POPULATION STRUCTURE OF THE GHOST SHRIMP CALLICHIrus MAJOR (CRUSTACEA, AXIIDEA, CALLICHIridAE) IN A SOUTHEAST BRAZILIAN BEACH

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ABSTRACT. – The aim of this study was to evaluate the population structure of Callichirus major from a sandy beach in Southeast Brazil and compare the results with previous studies along the Brazilian coast. Some of the evaluated parameters (e.g., population density and size of males and females) differed from other populations established in Brazil. The abundance of individuals varied considerably throughout the sampling period. The dorsal oval length (DO) of males, females, and ovigerous females was 6.55-15.65 mm (10.32 ± 2.5 mm), 5.95-15.05 mm (10.78 ± 2.5 mm), and 10.3-15.0 mm (13.03 ± 1.24 mm), respectively. The bimodal size class distribution of the population may indicate recruitment peaks. There was no significant deviation from the expected 1:1 overall sex ratio throughout the sampling periods and size classes. The average population density was estimated to 0.202 ± 0.494 ind m⁻² (0-4 ind m⁻²). The variations in the evaluated parameters among different populations studied are probably related to differences in environmental and latitudinal conditions and possibly to the influence of human activity in certain localities.

INTRODUCTION

Representatives of the family Callianassidae Dana, 1852 and related families (Crustacea: Decapoda; Axiidea) (sensu Poore et al. 2019 and Robles et al. 2020) play an important role in benthic unconsolidated sediments (Botter-Carvalho et al. 2007). These ghost shrimps promote bioturbation and directly influence the chemical (Waslenchuk et al. 1983, Ziebis et al. 1996, Bird et al. 2000, Webb & Eyre 2004) and physical (Wynberg & Branch 1994) properties of the sediment. Some Callianassidae species build gallery systems that are used as microhabitats by other organisms (Berkenbusch & Rowden 2003) such as bivalves, copepods, tanaidaceans (Rodrigues & Shimizu 1997), bacteria (Dworschak 2000), and symbiotic pinnotherid crabs (Peiró et al. 2014a).

Callichirus major (Say, 1818) (popularly known in Brazil as “corrupto” and “camarão fantasma”) typically inhabits dissipative sandy beaches (Rodrigues & Shimizu 1997, Botter-Carvalho et al. 2002, Abrunhosa et al. 2008) along the western Atlantic coast from the southeastern USA to the state of Santa Catarina, Brazil. This species lives inside deep galleries in intertidal or shallow sub-tidal areas and displays cryptic behavior (Rodrigues & Shimizu 1997). The unsatisfactory knowledge about the systematics of Callichirus major has been recently addressed in an oncoming publication (FLM pers. comm.). Therefore, we only considered for comparisons the taxonomic entity found between the biogeographic barriers of the Brazilian coast, from the Amazon River (state of Pará) to the southern occurrence area of the species (state of Santa Catarina) (sensu Felder & Robles 2009).

Since the 1980s, C. major has been commonly used as bait in commercial and recreational fishing activities along the Brazilian coast (Souza & Borzone 2003). Similar to other species of Axioidea and Gebiidea, C. major is regarded as a bait of excellent quality and has an expressive economic importance (Skilleter et al. 2005). In Ubatuba, a coastal city in the state of São Paulo, Brazil, the amateur fishing activity is intensified during the summer (Peiró & Mantelatto 2011) and the uncontrolled capturing of these crustaceans can affect their population and the associated community (Wynberg & Branch 1994). Aiming at the protection of C. major, the fishing activity has been banned since 1992 in Praia do Gonzaga, in Santos municipality in the state of São Paulo (Rodrigues & Shimizu 1997; Rio et al. 2019). Based on the most recent criteria established by the International Union for Conservation of Nature and Natural Resources – IUCN (2013) to assess the conservation status of a taxon, C. major has been recently classified within the threatened category Data Deficient (DD) (Peiró & Mantelatto 2016). The species was inserted within this category due to the impossibility of estimating the impact of human activity on its population along the Brazilian coast (Peiró & Mantelatto 2016).

