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Relative growth of the fiddler crab *Uca rapax* (Smith) (Crustacea: Decapoda: Ocypodidae) in a tropical lagoon (Itaipu), Southeast Brazil

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Abstract: The relative growth of the fiddler crab *Uca rapax* from a population of a tropical lagoon system of southeast Brazil was determined. Carapace height (CH), length (LMC) and height (HMC) of the major cheliped of males and abdomen width of females (AW) were employed as dependent variables and carapace width (CW) as independent variable. A total of 634 crabs, 357 males and 277 females, were sampled. The CW of males and females ranged from 2.61 to 21.94 mm (10.30 ± 2.53 SD) and from 2.24 to 18.22mm (9.31 ± 2.23 SD), respectively. The relationship between CW and LMC showed positive allometry in juveniles (logLMC = -0.6634 + 1.857logCW) and negative one in adult males (logLMC = 0.4570 + 0.8465logCW). The females showed allometric positive growth for CW x AW in juveniles (logAW = -0.7485 + 1.4410logCW) and adults (logAW = -0.4222 + 1.3127LogCW) with reduction of the allometry level in the adult phase.

Key words: abdome width, allometry, coast lagoon, major cheliped length, morphometry.

Resumo. Crescimento relativo do caranguejo violinista *Uca rapax* (Smith) (Crustacea: Decapoda: Ocypodidae) em uma laguna tropical (Itaipu), sudeste do Brasil. Uma população do caranguejo violinista *Uca rapax*, proveniente de uma população localizada em uma laguna tropical no sudeste do Brasil, teve seu crescimento relativo estudado. A largura da carapaça foi utilizada como variável independente enquanto que as medidas da altura da carapaça (CH), do comprimento (LMC) e altura (HMC) do maior quelípodo dos machos e do abdome das fêmeas (AW) foram empregadas como variáveis independentes. Foram amostrados um total de 634 crabs, 357 machos e 277 fêmeas. A largura da carapaça de machos e fêmeas variou de 2,61 a 21,94 mm (10,30 ± 2,53 DP) e 2,24 a 18,22mm (9,31 ± 2,23 DP) respectivamente. A relação entre CW e LMC nos machos foi alométrica positiva em juvenis (logLMC = -0.6634 + 1.857logCW) e alométrica negativa em adultos (logLMC = 0.4570 + 0.8465logCW). Nas fêmeas foi observado crescimento alométrico positive na relação CW x AW em juveniles (logAW = -0.7485 + 1.4410logCW) e adultos (logAW = -0.4222 + 1.3127LogCW) com redução do nível de alometria na fase adulta.

Palavras chave: alometria, comprimento do maior quelípodo, largura do abdome, laguna costeira, morfometria.

Introduction

Crabs of the genus *Uca* Leach, 1814 occur in intertidal sheltered zones of tropical and subtropical regions, burrowing in the sediment and feeding on sedimentary organic matter. Their digging activity causes bioturbation that influences the nutrient cycling and promotes transfer of energy and nutrients to nearby estuaries (Colby & Fonseca 1984, Genoni 1991, Castiglioni & Negreiros-Fransozo 2006). Fiddler crabs are important dietary items for a large number of fishes, birds and mammals, being responsible for a significant part of the macrobenthic production in the intertidal zone (Koch *et al*. 2005, Masunari 2006).

Uca are dimorphic animals: while males have one cheliped much larger than the other, in females both chelipeds are small. The major cheliped plays an important role in agonistic behavior and in courtship (Crane 1975). The major cheliped develops until the animal becomes sexually mature (Masunari & Ayoub 2003).

Size and form are closed related to feeding, and habitat occupation, among others ecological features, influencing the fitness of an organism, being the result of evolutionary processes (Peres-Neto 1995). Allometric growth occurs when some part of an animal's body grows at a different rate in relation to a reference dimension, generating changes in body proportions. Some changes are abrupt, marking crucial ontogenetic stages, such as prepuberal or puberal molting (Hartnoll 1978, 1982).

