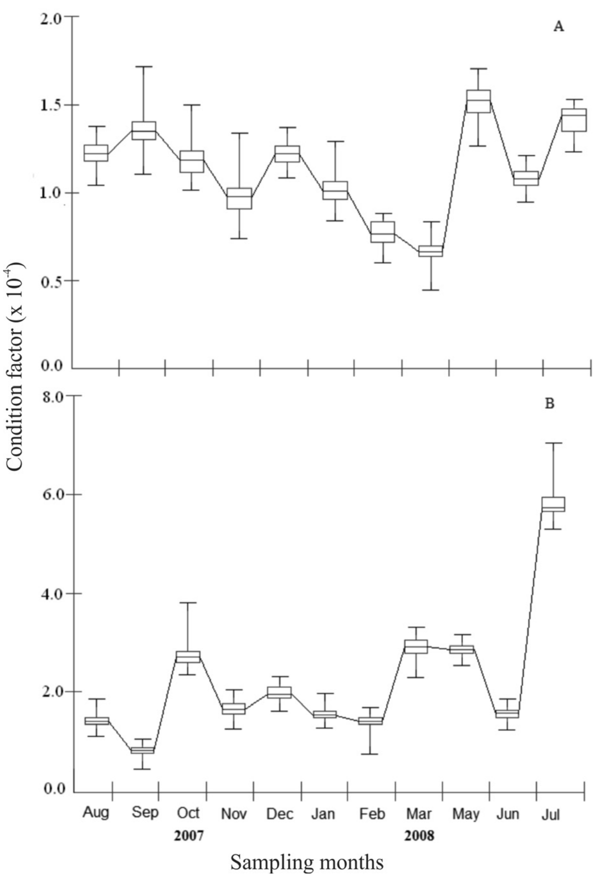


Fig. 2. Median, quartiles and the standard deviation of the monthly condition factor of males (A) and females (B) of *Goniopsis cruentata* (Latreille, 1803).

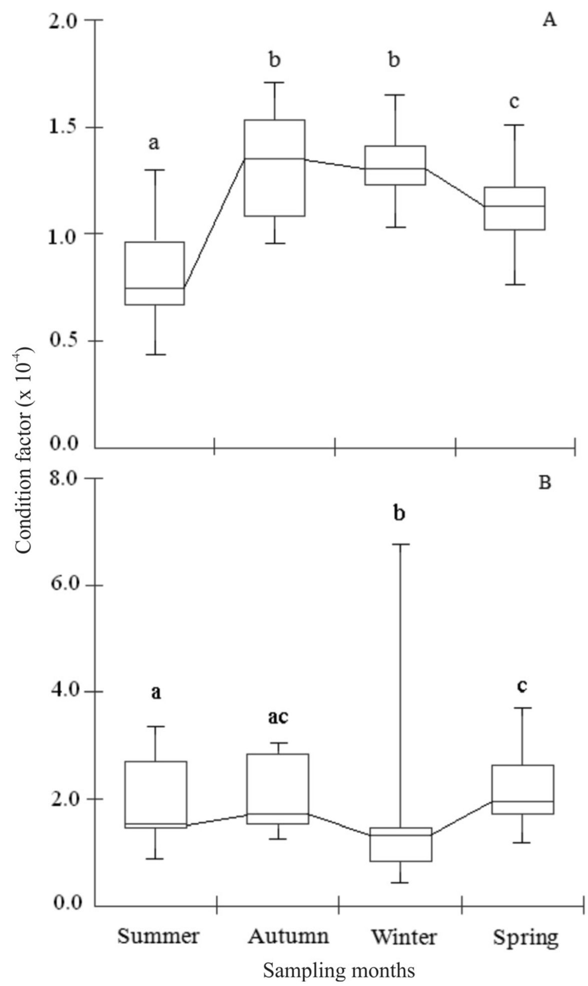


Fig. 3. Median, quartiles and the standard deviation of the condition factor to each season of males (A) and females (B) of *Goniopsis cruentata* (Latreille, 1803).

natural populations due to changes in shape along the organism growth (LE CREN, 1951; PINHEIRO & TADDEI, 2005). These changes occur typically among crustaceans (HARTNOLL, 1982, 2001), being also observed in *G. cruentata* (COBO & FRANSOZO, 1998). This fact may explain the weight growing faster than size.

The regression coefficients of both males and females of the present study for the relation HW *vs.* CW were in accordance with the established for aquatic organisms, between two and four (LE CREN, 1951). Such amplitude gives indicatives of changes in weight of the organisms between different phases of development and in the beginning of the first sexual maturation (MANTELATTO & FRANSOZO, 1992; PINHEIRO & FRANSOZO, 1993). This was also observed in the swimming crabs *Callinectes ornatus* Ordway, 1863 (BRANCO & FRACASSO, 2004; Baptista-Metri *et al*., 2005) and *C. danae* Smith, 1869 (Portunidae) (Branco *et al*., 1992; Baptista-Metri *et al*., 2005), in the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 (Trichodactylidae) (Pinheiro & Taddei, 2005), in the shrimp *Melicertus kerathurus* (Forskål, 1775) (Penaeidae) (Rodríguez, 1987). This result, and those of *Armases angustipes* (Dana, 1852) (Sesarmidae) (Kowalczuk & Masunari, 2000) and *U. cordatus* (Pinheiro & Fiscarelli, 2009), allow inferring that this rule may be extended to semi-terrestrial crabs.