Considering the IUCN DD category in which C. major is inserted and the potential impact of human activities on populations of the northern coast of the state of São Paulo, information on aspects of the population structure is crucial to the preservation of the species and the surrounding environment. The aim of this study is to evaluate aspects of the population structure of C. major in a sandy beach in Ubatuba São Paulo, Brazil, and compare the results with those of previously studied populations from the Brazilian coast. Considering the intense human disturbance in the study area at certain times of the year (Peiró & Mantelatto 2011), our hypothesis is that the C. major population of Ubatuba has a lower density and population structure features different from populations from preserved dissipative beaches of the Brazilian coast.

MATERIALS AND METHODS

Study area and sampling procedures: Sampling was conducted in the intertidal zone of the Perequê-áçu beach (23°24’S, 45°03’W), in Ubatuba, state of São Paulo, Brazil, southwestern Atlantic Ocean (Fig. 1). The area, located in the northern part of the Ubatuba Bay, is a semi-protected and dissipative beach of fine-grain sand and low slopes (Peiró et al. 2014b).

Samples were conducted during low tides (neap) in the daytime throughout the 1-year sampling period. In order to avoid major disturbances in the small C. major population of Perequê-áçu beach, sampling was bimonthly conducted (September 2008-July 2009), similar methodology that conducted
by Pescinelli et al. (2018) for an alpheid shrimp population in mud bottom. Individuals were collected from their galleries with two plastic sucking pumps (yabby pumps) (1 m length and 5 cm tube diameter), according to methodology described by Hailstone & Stephenson (1961) and Manning (1975). Although the fine-grained gallery sediment collapses easily, the sampling success was achieved by pumping each gallery opening twice. It is worth mentioning that the collapse of the sediment guaranteed that each gallery was sampled only once (Alves & Pezzuto 1998).

Water temperature and salinity were measured before each sampling with a common thermometer and an optical refractometer, respectively. The sampled ghost shrimps were individually placed in labelled plastic bags and frozen until the subsequent analysis in laboratory. After analysis, individuals were preserved in 80 % ethanol into labelled vials.

**Ghost shrimp analysis:** Body size estimates were based on the length of the dorsal oval (DO). This oval-shaped rigid structure provides accurate measurements of the carapace and has been widely used as an informative dimension of the body size (i.e. Manning & Felder 1991, see Heard et al. 2007 for an explanatory sketch). Each individual had their DO length measured with a calliper (precision: 0.05 mm). Males and females were identified by the positioning of the gonopore on the coxa of the fifth pereiopod and on the coxa of the third pereiopod, respectively (Souza et al. 2018). Ovigerous females were identified by the presence of eggs attached to the pleopods.

Voucher individuals were deposited in the Crustacean Collection at the Department of Biology, Faculty of Philosophy, Science and Letters at Ribeirão Preto, University of São Paulo (CCDB/FFCLRP/USP) under catalogue: CCDB 0363.

**Population structure:** The data normality was checked with the Shapiro-Wilk test (Zar 1996) and parametric tests were applied when data met the model assumptions; otherwise, equivalent non-parametric tests were used. To evaluate the relationship between the environmental parameters (water temperature and salinity) and abundance of individuals in each sample, the Pearson’s product-moment correlation coefficient was conducted. The DO size frequency distribution was calculated based on 1 mm length intervals and data were plotted as length-frequency histograms to analyze the population structure (Botter-Carvalho et al. 2007).

Deviations from the expected 1:1 sex ratio (male:female) were calculated with the Fisher’s exact test (Fisher 1934) based on the total number of males and females in the entire sample, in each sampled month, and in each size class. The sex ratio classification followed the patterns described by Wenner (1972) which include four classifications (pattern, reverse, intermediate, and anomalous). Sex ratio classifications for the Brazilian crustacean species, such as the ‘Predominance Pattern’ (Terossi & Mantelatto 2010) and ‘Near Pattern’ (Peiró & Mantelatto 2011), were also used.

