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## ORIGINAL ARTICLE

# Abundance and distribution of the swimming crab *Callinectes danae* Smith, 1869 (Crustacea, Decapoda, Portunidae) in the Ubatuba region, southeastern Brazil

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## Abstract

This study analysed the spatio-temporal distribution of *Callinectes danae* considering some environmental factors in three bays in Ubatuba, São Paulo, Brazil: Ubatumirim, Ubatuba and Mar Virado. Sampling was performed monthly (from January 1998 to December 1999) using a shrimp fishery boat provided with double rig nets. Six transects were established in each bay, three being in areas protected from wave action (at 5, 7.5 and 10 m depth) and three in exposed areas (at 10, 15 and 20 m). A total of 3039 specimens were obtained. The distribution of *C. danae* differed between years, among seasons, bays and transects (K–W;  $p < 0.05$ ). This species occurred with a higher abundance in the shallow transects of all bays studied. These transects were characterized by substrate composed of fine or very fine sand and by silt and clay, higher values of bottom temperature and lower salinity values. Based on canonical correspondence analysis, the most relevant environmental factors for the spatio-temporal distribution of *C. danae*, in addition to salinity, were the bottom-water temperature and the sediment texture.

**Key words:** *Brachyura*, environmental factors, South Atlantic, temporal and spatial distribution

## Introduction

Portunids of the genus *Callinectes* live in marine and estuarine areas of the Atlantic American coast and are commonly found inhabiting shallow coastal waters (Williams 1974; Powers 1977; Ng et al. 2008). They are very important along the Brazilian coast due to their high abundance and ecological significance as predators and voracious hunters in the estuarine–marine ecosystem. They also serve as a food resource for other aquatic organisms such as fish and coastal birds (Haefner 1990; Mantelatto & Fransozo 1997).

The swimming crab *Callinectes danae* Smith, 1869 is distributed in the Western Atlantic from Florida to Argentina, occurring in estuarine, coastal and

oceanic waters, with records at 70 m depth, in brackish or hypersaline environments (Norse 1977; Buchanan & Stoner 1988; Melo et al. 1989; Costa & Negreiros-Fransozo 1998; Sforza et al. 2010). It is an exploited species along the Brazilian coast, frequently caught by artisanal fishery in coastal communities (Severino-Rodrigues et al. 2001; Sforza et al. 2010) and by the commercial penaeid shrimp fishery (Loebmann & Vieira 2006; Keunecke et al. 2008).

The first bioecological observations for *C. danae* on the southern and southeastern Brazilian coast were conducted by Branco et al. (1992) and Negreiros-Fransozo & Fransozo (1995), and the distributional patterns and reproductive studies were addressed in Branco & Masunari (2000),

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Chacur et al. (2000), Chacur & Negreiros-Fransozo (2001), Baptista-Metri et al. (2005) and Sant'Anna et al. (2012).

Worldwide estimations indicate that the bycatch fauna amount is at least five times greater than the catch for fishery production (Clucas 1998). This is one of the major concerns of the FAO due to the considerable protein loss (FAO 1994). Among the groups that comprise the shrimp fishery bycatch in the state of São Paulo, Brazil, brachyuran crustaceans are prominent in both biomass and species diversity (Severino-Rodrigues et al. 2001). Thus, Mantelatto & Fransozo (1999) already reported on the disappearance of the portunid population from the São Paulo coast and suggested the need for frequent monitoring. Some stocks, such as in the Santos area, have undergone reductions (Severino-Rodrigues et al. 2001), requiring studies aimed at informing specific public bodies to protect these populations (Sant'Anna et al. 2012).

The life cycle, its demographics and the spatial distribution of swimming crabs of the genus *Callinectes* is complex. Williams (1974), Norse (1977), Paul (1982) and Lipcius & Van Engel (1990) reported that the distribution of swimming crabs in estuarine areas reflects a wide tolerance to low salinities. However, Buchanan & Stoner (1988) suggested that the distribution pattern of *Callinectes* species is also the result of complex intra- or interspecific interactions among other congener species. Fransozo et al. (1992), McClintock et al. (1993), Negreiros-Fransozo & Fransozo (1995) and Carvalho & Couto (2011) studied biological aspects related to the distribution, abundance, habitat and migration of *Callinectes* species on the Atlantic coast, and verified that the juveniles of the majority of the species inhabit estuaries, whereas mature females conserve energy in low-salinity environments to spawn before subsequently migrating with a well-developed egg mass to more saline waters, offshore, where the larvae hatch.

