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Population biology of *Uca mordax* (Smith, 1870) (Crustacea, Decapoda, Ocypodidae) from the southeastern coast of Brazil

Biologia populacional de Uca mordax *(Smith, 1870) (Crustacea, Decapoda, Ocypodidae) do litoral sudeste do Brasil*

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Abstract

The population biology of the fiddler crab *Uca mordax* (Smith, 1870) was investigated in an estuarine mangrove from the southeastern coast of Brazil. Samplings were monthly performed by 2 collectors for 30 min. using the technique of capture per unit effort during low tide periods. The allometric technique was used to determine crab size at sexual maturity (males and females). Thus, specimens were classified into juveniles and adults according to their size at sexual maturity for each sex. The specimens were distributed into size classes. Recruitment was based on the juvenile frequency and the reproduction peak in ovigerous females. The median size of males was 15.9 ± 2.7 mm carapace width (CW) (n = 557) and that of females, 14.6 ± 2.8 mm CW (n = 528). At sexual maturity, size of crabs was 11.9 mm CW for males and 11.5 mm CW for females. Juveniles were found throughout the year but more frequently in the winter and autumn. Sex ratio did not differ among seasons, except during the summer ($p < 0.05$). As regards sex ratio per size class, females predominated in the first size classes. Reproduction peak was observed in the summer. In short, the population biology of *U. mordax* was similar to that of most broad-front fiddler crab species.

Keywords: Fiddler crab. Maturity sexual. Recruitment. Sex ratio. Size distribution frequency.

Resumo

A biologia populacional do caranguejo violinista Uca mordax *(Smith, 1870) foi estudada em um manguezal estuarino do litoral sudeste do Brasil. As amostragens foram efetuadas mensalmente por meio da técnica de esforço de captura por dois coletores durante 30 minutos, em período de maré baixa. A técnica alométrica foi utilizada para determinar o tamanho no qual os caranguejos (machos e fêmeas) atingem a maturidade sexual morfológica. Os caranguejos foram classificados em juvenis ou adultos, de acordo com o seu tamanho, na maturidade sexual para cada sexo. Os espécimes foram distribuídos em classes de tamanho. O recrutamento baseou-se na frequência de juvenis e o período reprodutivo, na frequência de fêmeas ovígeras. O tamanho mediano obtido para os machos foi de 15,9 ± 2,7 mm de largura de carapaça (n = 557) e, para as fêmeas, foi de 14,6 ± 2,8 mm de CW (n = 528). O tamanho da maturidade sexual morfológica em machos é de 11,9 mm de largura de carapaça e, para as fêmeas, é de 11,5 mm de LC. Os juvenis foram encontrados ao longo de todo o ano, mas com maior intensidade durante o inverno e o outono. A razão sexual não difere ao longo das estações, exceto durante o verão (p < 0,05). Com relação à razão sexual em classes de tamanho, as fêmeas predominam nas primeiras classes. O pico reprodutivo mais evidente foi verificado no verão. De modo geral,* U. mordax *apresenta características populacionais semelhantes à maioria das espécies de caranguejos violinistas com fronte larga.*

Palavras-chave*: Caranguejo violinista. Frequência de distribuição de tamanho. Maturidade sexual. Razão sexual. Taxa de recrutamento.*

Introduction

Morphological changes in crabs of the genus *Uca* Leach, 1814 have been reported by many authors (1, 2, 3, 4, 5, 6, 7). According to (8), the variations in the growth pattern of certain organs or their parts relative to others in the same individual, or the differences between sexes within one same species as well as among different species, have biological significance. Such changes can mainly occur in the chelipeds, abdomen and pleopods of crabs and are more evident between sexes and juvenile *vs.* adult phases (9).

The onset of sexual maturity is a biological event of great importance for crabs since it is marked by a series of morphological and physiological transformations, which lead to habit and/or behavioral changes (10). Thus, such stage should be assessed in populational studies (11), considering the great inter or intraspecific variations.