Differences between the average size of males and females were tested using the Student t test. Reproductive and recruitment periods were identified by the proportion of ovigerous females in relation to the total number of females (Pinheiro & Fransozo 2002) and by the presence of juveniles in the samples (Alves & Pezzuto 1998), respectively. All statistical tests were conducted according to Zar (1996), adopting the significance level of p < 0.05.

**Population density estimation and capture efficiency:** The population density estimation was performed in a pre-chosen fixed area in the intertidal zone of the beach different from the area where the individuals were sampled. This area is located 46 m apart from a fixed reference point (23°24'59.99"S; 45°03'17.13"W), between the upper distribution limit of the species and the waterline on 0.0 m tidal, extending for approximately 30 m. Following the recommendations of Shimizu & Rosso (2000), the upper limit of the species distribution should be avoided during the samplings due to the very low densities of individuals in this area. In a preliminary study conducted six months before the beginning of the sampling, no individuals were found in the species upper distribution limit. To estimate the population density, in each month a 1 m² quadrant was randomly thrown 108 times in the established area to count the gallery openings. The density was estimated based on the number of openings per square meter (ind m⁻²). Each opening was considered a single gallery with only one individual (Rodrigues & Shimizu 1997).

The capture efficiency was monthly estimated as the percentage of individuals effectively captured in relation to the total number of gallery openings counted during the density estimation.

**RESULTS**

**Environmental parameters**

The water temperature ranged from 23 ºC (November 2008 and July 2009) to 28 ºC (March 2009) (24.7 ± 2.0 ºC) throughout the study period, demonstrating a seasonal variation with lower temperatures in winter and higher in summer. Salinity widely ranged during the study period, with a minimum of 16 psu in March 2009 and a maximum of 32 psu in September 2008 (27.2 ± 5.7).

Temperature and salinity were not statistically related to each other (r = –0.46; p = 0.301). There was not a significant relationship between salinity (r = –0.125, p = 0.789) and temperature (r = –0.237; p = 0.608) with the total number of individuals or the number of males, total females, ovigerous females, and juveniles (p > 0.05).

**Population structure**

**Abundance and size of individuals**

A total of 164 ghost shrimps were sampled, 67 males (40.9 %) and 94 females (57.3 %) of which 24 were ovi-
gerous (14.6 %). From the total, three individuals (1.8 %) were damaged and therefore their sex could not be determined and eight sexed individuals were unable to have the DO measured. The number of individuals sampled oscillated throughout the year, ranging from 7 (March 2009) to 49 (November 2008) (Table I).

![Graph showing size frequency distribution of Callichirus major](image)

Fig. 2. – *Callichirus major* (Say, 1818), size frequency distribution of individuals collected in Ubatuba, state of São Paulo, Brazil. Unidentified individuals (UI), dorsal oval length (DO).

The DO length ranged from 6.55 to 15.65 mm (10.32 ± 2.25 mm) in males, 5.95 to 15.05 mm (10.78 ± 2.5 mm) in females, and 10.3 to 15.0 mm (13.03 ± 1.24 mm) in ovigerous females. There was no significant variation in the DO length of males and females (t-test: 1.19; p = 0.2377).

The total population had bimodal size class distribution (Shapiro-Wilk, p = 0.001), with higher abundances in the 7-11 mm (comprised almost equally by males and females) and 13-14 mm (comprised mainly by ovigerous females) size classes (Fig. 2).

Juveniles (5-7 mm size class) were sampled mainly in May 2009. The percentage of ovigerous females in relation to the total number of females was 25.5 % (24 individuals), ranging from 13.8 % (July 2009, n = 4) to 100 % (March 2009, n = 3) (Table I, Fig. 3). Ovigerous females were sampled in almost all months, except for May 2009, with a high abundance in November 2008 (38.5 %; n = 10).

