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Population structure of the swimming crab *Achelous spinicarpus* (Crustacea, Portunoidea) in São Paulo northern coast, Brazil

Estrutura populacional do siri candeia *Achelous spinicarpus* (Crustacea, Portunoidea) no litoral norte paulista

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Abstract

The swimming crab *Achelous spinicarpus* is commonly captured as a "by catch" of the shrimp fishery. This study evaluated some aspects of the population structure of *A. spinicarpus,* such as sex-ratio and size classes' frequency distribution. A shrimp trawler equipped with double-rig nets was used to capture the swimming crabs at Ubatuba and Caraguatatuba areas, northern coast of São Paulo state, Brazil. A total of 1,057 individuals were collected in Ubatuba, including 598 males (525 juveniles and 73 adults) and 459 females (379 juveniles and 80 adults, including 15 ovigerous crabs). In Caraguatatuba 5,112 individuals were collected, of which 3,138 males (2,638 juveniles and 500 adults) and 1,974 females (1,746 juveniles and 228 adults, including 29 ovigerous crabs). The sex-ratio favors the number of males in both regions, probably because females have the habit of occupying deeper regions. The size classes' frequency distribution shows polymodality for both sexes, except for males in Ubatuba. This is the result of some age groups among the juveniles, which migrate to shallower areas, being affected by the fishing activity. Adults have the habit of staying in deeper areas characterized by colder waters.

Keywords: Brachyura, sex-ratio, Decapoda, bycatch, size distribution.

Resumo

O siri candeia, *Achelous spinicarpus*, é comumente capturado como "*by catch*" da pesca camaroeira. Este estudo avaliou alguns aspectos de sua estrutura populacional, como razão sexual e distribuição de frequência em classes de tamanho. Para coletar os siris, foi utilizado um barco de pesca camaroeiro equipado com redes "*double rig*" nas áreas de Ubatuba e Caraguatatuba, litoral norte do estado de São Paulo, Brasil. Um total de 1.057 indivíduos foi coletado em Ubatuba, incluindo 598 machos (525 juvenis e 73 adultos) e 459 fêmeas (379 juvenis e 80 adultas, incluindo 15 ovígeras). Em Caraguatatuba, 5.112 indivíduos foram coletados, dos quais 3.138 machos (2.638 juvenis e 500 adultos) e 1.974 fêmeas (1.746 juvenis e 228 adultas, incluindo 29 ovígeras). A razão sexual favoreceu o número de machos em ambas as áreas, provavelmente devido ao hábito de as fêmeas ocuparem regiões mais profundas. A distribuição de frequência em classes de tamanho apresentou polimodalidade para ambos os sexos, exceto para machos em Ubatuba. Isso é resultado de alguns grupos etários entre os juvenis, os quais migram para áreas mais rasas, sendo afetados pela atividade pesqueira. Os adultos permanecem em áreas mais profundas, caracterizadas por águas frias.

Palavras-chave: Brachyura, razão sexual, Decapoda, *by catch*, distribuição de tamanho.

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Introduction

The decapod crustaceans of the superfamily Portunoidea, popularly known as "swimming crabs", play a key role in the trophic web of coastal ecosystems, acting as predators of various groups of invertebrates and fishes (Branco and Lunardon-Branco, 2002). On the northern coast of São Paulo, this group is very abundant and presents one of the highest values in species richness, when compared to other brachyurans (Braga *et al*., 2005; Bertini *et al*., 2010a). Furthermore, many species of portunoids have a strong fishing potential and high commercial value, constituting an important food resource in most coastal cities. Among them, the species of the genus *Callinectes* Stimpson, 1860 are much exploited (Severino-Rodrigues *et al*., 2001), especially at the Western Atlantic Coast.

The swimming crab *Achelous spinicarpus* (Stimpson, 1871) has a wide geographic distribution along the Western Atlantic coast, occurring from North Carolina (United States of America) to Rio Grande do Sul (Brazil) (Melo, 1996). Since this species has no commercial value, it is discarded when captured by fishers. However, it plays a relevant ecological role in the food web by acting both as a predator and as prey and constituting an important food item for some fish species (Viana *et al.*, 2014; Motta *et al*., 2016).