The structural characterization of a population provides basic information about the management of natural resources. In the last twenty years, papers about population biology have been more accepted by the researchers. Learning the biological and ecological aspects of a species (juvenile recruitment, growth rate, and size at onset of sexual maturity) provides more information on its birth rate, mortality, growth, migration, and reproduction (12, 13).

As mentioned by (14), the fiddler crab *Uca mordax* (Smith, 1870) is distributed in Gulf of Mexico, Central America, north of South America, Guyana, and Brazil (from Pará to São Paulo States), where it can be found in mangroves and river margins. Such author also pointed out that there is a reasonable abundance of this species at higher mangrove levels, where the water is practically freshwater.

The biology of *U. mordax* is poorly known. (15) studied its larval development under laboratory conditions, and (16) investigated the relative growth of a population from Guaratuba, Paraná State, Brazil.

The current study describes the relative growth of *U. mordax* in an estuarine mangrove from the northern coast of São Paulo State, Brazil, with the aim of indicating its size at the onset of sexual maturity. Size frequency distribution, recruitment and sex ratio were also assessed to better understand the general biology of this species. A comparison with previous studies was also performed.

Materials and methods

Fiddler crabs were monthly collected from July 2001 to June 2002 in Itamambuca mangrove (23°24'43"S; 45°00'73"W), Ubatuba, São Paulo State, Brazil. Samplings consisted in the technique

of capture per unit effort by 2 collectors for 30 min during low tide periods.

Itamambuca mangrove is characterized by mangle vegetation composed exclusively of *Laguncularia racemosa* (Linnaeus). According to (17), tree density in Itamambuca reaches 1,250 trees per hectare, with a mean height of 4.8 m and mean diameter at breast height of 6 cm. The substratum is composed of poorly sorted medium sand and the organic matter content in the sediment is higher than that in other sites of the same region (Ubatuba, São Paulo State) (18).

All obtained specimens were separated according to sex and ovigerous conditions. Then, a precision caliper (0.01 mm) was used for the following measures: carapace width (CW), carapace length (CL), abdomen width (AW), propodus length (PL) and propodus height (PH) for both sexes, and gonopod length (GL) for males. In males, we measured the major cheliped and in females, the right one.

The handedness of the major cheliped was also recorded and tested by chi-square test (α = 5%) (19).

The mean size of specimens (CW) was compared between sexes and the mean size of the major cheliped (PL), between right and left sides through Mann-Whitney test (α = 5%) as data was not normally distributed (19). Specimens in pre- and post-molt stage, with defective carapaces and without some appendages, were not included in this part of the study.

The first maturation of *U. mordax* was determined through the alometric technique, using the software Mature I and Mature II (20, 21). The algometric equation $Y = aX^b$ (22) was adjusted to the dispersion points of juvenile and adult crabs.

Carapace width (CW) was adopted as the independent variable (X) and related to other body dimensions (dependent variables - Y): CL, AW, PL, PH, and CG. The allometric coefficient (b) represents the allometric degree of the studied body part. The statistical significance of the allometric coefficient was verified through Student's *t*-test at 5% level (H_0: b = 1). Then, all the obtained equations were linearized. The intercepts and the slopes of the straight lines in each development phase were compared by means of covariance analysis (α = 5%) (19).

The population structure was analyzed by season, grouping the data into 10 CW size classes (2 mm wide) according to demographic categories. The normality of distributions was tested through Shapiro-Wilk test (α = 5%) (19) and the homoscedasticity by means of Levene test (α = 5%) (19).

Recruitment was defined as the juvenile rate in each season, considering juveniles those specimens of smaller size than that at the first sexual maturity for each sex, which was obtained through the allometric technique. The juvenile rate was compared among seasons by using multinomial proportion test complemented with Tukey's test (MANAP; α = 5%) (23).