**Sex ratio**

The abundance of females was higher in most of the
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The overall sex ratio was 0.7:1 (M:F), not significantly different from the expected 1:1 (p = 0.145); the same pattern was observed when months and size classes were evaluated separately (Fig. 4).

Population density estimation and capture efficiency

The average population density was 0.202 ± 0.494 ind m$^{-2}$ (0-4 ind m$^{-2}$, N = 108) and had a clear oscillation throughout the sampling period (Table I). The lowest average density was in January 2009 (0.042 ± 0.201 ind m$^{-2}$) and the highest in July 2009 (0.398 ± 0.773 ind m$^{-2}$). The overall capture efficiency was 26.6 % and the minimum efficiency occurred in March 2009 (11.5 %), following an efficiency decrease initiated in the previous sampling period (January: 30.4 %). The maximum capture efficiency was in November 2008 (43.5 %) (Table I).

DISCUSSION

The population of C. major from Ubatuba had low densities, partially confirming our hypothesis, considering that other features of its structure (e.g. average sizes of male and female, sex ratio, and size of the smaller ovigerous female) were mainly similar to those of other previously studied populations from the Brazilian coast (Table II). The variation noticed for these features can be attributed to differences in the environmental and latitudinal conditions where the populations are established (i.e. Bauer 1992, Lardies & Castilla 2001, Wehrtmann et al. 2012) and possibly to the influence of human activity in some areas as discussed below.

The total abundance varied considerably throughout the sampling period. The lowest abundance was recorded in March 2009 and may be related to an increased bait catch activity in the previous summer months (December and January), when fishermen and tourists intensify their fishing activities (Peiró & Mantelatto 2011). The highest total abundance and the highest abundance of ovigerous females (38.5 % of the total female) were recorded in November 2008, right before the high fishing demand in summer.

As an alternative and nonexclusive hypothesis, we could presume that these variations in abundance were related to natural perturbations caused by climatic events. Even with the high variation in salinity recorded throughout the sampling period, this parameter (and temperature) was not related to the total number of individuals from all the demographic categories. However, the variation in salinity can be related to the rainfall periodicity in the region. Salinity was higher in the dry season and lower in the rainy season. The precipitation in Ubatuba during the summer generally reaches an average of 300 mm (www.climate-data.org). Despite their fossorial nature,

Table I. – Population parameters of CalliChirus major (Say, 1818) collected in Ubatuba, state of São Paulo, Brazil. Unidentified individuals (UI). Density of individuals (openings) per square meter (ind m$^{-2}$) and standard deviation (± sd). Capture efficiency percentage (Capture %).

<table>
<thead>
<tr>
<th>Sampling periods</th>
<th>N° of individuals</th>
<th>Density</th>
<th>Capture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Males</td>
<td>Females (ovigerous)</td>
</tr>
<tr>
<td>Sep. 2008</td>
<td>21</td>
<td>11</td>
<td>9 (2)</td>
</tr>
<tr>
<td>November</td>
<td>49</td>
<td>21</td>
<td>26 (10)</td>
</tr>
<tr>
<td>Jan. 2009</td>
<td>24</td>
<td>11</td>
<td>13 (5)</td>
</tr>
<tr>
<td>March</td>
<td>7</td>
<td>4</td>
<td>3 (3)</td>
</tr>
<tr>
<td>May</td>
<td>16</td>
<td>2</td>
<td>14 (0)</td>
</tr>
<tr>
<td>July</td>
<td>47</td>
<td>18</td>
<td>29 (4)</td>
</tr>
<tr>
<td>Total</td>
<td>164</td>
<td>67</td>
<td>94 (24)</td>
</tr>
</tbody>
</table>

Fig. 4. – CalliChirus major (Say, 1818) collected in Ubatuba, state of São Paulo, Brazil. A: Sex ratio males/females (M:F) by sampled month; B: Percentage of males in relation to total number of males and females by size class. Dorsal oval length (DO).