Allometric analysis is a powerful tool for both taxonomists and ecologist interested in intra- and interspecific morphological variation. These kind of analysis have been used to compare intraspecific variations among populations from different locations (e.g. Benneti & Negreiros-Fransozo 2004, Cardoso & Negreiros-Fransozo 2004, Castiglioni & Negrreiros-Fransozo 2004b, García-Dávila *et al*. 2005, Ibáñez-Aguirre *et al*. 2006), and to estimate mid-length sexual maturity, observing variations according to environmental conditions (e.g. Seiple & Salmon 1987, López *et al*. 1997, Pinheiro & Fransozo 1998, Flores & Negreiros-Fransozo 1999, Muiño *et al*. 1999, Flores *et al*. 2002, Colpo & Negreiros-Fransozo 2004, Dalabona *et al*. 2005).

Crustaceans are particularly suited to studies on relative growth due to their hard exoskeleton that facilitates precise body measuring. Also, their type of growth allows unequivocal division of their ontogeny into distinct phases, and exhibits great differences between the growth rates of males and females, and of juveniles and adults (Hartnoll 1978). For brachyuran crustaceans, changes are conspicuous in the male cheliped, female abdomen, and pleopods of both sexes during the transition from the juvenile to the adult stage (Castiglioni & Negreiros-Fransozo 2004b).

Five species of *Uca* have had their relative growth studied in Brazil: *Uca thayeri* Rathbun, 1900 (Negreiros-Fransozo *et al*. 2003); *Uca burgersi* Holthuis, 1967 (Benetti & Negreiros-Fransozo 2004); *Uca rapax* (Smith, 1870) (Castiglioni & Negreiros-Fransozo 2004); *Uca leptodactyla* Rathbun, 1898 (Masunari & Swiech-Ayoub 2003, Cardozo & Negreiros-Fransozo 2004); *Uca maracoani* (Latreille, 1802-1803) (Masunari *et al*. 2005) and *Uca mordax* (Smith, 1870) (Masunari & Disenha 2005).

Uca rapax is one of the most common species of *Uca*, occurring in Florida, the Mexican Gulf, the Caribbean, Venezuela, and Brazil (from Pará to Santa Catarina states). *U. rapax* lives in burrows in muddy and sandy mangrove sediments, along river banks and coastal lagoons (Melo 1996). This work aimed to determine the relative growth of *U. rapax* from Itaipu Lagoon (Fig. 1), in order to compare it with data from other locations and of congeneric species.

Materials and Methods

Crabs were collected monthly in Itaipú lagoon (Fig. 1) from July 2006 to March 2007, by digging the sediment enclosed in five areas of $0.25m^2$ during low tide. Individuals were sexed according to the presence of the major cheliped or the morphology of the abdomen. Measurements were taken to the nearest 0.01 mm using a digital vernier caliper. The following dimensions related to reproduction (Masunari & Swiech-Ayoub 2003, Benetti & Negreiros-Fransozo 2004, Cardozo & Negreiros-Fransozo 2004, Castiglioni & Negreiros-Fransozo 2004, Masunari & Disenha 2005, Masunari *et al*. 2005) were measured: carapace width (CW); carapace height (CH); major cheliped length (LMC); height of the major cheliped (HMC); and female abdomen width (AW). The individual wet weight (WW) was also obtained.

Allometric technique was employed to distinct adults from juvenile's crabs. The Iterative Process for the Determination of the Transition Point routine of the software Regrans (Pezzuto1993) was used to estimate the size at the onset of morphologic sexual maturity. This routine looks for the best fit where data set of the regression line could be divided in two subsets, corresponding to the puberty molting.

Individuals were classified as dextrous or sinistrous depending on the side of occurrence of the major cheliped (Yamaguchi 1977).

