



## Population ecology of the blue crab *Callinectes danae* (Crustacea: Portunidae) in a Brazilian tropical estuary

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### ABSTRACT

This paper aims at describing the population ecology of the swimming crab *Callinectes danae* Smith, 1869 in one of the most productive estuaries of Brazil, the Santa Cruz Channel. These crabs were monthly collected from January to December/2009 at four stations along the channel, two in the upper and two in the lower estuary. A total of 2373 specimens of *C. danae* were collected during the study. Males had a larger average carapace width than non-ovigerous females ( $60.0 \pm 15.6$  mm and  $52.9 \pm 12.4$  mm, respectively), an adaptation that gives greater protection for females during the copulation. Overall sex ratio did not differ significantly from 1:1. However, evaluating sex-ratio by sampling area, males and juveniles of both sexes occurred preferentially in the upper estuary ( $p < 0.05$ ), while adult females, including ovigerous, inhabited the lower estuary, an area of major marine influence ( $p < 0.05$ ). While juveniles look for estuarine waters due to the benefit from the shelter and abundance of food, ovigerous females migrate to areas of greater depth and higher salinity in order to provide a more favorable environment for embryonic and larval development and to enhance larval dispersal. Recruitment of juveniles was continuous along the year, but intensified from March to June and, with less intensity, from October to December

**Key words:** Brachyura, population biology, Santa Cruz Channel, sexual dimorphism.

### INTRODUCTION

The study of natural populations is essential to understand their ecological stability. In the coast of Brazil, marine and estuarine macrocrustaceans have been studied regarding some population aspects such as the distribution of individuals by size classes, density, seasonal abundance, sex ratio, age distribution, birth and mortality rates, and recruitment of juveniles (Noro and Buckup 2008).

The swimming crab *Callinectes danae* Smith, 1869 (Portunidae) is a very abundant macrocrustacean in the Brazilian estuaries, with a relevant ecological role. It is a common predator of benthic organisms (Netto and Lana 1994), feeding on macroinvertebrates such as Mollusca, Polychaeta and other Brachyura (Branco and Verani 1997), and constitutes a food resource for many aquatic organisms. This crab had its population ecology studied by some authors, such as Pita et al. (1985), Negreiros-Fransozo and Fransozo (1995), Branco

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and Masunari (2000), Chacur et al. (2000) and Baptista-Metri et al. (2005). However, these studies were only performed in the southern and southeastern Brazil. Research about this species is rare from other Brazilian coastal areas, including the northeastern littoral, where this crab has a major socio-economic importance. Except for papers published by Pereira-Barros and Travasos (1972) in Alagoas State, on its fisheries biology, and by Barreto et al. (2006) in Pernambuco State, on the size at sexual maturity of females, no information about *C. danae* is available.

This paper aims at describing the population ecology of the crab *C. danae* from a tropical estuary of the Brazilian northeast coast, as well as analyzing the spatial and seasonal fluctuation of the abundance and the ontogenetic migrations. This is a pioneer contribution to the population biology of this species in northeastern Brazil.

#### MATERIALS AND METHODS

The fieldwork took place at the estuarine complex of Santa Cruz Channel, Pernambuco State, northeast of Brazil. It is formed by six rivers that flow into a U-shaped channel, which separates Itamaracá Island from the continent (Fig. 1). It occupies an area of 730 km<sup>2</sup> between the latitudes 07°34'00" S / 07°55'16" S and longitudes 34°04'48" W / 34°52'24" W. The channel communicates with the Atlantic Ocean through two inlets: Catuama inlet in the North and Orange inlet in the South (Macedo and Koenig 1987). The region has a climate within the As' type of Koeppen system, i.e. hot and humid with rainy autumn and winter. It shows a dry season during the austral summer, between the months of September and February, and a rainy season from March to August (Cavalcanti and Kempf 1970).