Studies carried out on the southeastern Brazilian coast to date have only been performed in restricted areas, such as estuaries or single bays. Comparisons over a wider area, with several sampling sites, including many estuaries and bays, are not available in the literature for this region. An analysis of the distributional pattern variations of a species' population in relation to the environmental fluctuations on a wider scale might raise a more general hypothesis on the mechanisms that modulate such population features.

This study aimed to analyse the differential distribution of *C. danae* in three bays of the northern coast of the state of São Paulo, southeastern Brazilian,

which are characterized by a distinct physiography and conservation status.

## Materials and methods

### Study area

The Ubatuba region is characterized by innumerable spurs of the coastal mountains ('Serra do Mar') that form an extremely indented coastline (Ab'Saber 1955). The exchange of water and sediment between the coastal region and the adjacent shelf is very limited (Mahiques 1995). The region is under the influence of three water masses: Coastal Water (CWA = temperature > 20°C; salinity < 36), Tropical Water (TW = temperature > 20°C; salinity > 36), and South Atlantic Central Water (SACW = temperature < 18°C; salinity < 36) (Castro-Filho et al. 1987; Odebrecht & Castello 2001; De Léo & Pires-Vanin 2006).

During late spring and early summer, the SACW penetrates into the bottom layer of the coastal region and forms a thermocline over the inner shelf located at depths of 10–15 m (Castro-Filho et al. 1987). During winter, the SACW retreats to the shelf break and is replaced by the CWA. As a result, no stratification is present over the inner shelf during the winter months (Pires 1992; Pires-Vanin & Matsuura 1993). The sediment is composed of fine or very fine sand and silt and clay, given the low water movement within the bay and between the bay and the adjacent continental shelf (Mahiques et al. 1998).

The sampled bays (Figure 1) present contrasting physiographic features, both regarding their configuration and the orientation of river discharge. The Ubatumirim Bay faces southwest with several small islands close to its mouth. The islands are considered physical shields, such that the region is subjected to less intense hydrodynamics, which results in the deposition of fine sediments (Mahiques 1995). The bay receives freshwater inflow mainly from the Puruba, Ubatumirim and Fazenda Rivers, and is an area of lower occupancy and human activity in the region (Rodrigues et al. 2002). Ubatuba Bay faces the east and presents a seaward constriction formed by rocky projections, thus delimiting a shallower inner area and an outer area with a maximum depth exceeding 10 m (Mahiques 1995). The input of fluvial sediments is strongly dependent on the rainfall regime (Mahiques et al. 1998), leading to a higher contribution during the summer season. Four rivers flow into the bay and greatly influence its water quality (CETESB 1996), especially during rainy periods when large amounts of untreated sewage are introduced from Ubatuba City. The seaward end of Mar Virado Bay faces the southeast,