Growth ratios for the independent variable (CW) and the other variables (dependent) were determined by using the logarithmic transformation $\log Y = \log a + b \log X$ and the function $Y = aX^b$, where x is the independent variable (CW), Y is the dependent variable, "a" is the value of Y when X = 0, and "b" the slope of the regression line (Hartnoll, 1978, 1982; Lovett & Felder, 1989). The "b" value represents the relative growth constant (b = 1 means isometric growth; b > 1 means positive allometric growth; and b < 1 means negative allometric growth). The statistical significance of "b" was tested by Student's t-test, adopting a significance level of 5% (Negreiros-Fransozo *et al*. 2003, Benetti & Negreiros-Fransozo 2004, Castiglioni & Negreiros-Fransozo 2004, Cardozo & Negreiros-Fransozo 2004), and noting the confidence interval of the regression line (Masunari & Swiech-Ayoub 2003, Masunari & Disenha 2005, Masunari *et al.* 2005).

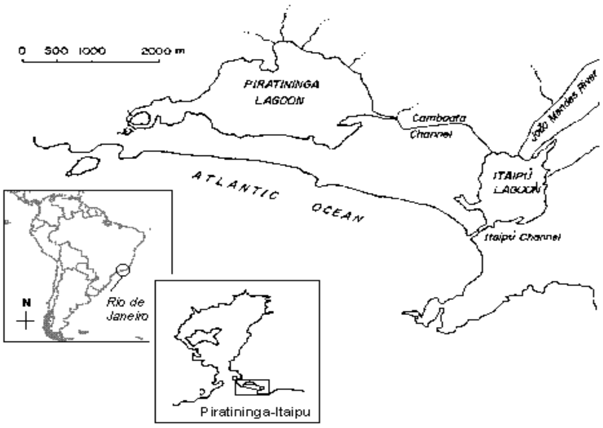

Figure 1. Location of the study area.

Results

A total of 634 crabs, 357 males and 277 females, were sampled. The CW of males ranged from 2.61 to 21.94 mm (10.30 $\pm$ 2.53 SD), and of females from 2.24 to 18.22 mm (9.31 $\pm$ 2.23 SD). The length of sinistrous and dextrous major chelipeds did not differ, and ranged from 1.72 to 37.57mm (17.26 $\pm$ 7.02 SD). The occurrence of sinistrous (48.21%) and dextrous (51.79%) crabs was statistically similar ($p < 0.01$).

The estimated CW sizes at the onset of sexual maturiry of males and females were 12.07 mm and 6.78 mm, respectively.

The relationship between CW and CH was negative for juveniles of both sexes (Figs. 2 and 3). The equation logCH = -0.1697 + 0.9581 logCW describes that relationship for juvenile males (significance test for slope STS = t[1.645] = -1.80, p < 5%) and logCH = -1.1686 + 0.9433logCW (TSD = t[1.68] = -1.42, p < 5%). For adults this relationship was positive for males and isometric for females. The equations describing that relationship for adults were logCH = -0.4049 + 1.1616logCW (STS = t [1.66] = 3.23 p < 5%) and logCH = -0.2253 + 1.0198logCW (STS = t [1.645] = 0.95, p > 5%), for males and females, respectively.

Concerning the relationship between CW and LMC, positive allometry was observed in juveniles and negative allometry in adult males. The relationship between LMC and CW (Fig. 4) was described by the following equations: logLMC = -0.7864 + 1.9814logCW (STS = t [1.68] = 5.09, p < 5%) for juveniles females, and logLMC = 0.4570 + 0.8465logCW (STS = t[1.66] = -2.19, p < 5%) for adults.

The relationship CW x HMC was allometric positive in juveniles and isometric in adults. The equations logHMC = -0.8481 + 1.5850logCW (STS = t [1.645] = 24.37, p < 5%) and logHMC = -0.2386 + 1.0127CW (STS = t [1.66] = 0.15, p > 5%) describe the relationship between HMC and (Fig. 5) CW for juveniles and adults, respectively.

A positive allometric growth was observed for the relationship between CW and WW, in both sexes and different life stages.

Table I shows the growth relationships between body dimensions for each sex and life history stages of *U. rapax*.