Studies focusing on *A. spinicarpus* are rare. In this sense it is possible to highlight only some works, such as Corbi-Corrêa and Fransozo (2002) and Pardal-Souza and Pinheiro (2013), evaluating some morphometric relationships and estimating the size at morphological maturity in southeastern Brazil, and Sanvicente-Añorve *et al*. (2008) on the same subject, in the Gulf of Mexico. Ogawa and D'Incao (2010) carried out a study on the growth of individuals from population collected in the northern coast of Santa Catarina. Lima *et al*. (2014) studied the ecological distribution of *A. spinicarpus* and *A. spinimanus* (Latreille, 1819) from Ubatuba region.

The swimming crab *A. spinicarpus* is considered a bioindicator of cold water masses (Pires, 1992; Lima *et al*., 2014), such as the appearance of the South Atlantic Central Water (SACW) in southeastern coast of Brazil, which causes an increase of nutrients in the region, favoring primary production. According to Pires (1992) and Andrade *et al.* (2015a), this water mass may affect the dynamics of decapod crustacean assemblages, so that their population structure (Andrade *et al*., 2015b).

Due to SACW influence and other peculiarities of the southeastern Brazilian coast, this locality has been the target of many community studies involving species richness, abundance and diversity of decapod crustaceans, in order to better understand the dynamics of the region's biodiversity (Fransozo *et al*., 2012; Bertini *et al*., 2010a; De Léo and Pires-Vanin, 2006; Alves *et al*., 2013; Furlan *et al*., 2013; Andrade *et al*., 2015a). Despite the large number of studies involving the decapod crustacean community on the north coast of São Paulo, studies at more specific ecological levels, such as populations, are necessary to understand the interactions that determine the biotic dynamics in these environments (Mantelatto *et al*., 1995; Braga *et al*., 2007). Thus, considering the importance of *A. spinicarpus* as a component of the assemblage of Portunoidea (Lima *et al*., 2014) this study aimed to investigate the structure of its population in a region affected by shrimp fishing in the southeast coast of Brazil, evaluating the sex ratio and frequency distribution of individuals in size classes.

Material and methods

Study areas

According to Mahiques (1995), due to its close proximity to the Serra do Mar, the southeastern Brazilian coast is characterized by a high number of coves and a cut relief, making its internal borders very irregular. These

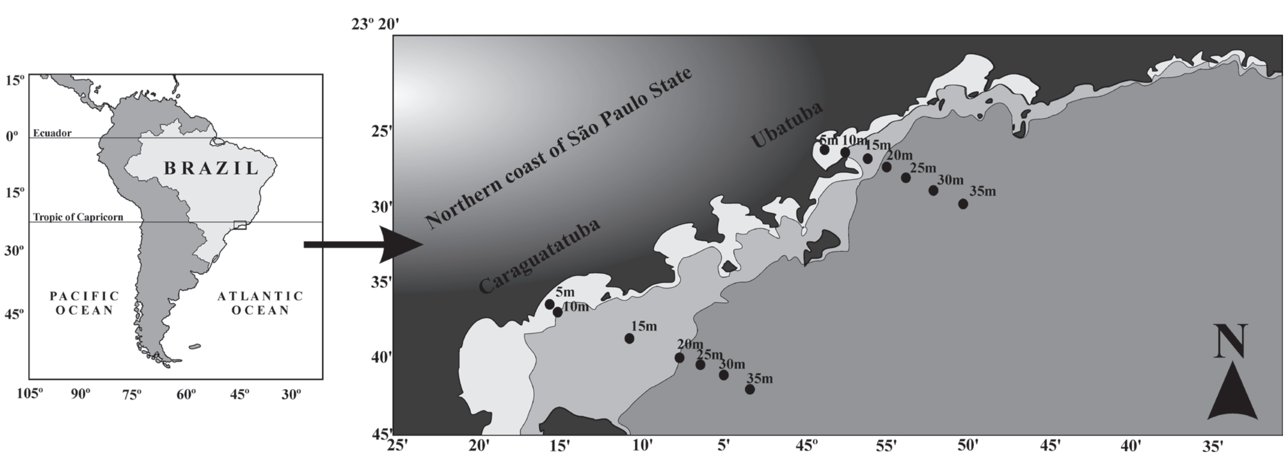

Figure 1. Collection sites in the studied areas in São Paulo northern coast, Brazil.

aspects allow the formation of diverse microhabitats favoring marine biotic development and establishment (Negreiros-Fransozo *et al*., 1991).