Four sampling stations were established along the Santa Cruz Channel (Fig. 1): 1 – Congo River mouth (7°46'26" S / 34°53'02" W); 2 – President Vargas bridge (7°46'28" S / 34°53'13" W); 3 – Paripe River mouth (7°48'03" S / 34°51'02" W); and 4 – Coroa do Avião sand bank (7°48'05" S /

34°50'28" W). For the purpose of this work, the first two sampling stations were considered the upper estuary, while the last two ones the lower estuary.

The upper estuary presents muddy substratum dominated by fine sand (Paiva et al. 2005), resulting from the slow water currents at this area. The mangrove forest occupies large areas, and during the low tide mud flats are exposed and the depths are lower than 2 m (Macedo et al. 2000).

At the lower estuary, Paripe River, the only one that springs from the Island, flows into the channel near the south inlet. It presents muddy sand substratum and the marine influence is remarkable along almost its whole extension (Silva and Koenig 1993). At the south inlet, the Coroa do Avião sand bank is formed by the deposition of sediments brought by the longshore drift (Silva et al. 2007). The depths at the area vary from 10 to 17 m (Eskinazi-Leça et al. 1980).

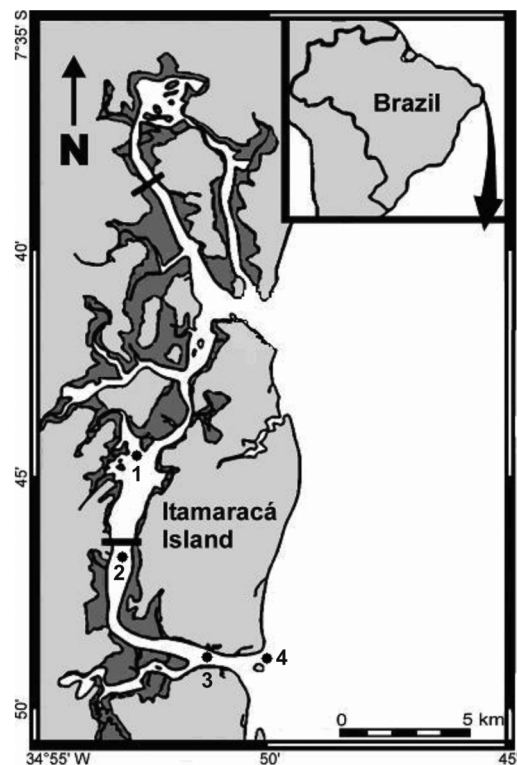


Fig. 1 – Santa Cruz Channel (SCC), with sampling stations indicated by numbers: 1 = Congo River mouth; 2 = President Vargas bridge; 3 = Paripe River mouth; and 4 = Coroa do Avião sand bank.

Monthly, samples were collected from January to December 2009 on full moon days; sampling started during ebb tide and ended during flood tide. Portunid crabs were collected with a dipnet and attracted with anchovie baits (Engraulidae). In each monthly fieldwork, the following abiotic variables were also obtained: water temperature and water samples for later analyses of salinity, pH and dissolved oxygen concentration (D.O.).

In the laboratory, the specimens were identified, sexed and classified as juveniles and adults by the morphology of the abdomen. Carapace width (CW) of each individual was measured using a 0.05 mm precision caliper, excluding lateral spines.

The analysis of abiotic variables was performed following the methods described by Strickland and Parsons (1960): the Winkler method for D.O. and the Mohr-Knudsen method for salinity. The pH values were obtained with a bench pH meter. Oxygen saturation (%) was calculated based on the values of D.O., salinity and temperature, using the equations of the International Oceanographic Tables (UNESCO 1973).

All statistical analysis were performed at  $\alpha = 0.05$ . The minimum, mean  $\pm$  standard deviation and maximum values of each abiotic variable were estimated. Student *t* test was used to compare abiotic variables between dry and rainy periods, and between upper and lower estuary. The minimum, mean  $\pm$  standard deviation and maximum values of CW and CPUE (catch per unit effort, as the number of crabs captured per hour) were estimated. Student *t* test was used to compare CPUE between dry and rainy periods, and CW between males and females. Kruskal-Wallis nonparametric test was used to compare CPUE and relative abundance of juvenile females, adult females, juvenile males and adult males between upper and lower estuary, followed by Dunn's *a posteriori* test when significant differences were found.