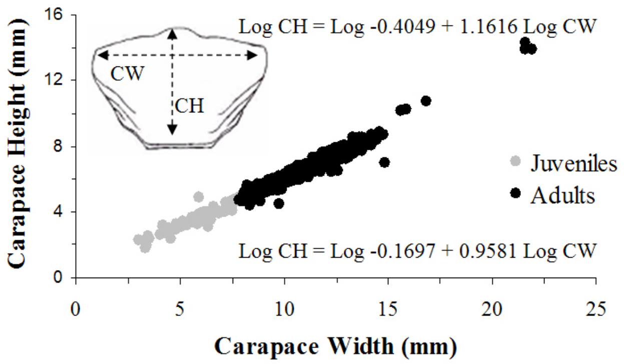

Figure 2. Relationship between carapace height and carapace width in males of *U. rapax* from Itaipu lagoon.

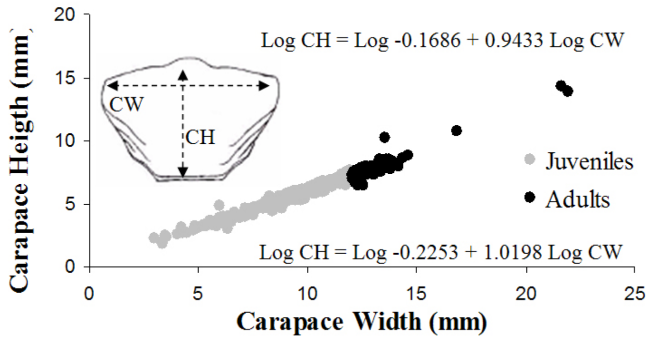

Figure 3. Relationship between carapace height (CH) and carapace width (CW) of females of *U. rapax* from Itaipu lagoon.

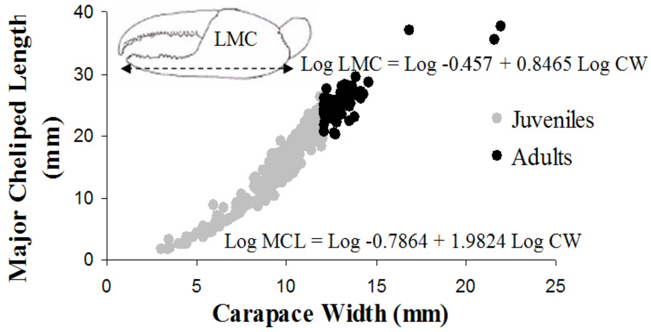

Figure 4. Relationship between major cheliped length (LMC) and carapace width (CW) of males of *U. rapax* from Itaipu lagoon.

In both juveniles and adults females allometric growth were positive for the relationship between CW and AW (Fig. 6), being described by logAW = -0.7845 + 1.4410logCW (STS = t [1.68] = 4.41, p < 5%), for juveniles, and logAW = -0.4222 + 1.3127LogCW (STS = t [1.645] = 1.75, p < 5%), for adults.

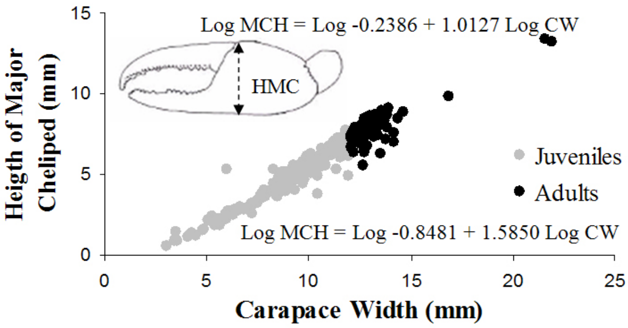

Figure 5. Relationship between major cheliped height (HMC) and carapace width (CW) of males of *U. rapax* from Itaipu lagoon.