The sampled regions in this study, both located on the north coast of the state of São Paulo, Brazil, differ in their hydrogeographic characteristics. The Ubatuba littoral area (23º 26' - 23º 31'S, 44º 55' - 45º 03' W) presents a diverse combination of environmental variables such as texture and amount of organic matter in the sediment, temperature and salinity of the water, which favors the occurrence of many decapod crustaceans (Mantelatto and Fransozo, 1999). In contrast, the Caraguatatuba littoral area (23° 36' - 23º 40'S, 45º 07' - 45° 25'W) presents a more homogeneous variation of these same environmental factors, because it is sheltered from the direct action of the waves and winds by the São Sebastião Island, showing bottom morphology with slightly variations (Barros *et al*., 1997). These areas are influenced by three water masses that, when compared to each other, have peculiar characteristics and distinct models of distribution throughout the year (Pires, 1992): Coastal Water (Temperature > 20 °C and Salinity < 36), Tropical Water (T > 20 °C and S > 36), and South Atlantic Central Water (T < 18 °C and S < 36) (Castro-Filho *et al*., 1987).

Biological data

The crabs were collected monthly from July 2001 to June 2003 in Ubatuba (UBA) and Caraguatatuba (CAR) areas, northern coast of São Paulo state. Seven sampling points were delimited in each region, at depths of 5, 10, 15, 20, 25, 30 and 35 m (Figure 1). For this, a shrimp fishing boat equipped with double-rig trawls was used. Each net has an opening of approximately, 4.5 m with distances between nodes of 20 and 15 mm, respectively, in the main net body and in the terminal cod. Each point was sampled for 30 minutes of trawling, covering an area of 18,000 m².

Collected crabs were identified according to Melo (1996), with sex determined by observing the abdominal morphology (triangular, males; rounded, females) and pleopods number (2 pairs, males; 4 pairs, females). Each swimming crab was measured using a caliper (0.01 mm) at their maximum carapace width (CW), excluding the lateral spine. All individuals were classified into demographic groups according to Haefner (1990), differentiating juveniles (immature) and adults (mature) by shape and adherence of the abdomen to thoracic sternites. Such groups are: juvenile males (JM), adult males (AM), juvenile females (JF), adult females (AF) and ovigerous females (OF).

Data analysis

The data were tested for normality (Shapiro Wilk test) and homoscedasticity (Levene test). Size (CW) was compared between sexes in each area (UBA_{males} VS. $UBA_{females}$, CAR_{males} VS. $CAR_{females}$) and within the same sex between areas (UBA_{males} VS. CAR_{males}; $UBA_{females}$ VS. $CAR_{females}$) by Student's *t* test.

The sex-ratio of the total individuals in each area was compared by the binomial test (Wilson and Hardy, 2002) to verify possible deviations from the 1:1 ratio. The population structure was evaluated based on the arbitrary distribution of individuals in size classes with a range of 2.3 mm and verification of the modal peaks.

In all analyzes, the level of significance was $\alpha = 0.05$ (Zar, 2010). Peakfit software version 4.12 (Sea Solve Software Inc., 1999 - 2003) was used to verify the existence of the modal peaks of the size class distribution.

Results

A total of 1057 individuals were collected in the Ubatuba area, of which 598 males (525 juveniles and 73 adults) and 459 females (379 juveniles and 80 adults, including 15 ovigerous). In the Caraguatatuba area, 5112 individuals were collected, of which 3138 males (2638 juveniles and 500 adults) and 1974 females (1746 juveniles and 228 adults, including 29 ovigerous).

The mean size of male individuals in the Ubatuba area was 19.7 ± 4.8 mm (minimum = 5.5 mm, maximum = 58.3 mm) and the mean size of females was 20.2 ± 5.6 mm (minimum = 8.2 mm, maximum = 55.5 mm). There was no difference in size between male and female ($t = -1.47$, $p = 0.14$). In Caraguatatuba there was no difference between the mean male (18.3 ± 4.4 mm, minimum = 10.1 mm, maximum = 41.9 mm) and female sizes (18.4 ± 4.8 mm, minimum = 9.8 mm, maximum = 40.7 mm) ($t = -0.56$, $p = 0.57$). When comparing the mean size of the individuals between areas, it was verified that males and females had larger mean sizes in Ubatuba than in Caraguatatuba ($t = 6.95$, $p < 0.01$ and $t = 7.17$, $p < 0.01$ respectively). The mean and standard deviation values of the male and female individuals' sizes in each area are shown in Figure 2.