The sex ratio and relative abundance of juveniles and adults were analyzed summing up all

samples collected in the whole studied period and by the discrimination of upper and lower estuary and by months. The  $\chi^2$  test was applied to verify whether sex ratio deviates significantly from 1:1 (Mendelian proportion). The recruitment was estimated through a multinomial proportion analysis (MANAP), which was applied to compare the relative abundance of juveniles and adults by month.

To characterize the population structure, the animals were grouped into CW classes with an amplitude of 5 mm.  $\chi^2$  tests were applied to check for the equality of sex ratios for each class. Size classes were plotted for males and females separately. The mode was estimated from the midpoint of the range shift. The Shapiro-Wilk test was used to test the normality of frequency distributions that was classified by the number of modes in: unimodal, bimodal and polymodal.

Pearson's coefficient of linear correlation (*r*) was used to assess the correlation between the CPUE, number of juvenile and adult males and females with abiotic variables by periods (dry and rainy).

## RESULTS

The data of abiotic variables are presented in Table I. Mean water temperature was  $29.3 \pm 1.4^\circ\text{C}$  (ranging from  $26.5^\circ\text{C}$  in July to  $31^\circ\text{C}$  in November), mean salinity was  $27.8 \pm 4.7$  (from 16.2 in July to 33.5 in December), mean pH was  $8.1 \pm 0.2$  (from 7.8 in July to 8.6 in May) and mean D.O. was  $4.4 \pm 0.7 \text{ ml.L}^{-1}$  (from  $3.5 \text{ ml.L}^{-1}$  in April to  $5.8 \text{ ml.L}^{-1}$  in December). Mean oxygen saturation was  $106.6 \pm 21.9\%$ , ranging from saturated (83.2%) in February to supersaturated (161.6%) in October.

Although the values of each abiotic variable have fluctuated during the sampling year, no significant differences were observed in the mean values between rainy and dry periods for temperature ( $t = 1.82; p = 0.07$ ), pH ( $t = 1.41; p = 0.16$ ), D.O. ( $t = 0.18; p = 0.85$ ) and oxygen saturation ( $t = 0.35; p = 0.09$ ). Salinity was the only factor that

**TABLE I**  
**Mean monthly values of each abiotic variable at Santa Cruz Channel. Temp = temperature; Sal = salinity; D.O. = dissolved oxygen; %Sat D.O. = dissolved oxygen saturation.**

Months	Rainy period				
	Temp	Sal	pH	D.O.	% Sat D.O.
Mar	30.5	29.2	8.0	4.2	95.6
Apr	30.4	27.3	7.9	3.8	92.9
May	30.3	26.1	8.6	4.3	126.6
Jun	28.5	23.4	8.0	4.4	102.2
Jul	26.5	16.2	7.8	5.3	92.1
Aug	27.0	26.3	8.0	3.9	116.6
<b>Mean ± sd</b>	<b>28.9 ± 1.8</b>	<b>24.8 ± 4.6</b>	<b>8.1 ± 0.3</b>	<b>4.3 ± 0.5</b>	<b>104.3 ± 13.0</b>
Months	Dry period				
	Temp	Sal	pH	D.O.	% Sat D.O.
Jan	29.3	32.1	8.4	4.8	84.2
Feb	30.0	29.8	8.1	3.5	83.2
Sep	28.5	27.6	8.1	3.8	102.3
Oct	29.3	30.6	8.1	4.2	161.6
Nov	31.0	31.9	8.3	4.9	104.4
Dec	30.5	33.5	8.3	5.8	117.8
<b>Mean ± sd</b>	<b>29.8 ± 0.9</b>	<b>30.9 ± 2.1</b>	<b>8.2 ± 0.1</b>	<b>4.5 ± 0.8</b>	<b>108.9 ± 26.4</b>

varied significantly between rainy and dry periods ( $t = 5.41$ ;  $p < 0.05$ ). On the other hand, no abiotic variables showed significant differences between upper and lower estuary ( $p > 0.05$ ). However, the mean salinity found in the lower estuary was higher (29.5) than in the upper estuary (26.5).