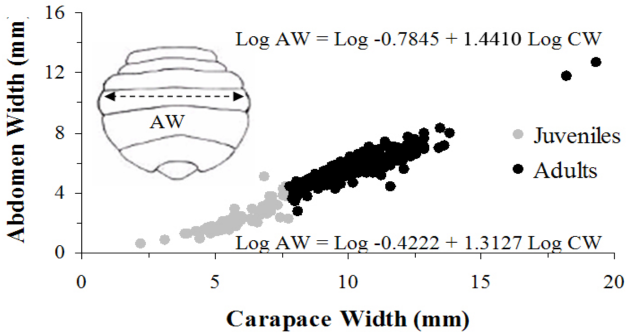

Figure 6. Relationship between abdomen width (AW) and carapace width (CW) of females of *U. rapax* from Itaipu lagoon.

Table I. *Uca rapax*. Statistics on the relationship between the independent variable carapace width (CW) and the dependent variables (CH) carapace height, (LMC) major cheliped length, (HMC) major cheliped height, (AW) abdomen width, (WW) wet weight, (JM) juvenile males, (AM) adult males, (JF) juvenile females, (AF) adult females, (*n*) size sample, (r) correlation coefficient, (R^2) determination coefficient, (a) intersection, (b) declivity, (*) significant (H_0: b =1; Student's t-test, α = 5%), (ns) non-significant, (+) positive allometry, (0) isometry, (-) negative allometry.

Variables	categories	*n*	r	R^2	a	b (I. C. 95%)	t (b=1)	ALL
CW x CH	JM	262	0.9802	0.9607	-0.1697	0.9581 (0.93–0.98)	-1.80 *	-
CW x LMC		258	0.9564	0.9780	-0.7864	1.9824 (1.93–2.03)	37.78 *	+
CW x HMC		254	0.9708	0.9422	-0.8481	1.5850 (1.54–2.13)	24.37 *	+
CW x WW		261	0.9815	0.9632	-3.8301	3.4988 (3.41–3.58)	59.49 *	+
CW x CH	AM	90	0.9250	0.8557	-0.4049	1.1616 (1.06–1.26)	3.23 *	-
CW x LMC		85	0.769	0.5876	0.4570	0.8465 (0.69–0.99)	-2.19 *	-
CW x HMC		85	0.7864	0.6139	-0.2386	1.0127 (1.83–1.18)	0.15 *	0
CW x WW		87	0.8846	0.7801	-3.3732	3.0941 (2.74–3.44)	12.31 *	+
CW x CH	JF	41	0.9598	0.9213	-0.1686	0.9433 (0.85–1.03)	-1.42 *	-
CW x AW		40	0.9207	0.8478	-0.7845	1.4410 (1.22–1.65)	4.41 *	+
CW x WW		40	0.9566	0.9151	-0.4017	3.6054 (3.23–3.97)	14.47 *	+
CW x CH	AF	238	0.9528	0.9078	-0.2253	1.0198 (0.97–1.06)	0.95 ns	0
CW x AW		237	0.9255	0.8567	-0.4222	1.3127 (1.24–1.38)	1.75*	+
CW x WW		237	0.9151	0.8375	-3.5273	3.0997 (2.92–3.27)	26.23*	+

Discussion

Carapace width is the main dimension used as an independent variable in relative growth analysis of crabs because it represents well the physiological changes that occur over their life history (Castiglioni & Negreiros-Fransozo 2004). The type of growth found in the present work agrees with Hartnoll's (1978, 1982) predictions for Brachyura.

The major cheliped has an important role in the reproductive behavior of *Uca*. That appendage is used by fiddler crabs in intra- and interspecific contests for territory defense, agonistic behavior, displays, and courtship. Bigger major chelipeds lead to an advantage in fights among males and in handling females during copulation (Crane 1975, Hartnoll 1982, Pinheiro & Fransozo 1999).

The allometric growth of the major cheliped of males was negative for juveniles and positive for adults. Negative allometric growth has never been reported in the literature about *Uca* (Table II).

According to Masunari & Swiech-Ayoub (2003), the reduction of allometry level of the chelipeds may be related to the necessity of males to maintain body balance, and hence the major cheliped reaches a much larger length than the carapace. The reduction of allometric level in the adult phase can prevent cheliped malformation that could impair the execution of displays. Castiglioni & Negreiros-Fransozo (2004), studying populations from São Paulo state coast, found conflicting results in two sites. At one site the level of allometry did not vary significantly, whereas at the other site the allometric level increased from juvenile to the adult phase (Table II). The phenotypic plasticity of the major cheliped are commonly related to environmental and population variables such as food availability, population density, intra and interespecific competition, and sex ratio.