The sex-ratio was significantly different from the 1:1 (male:female) pattern both in Ubatuba (1:0.7) as Caraguatatuba (1:0.6) (binomial test, $p < 0.05$), and thus more males were found in both areas. The frequency distribution analysis of size classes presented bimodal pattern for males and polymodal (with three peaks) for females in the Ubatuba area. In Caraguatatuba the pattern was polymodal for both sexes, with 4 and 3 peaks for males and females, respectively (Figure 2).

Discussion

Usually, males of the Brachyura species, which inhabit the marine environment, reach a larger body size than females, thus defining the competitive ability to access

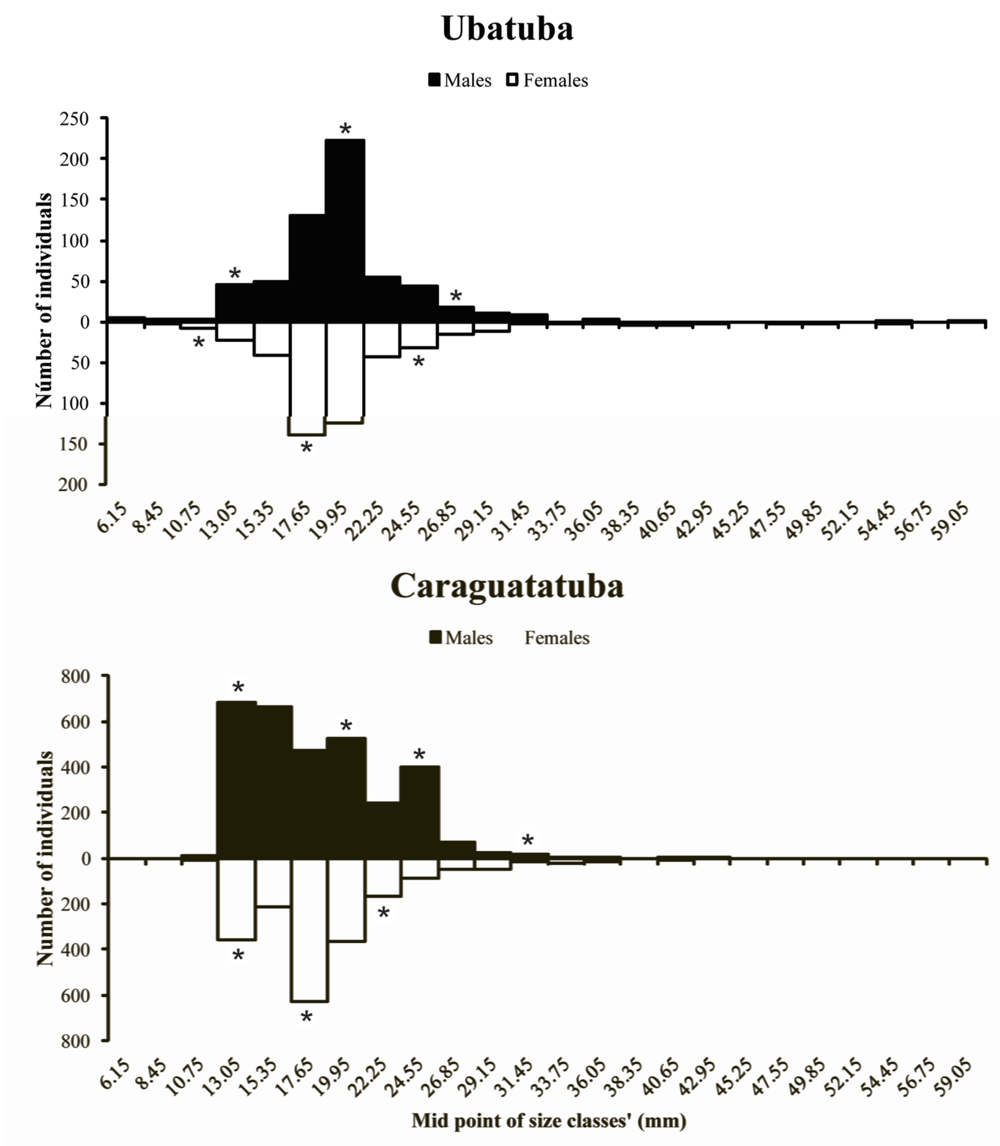

Figure 2. *Achelous spinicarpus* (Stimpson, 1871). Frequency distribution in size classes for males and females with indication of modal peaks (*) in the Ubatuba and Caraguatatuba areas, São Paulo northern coast, Brazil.