A total of 2373 specimens of *C. danae* were sampled during the study period, among those, 1210 males and 1163 females. The overall sex ratio was 1:0.96 (♂:♀), and it did not differ from the expected 1:1 proportion ( $\chi^2 = 0.9$ ;  $p > 0.05$ ). However, juveniles were significantly more abundant than adults ( $\chi^2 = 483.4$ ;  $p < 0.05$ ), totaling 72.5% of the population (Table II).

Significant differences ( $p < 0.05$ ) were observed in the sex ratio of the sampling areas (Fig. 2); males outnumbered females in the upper estuary, while females outnumbered males in the lower estuary. However, juvenile males outnumbered adult ones both in the upper and in the lower estuaries. Juvenile females outnumbered adult ones in the upper estuary, while adult females outnumbered juvenile females in the lower estuary. In addition, ovigerous females were only found in the lower estuary.

Monthly sex ratio did not differ from the Mendelian proportion, except in February, when males were significantly more abundant than females ( $\chi^2 = 5.8$ ;  $p < 0.05$ ). Juveniles were more abundant

TABLE II  
*Callinectes danae*. Absolute and relative abundances (%) of each sex and age groups at Santa Cruz Channel.

Sex \ Age	Absolute abundance				Relative abundance (%)			
	Juveniles	Adults	Ovigerous	Total	Juveniles	Adults	Ovigerous	Total
Males	933	277	-	<b>1210</b>	39.3	11.7	-	<b>51</b>
Females	789	351	23	<b>1163</b>	33.2	14.3	1.5	<b>49</b>
<b>Total</b>	<b>1722</b>	<b>628</b>	<b>23</b>	<b>2373</b>	<b>72.5</b>	<b>26.0</b>	<b>1.5</b>	<b>100</b>

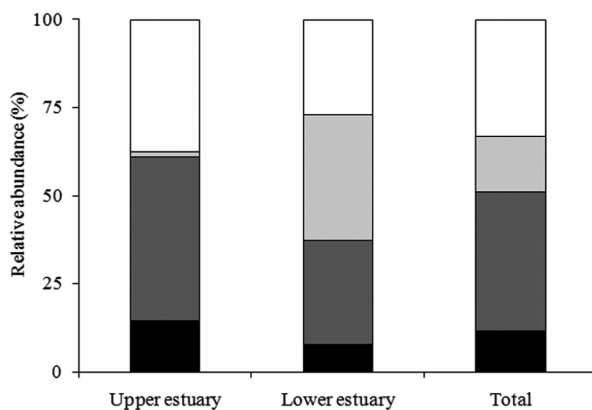


Fig. 2 – *Callinectes danae*. Relative abundance of adults and juveniles of both sexes, in the upper and lower estuaries at the Santa Cruz Channel. The total number obtained in these sites is also presented.

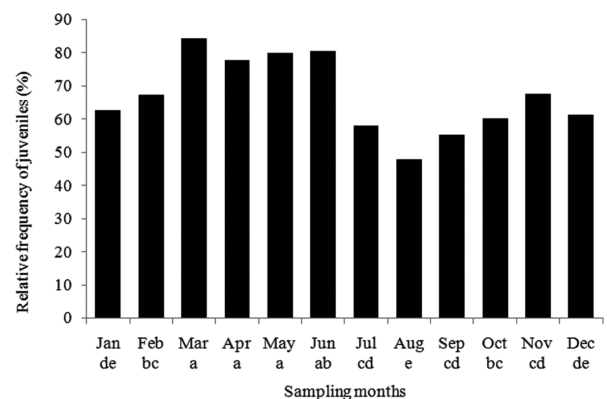


Fig. 3 – *Callinectes danae*. Temporal distribution of juveniles frequency at the Santa Cruz Channel. Note: months sharing at least one letter in common did not differ significantly among them ( $\alpha = 0.05$ ).

than adults in most months, except in August and September when no significant differences could be noticed ( $\chi^2 = 0.1$  and  $1.3$ , respectively;  $p > 0.05$ ) (Fig. 3). The recruitment of juveniles to the population is continuous, but intensified from March to June and, less intense, from October to December.