Sex ratio was analyzed for each month and size class. A chi-square test for goodness of fit (X^2; α = 5%) (19) was used to evaluate the sex ratio and compare the monthly percentages of males and females.

Results

During the sampling period we obtained 1,085 *U. mordax* specimens, of which 557 were males and 528 females (14 ovigerous crabs). For relative growth assessment and size determination at the onset of sexual maturity, only 372 males and 280 females were used as they were in intermolt stage and had no defective body parts or appendages.

Total crab size varied from 4.9 to 22.9 mm (15.9 $\pm$ 2.7) CW for males and from 4.3 to 20.8 mm (14.6 $\pm$ 2.8) CW for females. The smallest ovigerous females were 12.9 mm CW, whereas the largest ones measured 20.8 mm CW.

Males reached larger mean sizes (16.4 mm) than females (15.3 mm) ($p < 0.05$). The rate of males with greater chelipeds on the right side was 51.75 % ($p > 0.05$). All the obtained relationships between body parts were tested to determine the size at the onset of sexual maturity and those showing the best adjustment and most clear change from juvenile to adult phase were: CW *vs.* PL for males and CW *vs.* AW for females.

Males became sexually mature at 11.9 mm CW and females at 11.5 mm CW (Figure 1). The allometric equations for *U. mordax* are presented in Table 1.

The frequency distributions by size classes per season are represented in Figure 2. Juveniles were present throughout the year but at higher frequencies during the winter and autumn (Figure 3), indicating a recruitment period in such seasons.

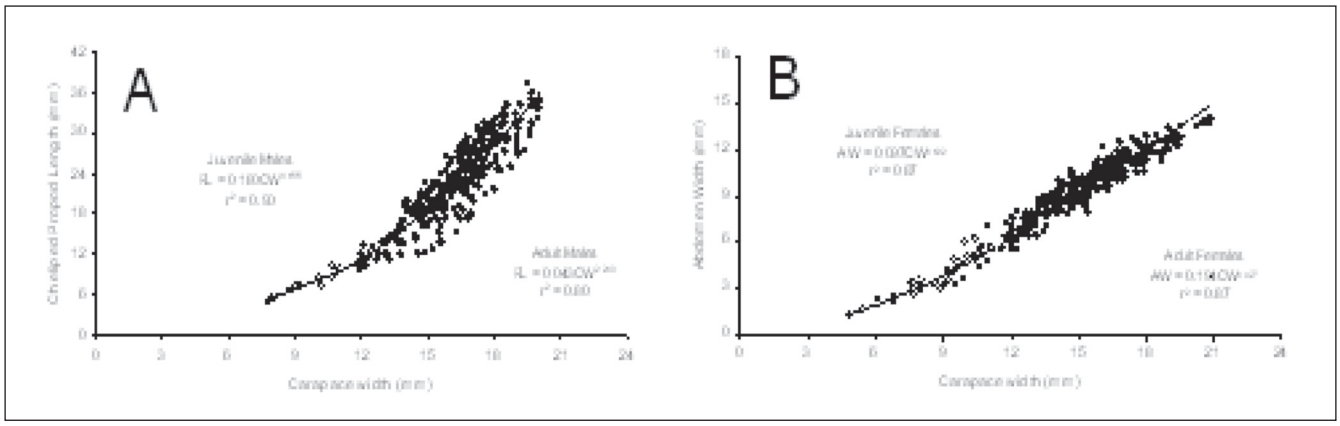

Figure 1 - *U. mordax*. Dispersion points and adjusted curve for the relationship CW *vs.* PL for males (A) and CW *vs.* AW for females (B) (closed cycle = juvenile males and females; open cycle = adult males and females; CW = carapace width; PL = cheliped propodus length; AW = abdomen width)

Source: Research data.