Table II. – Population parameters of CalliChirus major (Say, 1818) collected in Ubatuba, state of São Paulo, Brazil. Unidentified individuals (UI). Density of individuals (openings) per square meter (ind m$^{-2}$) and standard deviation (± sd). Capture efficiency percentage (Capture %).

<table>
<thead>
<tr>
<th>Size class (mm)</th>
<th>N° of individuals</th>
<th>Density</th>
<th>Capture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>6</td>
<td>0.398 ± 0.773</td>
<td>18.8</td>
</tr>
<tr>
<td>6-7</td>
<td>12</td>
<td>0.241 ± 0.471</td>
<td>11.5</td>
</tr>
<tr>
<td>7-8</td>
<td>10</td>
<td>0.056 ± 0.232</td>
<td>41.7</td>
</tr>
<tr>
<td>8-9</td>
<td>12</td>
<td>0.222 ± 0.439</td>
<td>43.5</td>
</tr>
<tr>
<td>9-10</td>
<td>21</td>
<td>0.098 ± 0.299</td>
<td>13.9</td>
</tr>
<tr>
<td>10-11</td>
<td>24</td>
<td>0.042 ± 0.201</td>
<td>30.4</td>
</tr>
<tr>
<td>11-12</td>
<td>16</td>
<td>0.222 ± 0.439</td>
<td>43.5</td>
</tr>
<tr>
<td>12-13</td>
<td>11</td>
<td>0.098 ± 0.299</td>
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<td>13-14</td>
<td>24</td>
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<tr>
<td>14-15</td>
<td>47</td>
<td>0.398 ± 0.773</td>
<td>18.8</td>
</tr>
<tr>
<td>15-16</td>
<td>67</td>
<td>0.202 ± 0.494</td>
<td>26.6</td>
</tr>
<tr>
<td>Total</td>
<td>164</td>
<td>94 (24)</td>
<td>26.6</td>
</tr>
</tbody>
</table>

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Callichirus species are sensitive to perturbations caused by tropical storms that carry the substrates they occupy and may generate massive changes in the population structure (Felder 2001, Bilodeau & Bourgeois 2004). Thus, eventual large freshwater discharges during summer could cause high mortality, decreasing the abundance in the subsequent months. Periodic decreasing densities in populations of Callichirus can be also associated with reductions in the bioturbation activity because decreased bioturbation reduces the gallery orifice or make it less frequently opened, leading to an underestimation of abundance (Posey 1986, Souza & Borzone 2019). In our study, there were no significant differences in the DO length of males and females. However, males were often larger than females. This seems to be a common feature in this species (Table II) and is probably related to the larger amount of energy females direct to reproductive activities in detriment of body growth (Shimizu & Rodrigues 2000). Regarding the population structure, our results were partially similar to observations of Shimizu & Rodrigues (2000) for another population from São Paulo state, i.e. there is a predominance of adult individuals in almost every sampling month (Fig. 3). However, the population studied by the aforementioned authors had a normal distribution, while our evaluation showed an abrupt decrease in the population abundance in the 10-14 mm size classes after an abundance peak in the 9-10 mm size class (Fig. 2). The reported over capture in summer might have favored the juvenile settlement, influencing population structure (Rodrigues & Shimizu 1997). The pressure of this over capture can generate a modal shift in the population structure to smaller size classes linked to the more intense recruitment allowed by the reduced competition for space. The reduced competition occurs due to the removal of largest individuals (Rodrigues & Shimizu 1997, Shimizu & Rodrigues 2000) since the bait catch season would be effective, similar to that established for the commercial penaeid shrimp trawling and mangrove crabs catching in certain regions of Brazil. In addition, studies estimating the genetic variability of these populations could serve as baseline to provide indicators of the gene flow between populations and more detailed management studies (Teodoro et al. 2015, Buranelli et al. 2019).