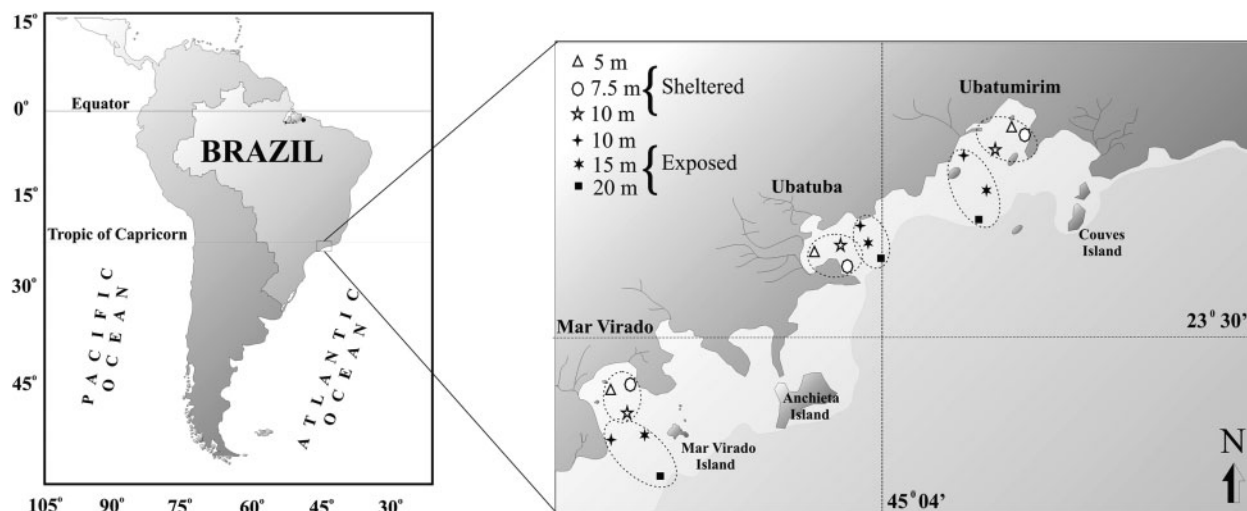


Figure 1. Map of the Ubatuba region on the northern coast of São Paulo State, southeastern Brazil, showing sampling areas and transects.

and Mar Virado Island is situated at the eastern border of the bay mouth. The predominant substrate is composed of sediment from two rivers: Lagoinha and Maranduba (Mahiques 1995).

#### *Swimming crab sampling and environmental features*

Swimming crabs were collected monthly, from January 1998 to December 1999 from the Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV) Bays on the northern coast of the state of São Paulo, Brazil (Table I). Six transects were established in each bay, three being in areas protected from wave action (at 5, 7.5 and 10 m depth) and three in exposed areas (at 10, 15 and 20 m depth) (Figure 1).

Each transect was sampled using a commercial shrimp fishery boat equipped with a double-rig, using a main net with a 20 mm mesh and a terminal cod net with a 15 mm mesh. Trawls were carried out

for 30 min each, sampling a total area of approximately 18,000 m<sup>2</sup>.

Swimming crabs were identified according to Melo (1996); their sex was determined by abdominal morphology, and the major carapace width (CW) was measured, as well as the lateral teeth, using callipers (0.1 mm). All specimens were classified into demographic groups: JM = juvenile males, AM = adult males, JF = juvenile females, AF = adult females, OF = ovigerous females, and NO = adult non-ovigerous females. The distinction between adult and juveniles was made based on Haefner (1990).

The abiotic data were collected from the midpoint of each transect, at the end of each trawl, with a stationary boat, while the trawl nets were brought onto the deck and the biological material screened. Salinity and temperature (°C) were recorded from bottom-water samples obtained with a Nansen bottle. Depth was measured in each transect using an ecobathymeter coupled with a GPS (geographic positioning system). Substrate samples were

Table I. Station information for trawls taken between January 1998 and December 1999 in bays along the northeastern coast of São Paulo State, Brazil: depths and coordinates (south latitude; west longitude). Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV). 10 S: 10 m Sheltered. 10 E: 10 m Exposed.

Bay	Station depth (m)					
	5	7.5	10 S	10 E	15	20
<i>UBM</i>						
Latitude (S)	23°21'18"	23°21'45"	23°23'00"	23°22'00"	23°24'00"	23°25'20"
Longitude (W)	44°54'20"	44°53'36"	44°54'48"	44°56'40"	44°55'00"	44°55'15"
<i>UBA</i>						
Latitude (S)	23°26'33"	23°26'48"	23°26'10"	23°25'16"	23°26'42"	23°27'12"
Longitude (W)	44°03'15"	44°02'12"	45°01'36"	45°00'57"	44°59'57"	44°58'45"
<i>MV</i>						
Latitude (S)	23°32'03"	23°32'07"	23°33'36"	23°34'21"	23°35'00"	23°36'13"
Longitude (W)	45°12'18"	45°11'14"	45°11'32"	45°12'30"	45°10'20"	45°08'11"

collected using a Van Veen grab (0.06 m<sup>2</sup> in area) and the samples used to analyse the organic matter content and granulometric composition. Each sample was placed in a plastic bag, tagged and frozen to minimize the decomposition of organic matter.

The sediment for granulometric analysis was separated into two samples of 50 g each and 250 ml NaOH (0.2N) was added to suspend silt and clay. The subsamples were washed through a sieve (mesh size = 0.063 mm) that only allowed the silt and clay fraction to pass. The remaining sediment was dried and submitted to graduated sieving (see Wentworth 1922).