The mean CW of males was  $60.0 \pm 15.6$  mm (ranging from 23.6 to 95.6 mm), that of non-ovigerous females was  $52.9 \pm 12.4$  mm (from 25.0 to 82.3 mm) and that ovigerous females was  $64.8 \pm 5.2$  mm (from 50.5 to 72.0 mm). Males were significantly larger than non-ovigerous females ( $t = 9.48$ ;  $p < 0.05$ ), while ovigerous females were significantly larger than males ( $t = -3.61$ ;  $p < 0.05$ ) and non-ovigerous females ( $t = -8.14$ ;  $p < 0.05$ ).

The swimming crabs were distributed into sixteen CW classes, ranging from 20.0 to 100.0 mm CW (Fig. 4). Females were distributed in a smaller amplitude (27.5 |– 82.5 mm) than males (22.5 |– 97.5 mm). There were significant differences in the proportion of males and females by size class, with males being dominant in all four classes from 75.0 to 95.0 mm ( $p < 0.05$ ). Females were dominant in the classes of 25.0 |– 30.0 and 35.0 |– 40.0 mm ( $p < 0.05$ ). The distribution by size class for both sexes tends to bimodality ( $p < 0.05$ ). However, one characteristic mode for each sex can be detected (Fig. 4): 52.5 mm for males and 47.5 mm for females.

Mean CPUE was  $64.6 \pm 51.0$  ind.h<sup>-1</sup>, ranging from 9.8 ind.h<sup>-1</sup> in March to 225.0 ind.h<sup>-1</sup> in

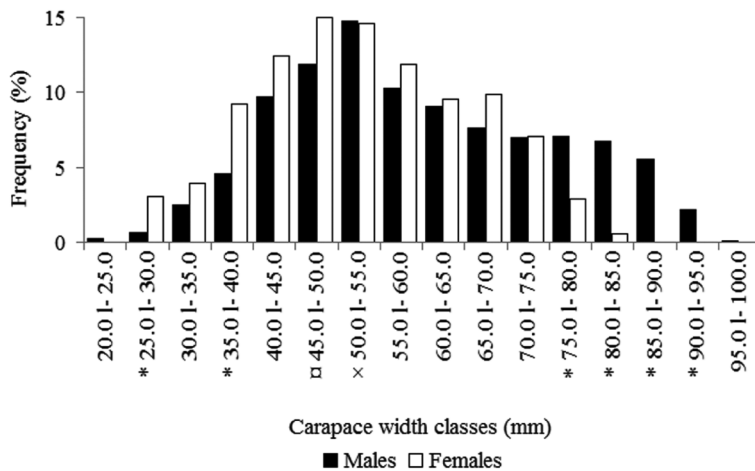


Fig. 4 – *Callinectes danae*. Frequency distribution of males and females into CW size classes at the Santa Cruz Channel. \* = significant differences ( $\alpha = 0.05$ ); □ = mode of females; × = mode of males.

TABLE III

*Callinectes danae*. Minimum, mean and maximum values of catch per unit effort (CPUE = # of individuals per hour) by sampling area and collection period at the Santa Cruz Channel.

Sources of variation		CPUE (ind. h <sup>-1</sup> )		
		Min.	Mean ± sd	Max.
Sampling area	Upper estuary	11.6	85.8 ± 55.1	225.0
	Lower estuary	9.8	33.5 ± 20.2	87.1
Period	Dry	11.6	40.9 ± 51.1	225.0
	Rainy	9.8	57.9 ± 50.0	182.0

February. The CPUE in the upper estuary was significantly higher than in the lower estuary ( $p < 0.05$ ). No significant differences were found between dry and rainy periods ( $t = -0.78$ ;  $p = 0.44$ ) (Table III).