Table 1 - Results of the regressions obtained for the *U. mordax* (Smith, 1870) population from Itamambuca mangrove. Carapace width (CW) was used as the independent variable

Relationship	Category	*n*	Power equation ($Y = aX^b$)	Linearized equation (Log y = log a + b log x)	r^2	*t* (b = 1)	Allometry level	Cut point CW
CL	JM	35	$CL = 0.768CW^{0.9748}$	LogCW = − 0.114 + 0.974 logCL	0.975	0.96	0	
	AM	398	$CL = 0.881CW^{0.9219}$	LogCW = − 0.055 + 0.921logCL	0.933	6.58*	−	
	JF	61	$CL = 0.767CW^{0.9789}$	LogCW = − 0.115 + 0.978 logCL	0.969	1.00	0	
	AF	399	$CL = 0.731CW^{1.0004}$	LogCW = − 0.130 +1.000 logCL	0.954	0.04	0	
AW	TM (ns)	432	$AW = 0.395CW^{0.8480}$	LogCW = − 0.403 + 0.848 logAW	0.915	12.66*	−	
	JF	56	$AW = 0.096CW^{1.6816}$	LogCW = − 1.017 + 1.681 logAW	0.897	7.71*	+	11.5 mm
	AF	388	$AW = 0.194CW^{1.4266}$	LogCW = − 0.712 + 1.426 logAW	0.893	18.80*	+	
PL	JM	35	$PL = 0.179CW^{1.6549}$	LogCW = − 0.747 + 1.649 logPL	0.901	7.92*	+	
	AM	359	$PL = 0.043CW^{2.2402}$	LogCW = − 1.366 + 2.240 logPL	0.795	22.42*	+	11.9 mm
	TF (ns)	449	$PL = 0.435CW^{0.9332}$	LogCW = − 0.361 + 0.933 logPL	0.908	5.15*	−	
PH	TM (ns)	408	$PH = 0.091CW^{1.6136}$	LogCW = − 1.040 + 1.613 logPH	0.934	29.1*	+	
	TF (ns)	455	$PH = 0.193CW^{0.7783}$	LogCW = − 0.713 + 0.778 logPH	0.777	11.68*	−	
GL	JM	33	$GL = 0.191CW^{1.3050}$	LogCW = − 0.718 + 1.305 logGL	0.908	4.12*	+	
	AM	401	$GL = 0.509CW^{0.9099}$	LogCW = − 0.293 + 0.909 logGL	0.720	3.28*	−	

Note: * = ns means that juvenile and adult categories did not differ concerning growth rate, thus they were grouped (CL = carapace length; CW = carapace width; AW = abdomen width; PL = cheliped propodus length; PH = cheliped propodus height; GL = gonopod length; JM = juvenile male; AM = adult male; TM = total male; JF = juvenile female; AF = adult female; TF = total female; *n* = number of specimens; 0 = isometry; + = positive allometry; − = negative allometry; ns = non significant; * = significant by Student's *t*-test ($p < 0.05$); r^2 = determination coefficient)

Source: Research data.