Measures of central tendency ( $\phi$ ) were used to determine which of the grain-size fractions was most frequent in the sediment, based on the percentages in each transect. These values were based on the graphical depiction of the cumulative frequency–distribution curves of the sediments based on the  $\phi$  scale ( $\phi = -\log_2$  of the diameter of the grain in mm), and the following classes were obtained:  $-1 = \phi < 0$  (gravel);  $0 = \phi < 1$  (coarse sand);  $1 = \phi < 2$  (medium sand);  $2 = \phi < 3$  (fine sand);  $3 = \phi < 4$  (very fine sand); and  $\phi \geq 4$  (silt and clay). From these values, measurements of central tendency were calculated to determine the most frequent granulometric fractions in the sediment samples. These values were calculated from the data extracted from the cumulative curves of frequency distribution of such sediment samples. Finally, the values corresponding to the 16th, 50th and 84th percentiles were used to determine the mean diameter (MD) using the formula:  $MD = (MD_{16} + MD_{50} + MD_{84}) / 3$  (Suguio 1973).

The organic matter content of the sediment was estimated as the difference between the initial and final ash-free dry weights of three subsamples (10 g each) incinerated in porcelain crucibles at 500°C for 3 h. Details concerning the analysis of environmental factors can be found in Bertini et al. (2001) and Almeida et al. (2012).

#### Data analyses

Non-parametric analyses were performed because our data did not present a normal distribution (Shapiro–Wilk,  $p > 0.05$ ) or homoscedasticity (Levene's test). The abundance was compared concerning its spatial (among bays, areas and transects) and temporal (seasons – summer: January–March; autumn: April–June; winter: July–September; spring: October–December) distribution, using a Kruskal–Wallis test, followed by an 'a posteriori' Dunn test, adopting a significance level of 0.05 (Zar 1999).

The abundance of species in each demographic group was also evaluated using a canonical

correspondence analysis (CCA) ( $\alpha = 0.1$ ) that was performed using R Development Core Team (v. 2006). The mean value of species abundance and the environmental factors were calculated for each demographic group for each month. Alternative data transformations were tested with respect to their capacity to improve the normality of the data; the  $\ln(1 + x)$  was the most appropriate transformation based on the lowest Kolmogorov–Smirnov's D (more details in Castilho et al. 2008a, 2008b). The CCA is a statistical multivariate procedure that measures the association power between two variable groups. The first group of variables included the environmental features (bottom-water temperature and salinity, organic matter content and sediment texture), whereas the second group of variables included the species abundance (AM, AF, NO, OF, JM and JF).

#### Results

The greatest variation in bottom temperature during the study period occurred in the summer and spring of both years. The variation during summer was from 20.5 to 27.5°C, and during spring from 17.9 to 24.2°C, when significant differences were observed between exposed and sheltered areas, among transects, and among bays (Table II). With respect to bottom salinity, the greatest variation occurred in the spring of 1998 and 1999 at UBM (from 32.2 to 35.1) and in the winter (from 31.7 to 35.5), and in both years at UBA and MV during spring (from 32.9 to 35.6).

The analysis of the temperature–salinity (T–S) diagram showed three water masses acting throughout all seasons in all studied bays. The CWa was predominant (CWa:  $T > 20^\circ\text{C}$ ,  $S < 36$ ), characterized by low salinity and high temperatures. During the spring, the SACW (SACW:  $T < 18^\circ\text{C}$ ,  $S < 36$ )

Table II. Results of the Kruskal–Wallis test for bottom-water temperature and salinity on transects in Ubatumirim, Ubatuba and Mar Virado, São Paulo State, Brazil.

	Year	Bottom-water temperature	Bottom-water salinity
		DF / test values	DF / test values
Bays	1998	2 / $H = 1.45$	2 / $H = 0.60$
	1999	2 / $H = 0.39$	2 / $H = 22.53^*$
Area	1998	5 / $H = 19.92^*$	5 / $H = 4.96$
	1999	5 / $H = 9.91$	5 / $H = 33.24^*$
Transects	1998	5 / $H = 47.45^*$	5 / $H = 8.86$
	1999	5 / $H = 24.25^*$	5 / $H = 18.55^*$
Seasons	1998	3 / $H = 65.47^*$	3 / $H = 58.62^*$
	1999	3 / $H = 135.42^*$	3 / $H = 36.23^*$

$H$  = value of the statistic test; DF = degrees of freedom;  $^*p < 0.05$ .