No significant correlation between abiotic variables and CPUE was observed ( $p > 0.05$ ). However, when analyzing separately dry and rainy periods, a significant influence of the D.O. was observed in the rainy period ( $r = 0.75$ ;  $p = 0.01$ ).

After separating sex and age groups, some other significant correlations could be noticed:

the oscillation of the number of juvenile females was positively correlated with the variation of the temperature ( $r = 0.81$ ), while the number of adult females was negatively correlated with temperature, salinity and pH ( $r = -0.74$ ,  $-0.75$  and  $-0.69$ , respectively), for both dry and rainy periods. The oscillation of the number of juvenile males was negatively correlated to that of dissolved oxygen during the dry period ( $r = -0.82$ ), and positively correlated to that of temperature during the rainy period ( $r = 0.83$ ).



## DISCUSSION

Studies conducted at Santa Cruz Channel have demonstrated that this environment can be regarded as a coastal water body under terrigenous influence, because several rivers flow into it (Cavalcanti et al. 1981). No physicochemical variable assessed in the present study varied significantly among the sampling stations, a feature that may be due to the tidal effect and to the non-simultaneous collection of samples. However, the mean salinity was higher in the lower estuary, showing that this area has saltier water and greater marine influence. Although oscillations in abiotic variables have been observed throughout the year, salinity was the only one that varied significantly between dry and rainy periods; this is a result of a considerable increase in the runoff during rainy months. Seasonal variations of salinity in the region have been plenty evidenced previously (Macedo et al. 1973).

Due to the complexity of the marine habitat, the distribution of many species can vary according to their stage of development. The blue crab *Callinectes sapidus* presents sexual and ontogenetic differences in the movement across the estuary, causing habitat partitioning between sexes and ages (Hines et al. 1987). Other studies have also suggested habitat partitioning for portunids (Negreiros-Fransozo and Nakagaki 1998). However, this ecological aspect still remains poorly described for tropical and subtropical zones. Regarding the spatial distribution of *C. danae* at Santa Cruz Channel, a sex-specific spatial segregation was revealed, causing a habitat partitioning. Males and juveniles of both sexes preferentially reside in the upper estuary, while adult females, including the ovigerous, dominate in the lower estuary, which is the area of stronger marine influence. Such pattern seems to be a characteristic of *C. danae*, as it has been shown by several authors, such as Pita et al. (1985) and Chacur et al. (2000) in Southwestern Brazil, and Branco and Masunari (2000) in Southern Brazil. Furthermore, Pereira-

Barros and Travassos (1972) have suggested a reproductive migration of females of *C. danae* at Mundaú Lagoon, state of Alagoas, Northeastern Brazil, based on the absence of females inside the lagoon in most months. However, as these latter authors obtained samples from debarkment areas of the canoes that fished throughout the whole lagoon, this information is controversial. Thus, the present paper brings new light to the migration phenomenon for the northeastern coast of Brazil.

As cited by Buchanan and Stoner (1988), this pattern of distribution of swimming crabs is the result of a combination between habitat preferences and intra/ interspecific interactions. In the present study, an ontogenetic migration of *C. danae* can be proposed. The juvenile crabs migrate to estuarine areas, where they are protected from predation pressure that is usually higher in open seas and additionally the abundance of shelter and food is available in this environment, as suggested by Hines et al. (1987) and Guerin and Stickle (1997). After development, adult and ovigerous females migrate to the lower estuary and the open sea. These areas of greater depth and salinity are propitious to embryonic and larval development, as recorded for other portunids such as *C. sapidus* by Williams (1974), *C. similis* by Hsueh et al. (1993) and *C. ornatus* by Negreiros-Fransozo and Fransozo (1995).

Sexual dimorphism in the carapace width of *C. danae*, being males larger than females, is largely known (Williams 1974, Baptista-Metri et al. 2005). The larger size of males is supposed to be an adaptation that performs protection to females throughout the time-consuming copulatory embrace and immediately after copulation, as has been reported for portunids such as *C. ornatus* by Mantelatto and Fransozo (1996) and *A. cribrarius* by Pinheiro and Fransozo (1998). This sexual difference in size arises at the puberty molt, when metabolic energy is intended for somatic growth in males, while in females, it is distributed between egg production and growth (Hartnoll 1985).