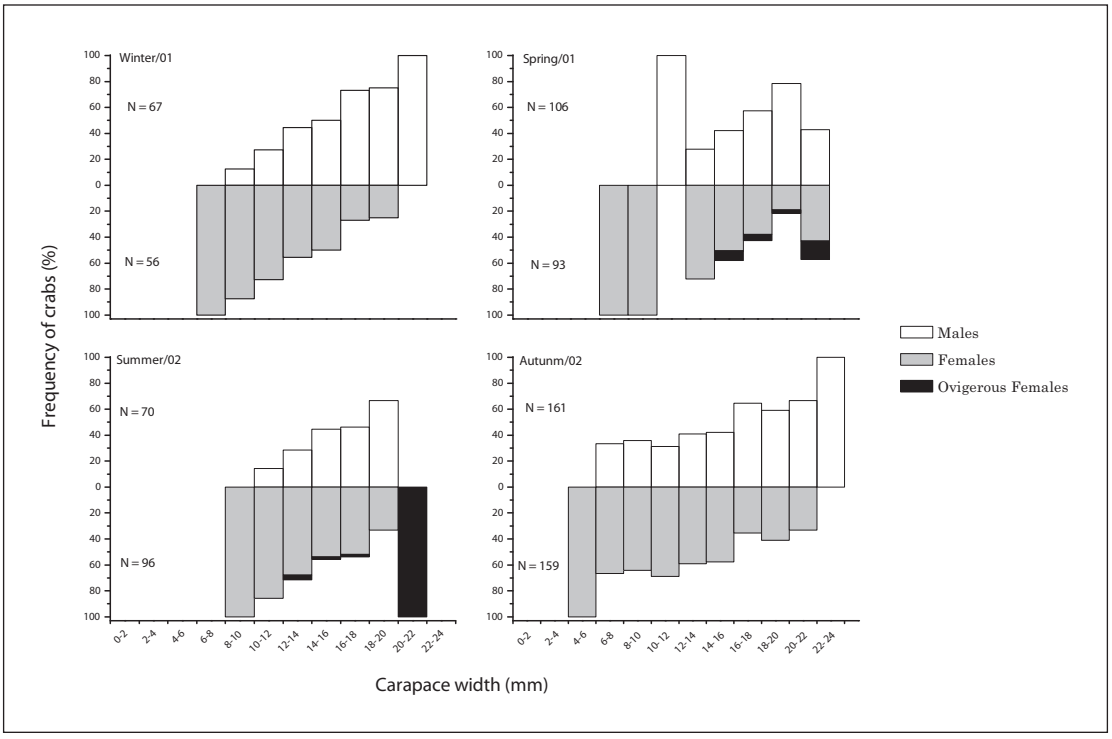

Figure 2 - *U. mordax*. Frequency distribution histogram by size classes carapace width (mm) in each demographic category

Source: Research data.

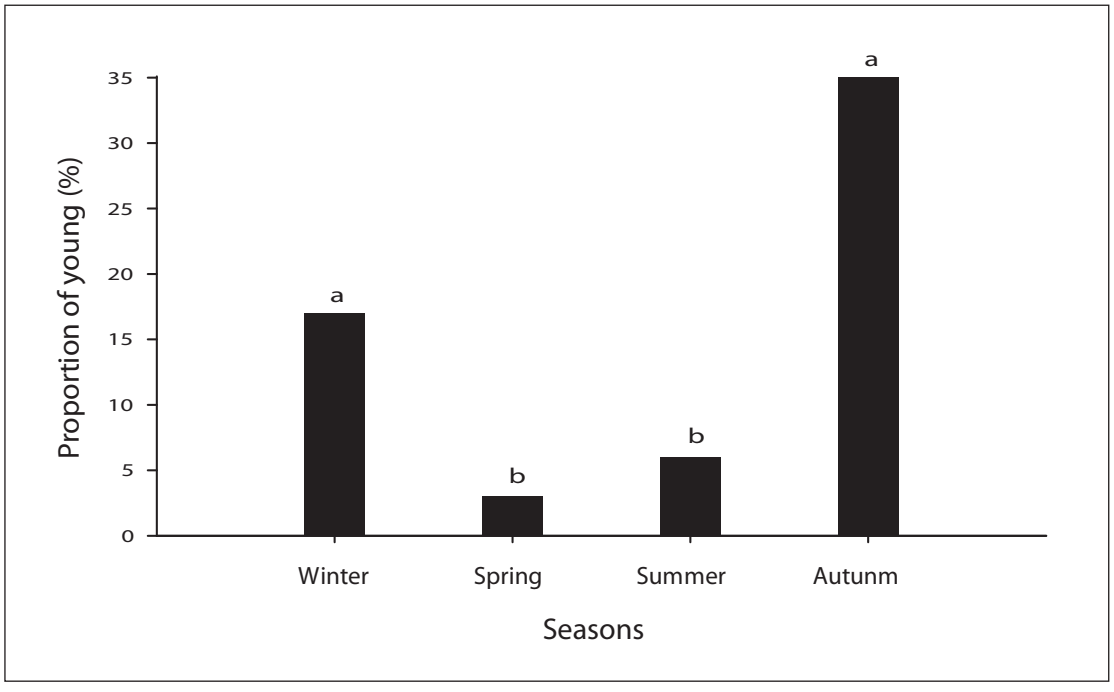

Figure 3 - *U. mordax*. Recruitment ratio of U. mordax in the Itamambuca mangrove throughout a year period. Bars with at least one same letter in common did not differ statistically ($p > 0.05$)

Source: Research data.