The high abundance in November, followed by a decrease after summer, could indicate that this population has been going through an adaptive process of recovering after the intense exploitation activity. The populations of C. major in the north coast of the state of São Paulo have been exploited as baits for recreational and commercial fishing for over 30 years by the native fishermen community (FLM and DFP personal observations). However, a long-term monitoring is required to confirm this hypothesis and to evaluate the effect of the bait catch activity on the size and sexual maturity of populations. Before a municipal decree prohibiting the capture of C. major in Santos, state of São Paulo, in 1992, evaluations demonstrated a decrease in the size of individuals caused by the intense bait catch activity (Rodrigues & Shimizu 1997). Since the complete interruption of this activity is practically unfeasible as it also involves socioeconomic aspects and constant monitoring, alternative preservation actions could be implemented. The establishment of a closed fishing area (Ovigerous females) and constant monitoring, alternative preservation actions
activity aims at adult individuals, making the predatory effect more significant to them (Botter-Carvalho et al. 2007).

Although the average and maximum size of individuals from different populations of the state of São Paulo are similar, individuals from northernmost Brazil populations are smaller (state of Pernambuco, Botter-Carvalho et al. 2007). The minimum size of ovigerous females, indicating the size at the onset of sexual maturity, is also larger in populations from the coast of São Paulo (Table II). These differences may be related to variations in the environmental parameters associated with the latitude where the populations are established, as demonstrated for other marine decapod crustaceans (Bauer 1992, Castilho et al. 2007). Unfortunately, a more detailed comparison between populations from different latitudes is impaired by the distinct methodology used by the authors to estimate the size of individuals (see Table II, for details). In this context, Shimizu & Rodrigues (2000) explained that the DO length provides a more accurate size estimation than the carapace length (CL) since DO has better defined contours and is more calcified; moreover, it is linearly correlated to the CL. The use of other size estimations, such as the CL and the lineanthalassinica (LL), can lead to measurement inconsistencies or errors since the exoskeleton of individuals has relatively soft regions that are easily damaged by the suction pump. Thus, we argue for a standardization in the use of DO length as an estimation of the total body size of ghost shrimps, as suggested by Shimizu & Rodrigues (2000). This standardization will allow future trustworthy comparisons and serve as baseline for the stipulation of the minimum capture size and preservation periods.

The overall sex ratio was not significantly different from Fisher’s principle (1930), i.e., natural selection favors an equal male:female ratio in the offspring of animal species. However, deviations from this ratio are very common among marine crustaceans (Terossi & Mantelatto 2010, Peiró & Mantelatto 2011). These deviations can be attributed to differences in the life cycle, migration, mortality, and differential growth between sexes (Wenner et al. 1974). Although the number of females was higher in most of the sampled months and in nearly all size classes, the difference was not statistically significant. It is noteworthy that in May 2009 there was a higher discrepancy between sexes, i.e., we captured two males and 14 females, resulting in a p-value of the Fisher’s test of 0.0538, which is very near of a significant value. So, it is possible that these non-significant values were influenced by the low abundances of the studied population.

Considering the overall sex ratio pattern observed, the studied population probably fits the ‘Predominance Pattern’ (proposed by Terossi & Mantelatto 2010), in which there is a predominance of one of the sexes in nearly all size classes. A sex ratio favouring females is a common feature of the group, and was observed in C. major (Table II), Audacallichirus mirim (Rodrigues, 1966) (Pezzuto 1998, as Sergio mirim), Trypaea austrosulcans Dana, 1852 (Hailstone & Stephenson 1961), Filholfianassa filhol (A. Milne-Edwards, 1878) (Devine 1966, as Bifarius filholi), Lepidophthalmus louisianensis (Schmitt, 1935) (Felder & Lovett 1989), and Neotrypaea harmandi (Bouvier, 1901) (Tamaki et al. 1997) (see Manning & Tamaki 1998).