receptive females, as well as protecting them during copulation (Hartnoll, 1969). Thus, males invest more energy in somatic growth than females (Hartnoll, 1982). However, the absence of difference between the mean males and females sizes reveals that, for *A. spinicarpus*, size cannot be considered as an indication of sexual dimorphism. Such pattern is not common for Brachyura, since size difference has already been related in Southeastern Brazilian coast (Bertini *et al*., 2010b; Almeida *et al*., 2013; Fransozo *et al*., 2013; Silva *et al*., 2014; Andrade *et al*., 2015c). However, a different pattern was also observed by Ogawa and D'Incao (2010) for *A. spinicarpus*, who collected samples from 10 to 100 m in depth and described females with mean sizes larger than males. The results described by Sanvicente-Añorve *et al*. (2008), who collected this species in the Gulf of Mexico (unspecified depths), indicate similar mean size between males and females.

In nature, populations in which males and females do not present major morphological differences are those in which males do not undergo intraspecific competitions for females. This is common in populations with very high densities, such as *A. spinicarpus*, which was the second most abundant Brachyura species in Ubatuba and the first in Caraguatatuba (Braga *et al*., 2005). Populations of this species can occur at so high densities in some depths that, according to a study by Pires (1992), in the Ubatuba region, *A. spinicarpus* comprised about 90% of the megafauna in areas affected by the water mass South Atlantic Central Water.

Although the abundance of *A. spinicarpus* was higher in Caraguatatuba, the mean size of the individuals at this site was lower than in Ubatuba. According to Braga *et al*. (2005), Ubatuba presents a high abundance of other species of portunids (possible competitors), more than in Caraguatatuba. Therefore, the fact that Ubatuba presents a greater number of possible competitors may have affected the occurrence of larger individuals in this area.

Just after the birth, the sex-ratio tends to be close to 1:1. Nevertheless, along the ontogenetic development, factors such as longevity, mortality and differential growth between the sexes can affect this relation (Wenner, 1972; Hartnoll, 1982). In addition, differential behavior among demographic groups can also cause deviations in Mendelian patterns. Pinheiro *et al*. (1996) verified a pattern of differential distribution by demographic groups of the swimming crab *A. cribrarius*, in which juveniles and adult males occupied shallower areas, whereas adult and ovigerous females were found in deeper areas. According to Pinheiro and Fransozo (1999), this fact occurs because females in reproductive activity migrate to deeper regions, which are more susceptible to the influence of water masses, so that a more efficient dispersion of the larvae occurs after spawning. Thus, demographic groups are susceptible to be captured in different abundances, according to their distribution.

The differential occupation of space by demographic groups of *A. spinicarpus* was confirmed by Silva (2015), in Ubatuba and Caraguatatuba, whose study suggests that abiotic factors such as temperature, salinity and sediment characteristics influence the distribution of the demographic groups of this species. This feature may represent an ontogenetic ecological niche strategy, in that individuals occupy different spaces throughout development, reducing intraspecific competition by resources (in this case, space). Therefore, the deviation from the 1:1 pattern of sex-ratio for *A. spinicarpus* found in the present study could be caused by the differential occupation by demographic groups at the sampling points. In addition, the collections may have covered only the main occupation area of the juveniles, since this species extends its distribution to 500 m (Melo, 1996). This also explains the high number of juvenile individuals found during the collections and the low number of ovigerous females, since these would be in deeper areas (Ogawa and D'Incao, 2010; Pardal-Souza and Pinheiro, 2013).

According to Díaz and Conde (1989), bimodality or polymodality are usually reflections of recruiting pulses, differential or catastrophic mortality, or behavioral differences. The possibility of behavioral differences, mainly related to the occupation of non-sampled areas in this study, cannot be ruled out, since groups of individuals of different sizes, mainly ovigerous females, can be spatially segregated, occupying deeper and non-sampled areas in this study, as suggested by Negreiros-Fransozo and Fransozo (1995) and Negreiros-Fransozo *et al*. (1999) for *C. ornatus*, in the Fortaleza and Ubatuba coves, Ubatuba area.

The importance of the studied areas as places of juvenile development of *A. spinicarpus* is evident. This is justified by the high number of captured juvenile individuals. The lack of information about this species hinders the clarification of some questions suggested in this paper, for instance, if differential distribution occurs among demographic groups. Studies aiming at characterize the spatio-temporal distribution, reproduction features and juvenile recruitment can serve as important tools that may help to understand such aspects, especially in areas such as Ubatuba and Caraguatatuba, where the growing expansion of tourism and fishing activity can cause environmental impacts.

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