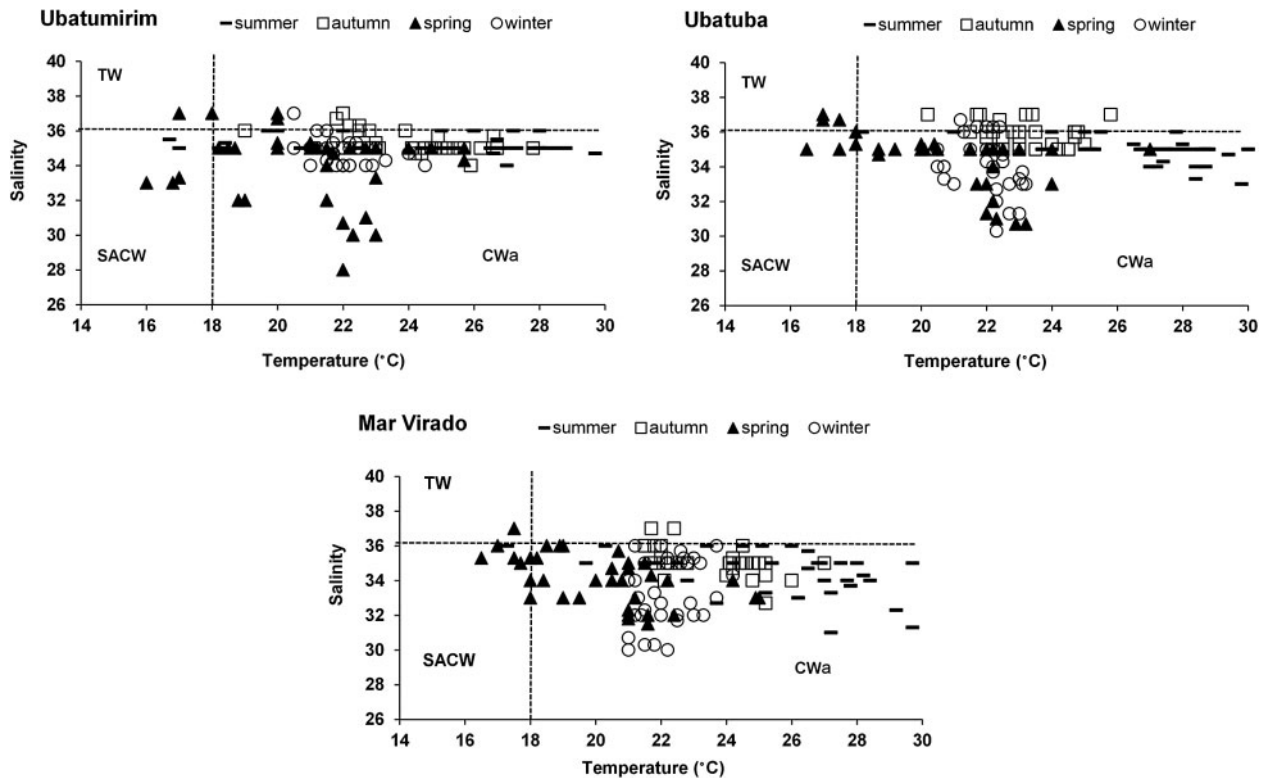


Figure 2. T-S diagrams of the temporal variation in bottom-water temperature and salinity during the sampling period (January 1998–December 1999) at Ubatumirim, Ubatuba and Mar Virado, São Paulo State, southeastern Brazil. CWa, Coastal Water; TW, Tropical Water; SACW, South Atlantic Central Water.

was detected at the UBA and MV bays, whereas it was less evident in the summer at UBM (Figure 2).

The grain diameter varied among transects and bays, but there was a predominance of fine sand, very fine sand and silt and clay in all sampled areas. There was a higher percentage of silt and clay in the north–south direction (from UBM to MV), which comprised more than 70% of the sediment in almost all transects of the MV. The highest percentage of organic matter content in the sediment was found at the UBA (5.9%), followed by MV (4.5%) and UBM (3.6%). The lowest mean of organic matter content in the sediment (2.9%) and phi value (3.0) were recorded at 20 m depth (exposed), whereas the highest mean of organic matter content (6.2%) and phi value (5.3) was at a depth of 10 m (sheltered). In general, there was a trend for a higher concentration of organic matter in the substrata that contained finer grains (Figure 3).

The higher abundance of *Callinectes danae* was associated with higher temperatures: from 25°C to 28°C at the UBM and MV bays, and from 28°C to 31°C at the UBA bay. The association of the abundance and bottom temperature was significant at UBM and UBA (UBM:  $H = 26.190$ ,  $DF = 4$ ,  $p < 0.001$ ; UBA:  $H = 17.411$ ,  $DF = 4$ ,  $p = 0.002$ ).