The abdomen shows a marked dimorphism in crabs, being the female's body part where eggs are incubated during embriogenic periods. *Uca rapax* from Itaipú lagoon had a positive allometric growth in juveniles (b = 1.44) and adults (b = 1.31). The shift in the level of allometry during the adult phase is probably related to the fact that this organ does not act independently, like the chelipeds. The abdomen works in conjunction with the sternum. After it reaches an effective size in the puberty moult, any disproportionate growth in its length would reduce the efficiency of the walking mechanism, hampering the pereiopod steps. The same growth pattern was also described in *U. rapax* by Castiglioni & Negreiros-Fransozo (2004) and in *U. thayeri* by Negreiros-Fransozo *et al.* (2003), in Ubatuba (São Paulo State) coast.

Table II presents the allometric level for the relationships of CW with LMC and AW calculated for several species of *Uca* from different localities.

The relationship between carapace width and height did not follow a well-defined pattern. Juveniles of both sexes and adult males showed a negative allometric growth while adult females showed isometric growth. Juveniles of *U. rapax* had a higher growth rate in length than in width. In females, after the puberal moult, and with the increase of gonadal volume, the carapace started to show isometric growth between length and width. However, the CW x CH relationship is not suitable in expressing biological changes in the life history of crabs since alterations in carapace shape do not represent the transition from the juvenile to the adult phase. Secondary sexual characters, such as chelipeds and abdomen morphology represent better those changes (Santos *et al.* 1995).

The relationship between CW and WW showed high levels of allometry in all categories. Since CW is a variable that expresses surface area, and WW expresses volume, it was an expected result. As the crab grows, its volume increases at a rate three times bigger than its surface area. In crabs raised commercially, the CW x WW relationship is commonly used because it supplies essential information for biomass projections in aqua-culture and favors the exploitation and handling of trading important species (Pinheiro & Taddei 2005).

The allometric growth of *U. rapax* in Itaipú lagoon differed from other *Uca* populations studied along the southern Brazilian coast, indicating that growth could have been influenced by environmental variables in this section of the coast.

Tabela II: Allometry levels for *Uca* spp. using carapace width (CW) as independent variable. (1) Cavalo River population, (2) Ubatumirim population, (3) Itamambuca population, (0) isometry, (+) positive allometry.

Species	Authors	Males (CW x LMC)		Females (CW x AW)	
		juvenile	adult	juvenile	adult
Uca burgersi (1)	Benetti & Negreiros-Fransozo (2004)	1.66 (0)	2.01 (+)	1.29 (0)	1.64 (+)
Uca burgersi (2)	Benetti & Negreiros-Fransozo (2004)	1.62 (+)	2.04 (+)	1.40 (+)	1.59 (+)
Uca leptodactyla	Masunari & Swiech-Ayoub (2003)	2.19 (+)	1.24 (0)	1.30 (+)	1.07 (0)
Uca mordax	Maunari & Disenha (2005)	1.51 (+)	2.37 (+)	1.22 (+)	1.60 (+)
Uca rapax (2)	Castiglioni & Negreiros-Fransozo (2004)	1.43 (+)	1.86 (+)	1.45 (+)	1.31 (+)
Uca rapax (3)	Castiglioni & Negreiros-Fransozo (2004)	1.55 (+)	1.52 (+)	1.67 (+)	1.23 (+)
Uca thayeri	Negreiros-Fransozo *et al.* (2003)	1.52 (+)	2.24 (+)	1.32 (+)	1.10 (+)
Uca maracoani	Masunari *et al.* (2005)	1.39 (+)	1.95 (+)	1.00 (0)	1.51 (+)
Uca rapax	This study	1.98 (+)	0.84 (-)	1.44 (+)	1.31 (+)

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