Despite being a common feature, this sex ratio deviation is not fully understood (Rowden & Jones 1994). An explanation for the deviated sex ratio favoring females would be that their movement toward the top of the galleries to provide ventilation for their eggs (or to hatch larvae) would make them more susceptible during the sampling surveys (Nates & Felder 1999, Botter-Carvalho et al. 2007). Another explanation would be related to the agonistic and territorial behavior of males. When two adult males meet in the same gallery while searching for females, they fight and one of them ends up mutilated or killed, favouring the predominance of females of larger size classes (Hailstone & Stephenson 1961, Felder & Lovett 1989, Rodrigues & Hödl 1990, Tamaki et al. 1997, Simão et al. 2006, Botter-Carvalho et al. 2007).

The population was characterized by oscillating densities, with high peaks (e.g., November 2008, March, and July 2009) followed by decreases. The main hypothesis to explain the decreased density in January 2009 is related to the intense bait catch activity during summer (Peiró & Mantelatto 2011, 2016). Similarly, Souza & Borzone (2003) assessed the abundance of ghost shrimp in five sectors of a beach from state of Paraná and noticed that the sector that presented intense extraction activity was the only one that showed markedly decreases in population density after the intense bait extraction in summer accompanied by a decrease in the average size of individuals (Souza & Borzone 2003).

Seasonal variations in the density of callianassidean populations from sandy beaches are generally associated to recruitment events (Tamaki & Ingole 1993; Souza et al. 1998). For instance, there is an intense recruitment in populations from the state of Paraná in early summer (Souza et al. 1998) and in June and October in populations from São Sebastião, state of São Paulo (Rodrigues & Shimizu 1997). Seasonal variations in recruitment are frequently observed in this species, which is attributed to factors such as predation, environmental and biogeographical conditions acting on individuals during larval development (Rodrigues 1976). Considering the peak of ovigerous females in the studied population (November 2008) and the larval development period (nearly 32 days at temperatures around 23 °C) (Rodrigues 1976), we indirectly estimated the juvenile settlement between December and January. However, these juveniles were identified in the population only about 5 months later (May). Shimizu & Rodrigues (2000) also found individuals from small size classes about 5-7 months after the estimated
settlement period and attributed this finding to the selectivity of the sampling method.

The capture efficiency may be a subjective criterion when the quality of suction pumps is taken into account. Moreover, the collectors’ ability can also influence the results. In this study we used the same suction pump and the same sampling effort (i.e., two pumpings) throughout the surveys since subsequent pulls of the same gallery have not been effective in the capture of additional specimens (Manning 1975). This methodology enabled reliable comparisons between the sampled months, but the capture efficiency results should be interpreted with caution when comparing different studies.

The structure of the galleries of ghost shrimps was described by Rodrigues & Shimizu (1997) based on glass moulds built up to observe the behavior of individuals. The gallery is a long narrow tunnel perpendicular to the beach sand from which lateral projections (up to 30 cm long) extend parallel to the sand line, where is find coarser granulation materials, compared with the surrounding sand and mud [see fig. 2, p. 160 of Rodrigues & Shimizu (1997) for details]. During laboratory observations, animals systematically visited these lateral projections, probably to deposit large sediment particles found during excavation and those that entered through the gallery opening. The displacement of shrimps toward the lateral projections of galleries might be responsible for low capture rates. The Indaiá River flows into the Perequê-Açu beach and, depending on the rainfall intensity, this water flow may carry debris that force the shrimps to reach more often the lateral galleries.

Based on our evaluations and comparisons with previous studies, it is plausible to assume that the population features of C. major are variable throughout the Brazilian coast. However, the compiled overview is far from being understood. The conservation status of C. major on the Brazilian coast was evaluated according to the IUCN considering the economic importance and the constant demand of this species for economic purposes. Even though the species is currently evaluated as ‘Data Deficient’ (DD), Peiró & Mantelatto (2016) suggested that it may change to, at least, ‘Vulnerable’ (VU) in some regions on the Brazilian coast, although the wide distribution is still an important criterion for a possible classification as ‘Least Concern’. Thus, population studies to fill in the gaps in the knowledge about C. major are strongly recommended.

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