Sex ratio did not differ among months ($p > 0.05$), except for January 2002 ($p < 0.05$) (Figure 4). As regards size classes, females predominated in the initial classes, whereas males prevailed in the intermediate and final classes, except in class 20-22 mm CW (Figure 5).

Discussion

Sexual maturity represents an important biological event characterized by morphological and physiological changes that can be caused by environmental or behavioral alterations (10).

As mentioned by (24) and (25), the relationships CW *vs.* PL and CW *vs.* AW for males and females, respectively, best evidenced the morphological sexual maturity of crabs, which can be exemplified by the *U. mordax* population in Itamambuca mangrove.

Uca mordax population in Guaratuba Bay, studied by (16), reached the maximum sizes of 20.0 mm CW (males) and 18.5 mm CW (females). These values are slightly lower than those obtained in the present study (22.9 mm CW for males and 20.8 mm CW for females). At sexual maturity, males had similar sizes in both places but females from Itamambuca, São Paulo State, were larger (11.5 mm CW) than those from Guaratuba, Paraná State (8.77 mm CW). The size of the smallest ovigerous females from Itamambuca (12.9 mm CW) was similar to that at sexual maturity, according to the mean relative growth (11.5 mm CW), supporting our results.

Size differences between these two *U. mordax* populations may be due to latitude effects, as stated by (26). Such effects could also be caused by the differences in the food availability and habitat features (7, 17).

Recruitment is year-round and peaks were mainly observed during autumn-winter-spring for most of the previously studied species. Reproduction peak occurs during summer for *U. mordax* (16), *U. thayeri* Rathbun, 1900 (27), *U. burgersi* Holthuis, 1967 (24) and *U. vocator* (Herbst, 1804) (17); late-spring-summer for *U. rapax* (Smith, 1870) (18, 25).

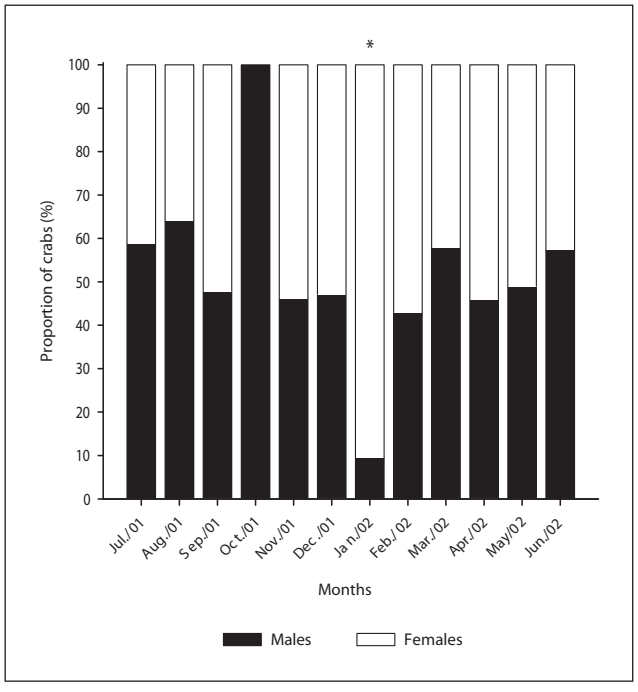

Figure 4 - *U. mordax*. Sex ratio by months for population from Itamambuca. Asterisks above the columns indicate significant differences between the proportions of males and females ($p < 0.05$)

Source: Research data.