The constant *b* of increase in weight was higher in males, what is commonly observed among crustaceans (Branco & Thives, 1991; Pinheiro & Fransozo, 1993; Kowalczuk & Masunari, 2000; Branco & Fracasso, 2004; Myiasaka *et al*., 2007; Mohapatra *et al*., 2010), and also observed in fishes (Liao & Chang, 2011). This difference may be a result of differential diet and higher index of feeding; additionally, the androgen gland improves the weight of the crab after maturity, leading to higher *b* values in males (Bliss, 1968; Pinheiro & Fiscarelli, 2009). A higher *b* value can also be explained by the fact that males were larger and that weight was positively correlated to size.

This lower regression coefficient of the female *G. cruentata* led to a higher condition factor, what is probably caused by the larger and heavier gonads of the females (Pinheiro & Taddei, 2005). In this study, Pinheiro & Taddei (2005) found that the ovaries were three times larger than the testis of a male with similar size. Pinheiro *et al.* (1999) observed that the condition factor of females of *A. cribrarius* was about 1.2 times larger than that of males, similar to the result observed by Pinheiro & Fiscarelli (2009) for *U. cordatus* (1.5 times) and to *G. cruentata* (1.5 times) in the present study.

In *U. cordatus* the condition factor is higher (Pinheiro & Fiscarelli, 2009) than that of *G. cruentata*, probably due to the larger size attained by this species. *Dilocarcinus pagei*, which is smaller than *U. cordatus*, presents values more similar to those of *G. cruentata* (Pinheiro & Taddei, 2005), showing that the size is also an important feature influencing the condition factor.

The condition factor of males and females showed seasonal variation, what is largely observed among crustaceans (Pinheiro & Taddei, 2005; Pinheiro & Fiscarelli, 2009), and fishes (Le Cren, 1951; Dutil *et al*., 2003). There was no clear pattern in the variation of the condition factor among males, but it decreased from November to March, coinciding with the dry season, which was the reproductive period of this species at the area (José J. P. R. Lira, pers. observ.). According to Pinheiro & Taddei (2005), a decrease in the condition factor of males can probably be due to the molt period, which may occur during the summer after copulation with the females. Cobo & Fransozo (2005) observed that the molt of *G. cruentata* occurs in all months of the year, but it is intensified in September, in the dry period, which corroborates the hypothesis that biological activities are favored in the summer (Sastry, 1983; Castiglioni *et al.*, 2010). The higher condition factor during the following seasons (autumn, winter and spring) may be due to the fact that males are in the intermolt period (Pinheiro & Taddei, 2005).

Regarding females, the condition factor was lower from November to February, similar to the males, period of spawning intensification of the species at the area (José J. P. R. Lira, pers. observ.). After spawning, the organism directs energy budget to gonad reorganization (Agostinho *et al*., 1990; Pinheiro & Taddei, 2005), what may explain this lower condition factor in *G. cruentata*. Comparing seasons, this result was clearly evidenced: a lower condition factor was observed during the summer, period of higher occurrence of ovigerous females at the area (José J. P. R. Lira, pers. observ.). The higher condition factor in the autumn may be due to a higher energy intake after the spawning period (Agostinho *et al*., 1990; Pinheiro & Fiscarelli, 2009), as well as in the spring, when females may store energy as a way to intensify the breeding activity during the summer. The lower condition factor in the winter can be a result of the molt period of the females. There is no data in the literature suggesting that males and females molt in different periods of the year. However, since in terrestrial brachyuran crabs growth and reproduction are mutually exclusive events (Hartnoll, 1985), females may molt in the period which breeding is not occurring or occurs in a lower level, as observed for several brachyuran species (Hartnoll, 2006).

According to Branco *et al*. (1992), the condition factor oscillation meets the reproductive activity only in species with seasonal reproduction. Even though *G. cruentata* breeds continuously, with peaks of ovigerous females in certain periods of the year (Silva & Oshiro, 2002; Cobo & Fransozo, 2003), the condition factor seemed to follow the breeding activity in this species.

The results obtained for *G. cruentata* demonstrated that: (1) both sexes of this species showed a positive allometric growth of weight in function of size; (2) males attained greater weight than females of similar size; (3) the condition factor of females was higher than that of males; (4) probably females showed lower condition factor during summer due to the spawning intensification period; (5) apparently the condition factor of males did not evidence any relation with reproductive activity, but probably with the molt.

The condition factor is an important parameter that provides relevant information about the biological activity of the species, being useful to future management of this species, as well as other semi-terrestrial crabs.

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