The unimodal distribution of size frequency usually reflects a continuous recruitment, as has been reported for *C. ornatus* by Mantelatto (1995). On the other hand, bimodality may indicate differential migration of demographic categories, as observed in the present study, and/or recruitment through pulses (Díaz and Conde 1989). At the Santa Cruz Channel, the recruitment of juveniles into the population of *C. danae* occurs year-round, but it is enhanced from March to June and from October to December, probably as a result of the seasonal intensity in the reproduction of the species.

The Brazilian federal legislation that deals with swimming crabs fisheries established in 1983 (ordinance # N-24/83) allows only to fish *C. danae* bigger than 120.0 mm CW, in inland waters. This value is far above the mean CW found in this study; actually, it is nearly twice the size (males – 60.0 mm; non-ovigerous females – 52.9 mm, and ovigerous females – 64.8 mm). It is also much higher than those averages found by other authors, as Baptista-Metri et al. (2005) at Shangri- Lá Beach, state of Paraná (males – 66.7 mm; females – 61.0 mm). These studies show how this ordinance is outdated and inaccurate. Further studies about the reproductive pattern of *C. danae* are highly desirable in order to establish the correct size of this swimming crab for secure fishing.

In the present study, all evaluated abiotic variables exerted some influence in the abundance of *C. danae*. Chacur et al. (2000) concluded that salinity is the most important factor to explain the distribution of *C. danae*. On the other hand, Buchanan and Stoner (1988) argued that temperature is the most important factor affecting the temporal abundance of this species. Although it is possible to isolate each environmental variable and to consider the influence of each one separately, the behavior of an individual at a certain time will be determined not only by an exogenous factor, but by the influence and interaction of many variables in synergistic action and by endogenous factors (Soares-Gomes and Figueiredo 2002).

## CONCLUSION

An ontogenetic and sex-specific migration of the swimming crab *Callinectes danae* in a tropical Brazilian estuary is suggested. Males, ovigerous and non-ovigerous females, as well as juveniles and adults, showed a clear spatial segregation within the estuary.

The present paper is an important contribution to the knowledge on the ecology of this species on the northeast Brazilian coast. Still, more studies in this region are necessary, due to its ecological and socioeconomic importance.

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## RESUMO

O presente trabalho tem por objetivo descrever a estrutura populacional do siri *Callinectes danae* Smith, 1869 em um dos estuários mais produtivos do Brasil, o Canal de Santa Cruz. As coletas foram realizadas mensalmente de Janeiro a Dezembro/ 2009 em quatro estações ao longo do canal, duas no estuário superior e duas no estuário inferior. Um total de 2373 exemplares de *C. danae* foi coletado. Os machos apresentaram média de largura de carapaça superior à das fêmeas não-ovígeras ( $60,0 \pm 15,6$  mm e  $5,9 \pm 12,4$  mm, respectivamente),



uma adaptação que confere maior proteção às fêmeas durante a cópula. A proporção sexual total não diferiu significativamente de 1:1. Porém, avaliando a 'sex-ratio' por área de coleta, os machos e os juvenis residem preferencialmente no estuário superior ( $p < 0,05$ ), enquanto as fêmeas adultas e ovígeras habitam no estuário inferior, área de maior influência marinha ( $p < 0,05$ ). Enquanto os juvenis procuram águas estuarinas devido a abundância de abrigos e comida, as fêmeas ovígeras migram para áreas de maior profundidade e maior salinidade visando prover um ambiente mais favorável ao desenvolvimento embrionário e larval, além de favorecer a dispersão da prole. O recrutamento de juvenis foi contínuo ao longo do ano, mas intensificado entre Março e Junho, e em menor intensidade, de Outubro a Dezembro.

**Palavras-chave:** Brachyura, biologia populacional, Canal de Santa Cruz, dimorfismo sexual.

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