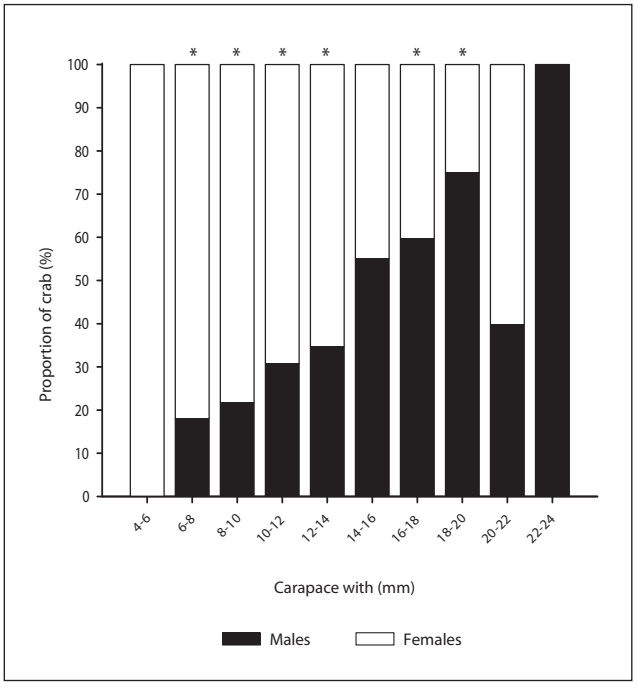

Figure 5 - *U. mordax*. Sex ratio by size classes of carapace width (mm) for population from Itamambuca. Asterisks above the columns indicate significant differences between the proportions of males and females ($p < 0.05$)

Source: Research data.

Allometric studies performed by (28), (29) and (2) demonstrated that throughout the ocypodid life cheliped growth in males has a direct relationship with morphological sexual maturity. This is also observed in *U. mordax*, which shows a positive allometry concerning the relationship CW *vs.* PL.

Abdominal width growth is generally used to characterize the sexual dimorphism in representatives of the infraorder Brachyura. Similarly to *U. mordax*, the relationship CW *vs.* AW in males has presented negative allometry, since these structures have the function of protecting the gonopods in males (30). A similar pattern was found in *U. burgersi* by (31), *Eriphia gonagra* (Fabricius, 1781) by (32) and *Goniopsis cruentata* (Latreille, 1803) by (33).

When *U. mordax* mean size is compared between sexes, females show to have a smaller maximum size, probably because they spend a reasonable amount of energy for reproductive purposes (34, 35), whereas males invest their energy in somatic growth, consequently reaching higher sizes. Such difference could also be related to cohort and agonistic behavior, as reported by others (36, 37).

According to (3), the frequency distribution of cheliped laterality can vary with the population structure. In the present paper, the percentage of right chelipeds was higher but not statistically significant, which was also observed by (38) and (39).

Broad-front fiddler crabs are known to incubate their eggs inside burrows in order to protect them against extreme environmental conditions, favoring embryonic development and larval hatching synchronically (40). A small number of *U. mordax* ovigerous females (11) were captured during this study and most of them were found inside burrows, suggesting they keep buried while incubating.

Uca mordax recruitment showed to be continuous throughout the studied period, presenting an elevated frequency of juveniles in the autumn and winter. Such fact was also observed by (27), who mentioned that juveniles become adults during the coldest months of the year in the northern coast of São Paulo State.

The proportion of male and female crabs tends to be very close to 1:1. However, such relation can be influenced by a series of factors, such as life span, migration, mortality, differential growth, and sex change (40). Nevertheless, *U. mordax* sex ratio did not present statistical difference over seasons, except during the summer.

In short, the species *U. mordax* follows the general pattern of population biology presented by the previously studied broad-front fiddler crabs in the southeastern coast of Brazil.

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