There was no association between the abundance of swimming crabs and salinity (Figure 4).

The highest concentration of swimming crabs occurred in the intermediate size classes of organic matter content of sediment at UBM and UBA; however, at MV the highest abundance was observed in the size class that comprised the superior organic matter content. Nevertheless, a significant difference among the organic matter content classes was only observed in UBM ( $H = 22.786$ ,  $DF = 4$ ,  $p < 0.001$ ). However, individuals concentrated at sites with the highest values of phi as follows: at UBM in the classes from 4 to 5 ( $H = 108.733$ ,  $DF = 5$ ,  $p \leq 0.001$ ), at UBA and MV in the classes from 5 to 6 (UBA:  $H = 73.648$ ,  $DF = 5$ ,  $p < 0.001$ , MV:  $H = 49.051$ ,  $DF = 5$ ,  $p < 0.001$ ).

A total of 3039 specimens of *C. danae* were obtained from 144 trawls; 1611 in 1998 and 1428 in 1999 ( $H = 24.494$ ,  $DF = 5$ ,  $p = 0.001$ ). The highest abundance was recorded at UBM (1485), where the mean number of individuals (123.7) differed significantly from that of the other bays ( $H = 22.486$ ,  $DF = 2$ ,  $p = 0.001$ ). The UBA bay showed the second-highest abundance value (1048), followed by MV (506).

With respect to bathymetry, the highest abundance of *C. danae* occurred in both years along the

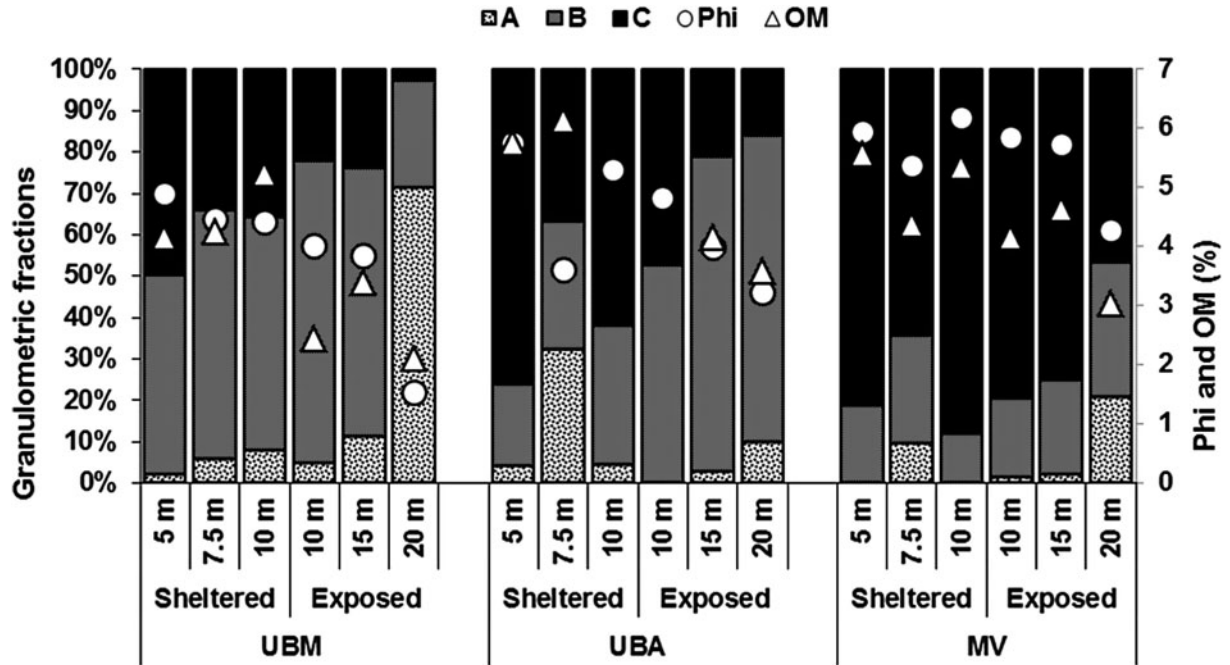


Figure 3. Proportions of grain-size classes, central tendency of bottom sediments (phi), and mean values of the organic-matter content (% OM) for each transect in Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV), São Paulo State, southeastern Brazil (January 1998–December 1999). A = Class A (gravel, very coarse sand, coarse sand, and intermediate sand). B = Class B (fine and very fine sand). C = Class C (silt and clay).

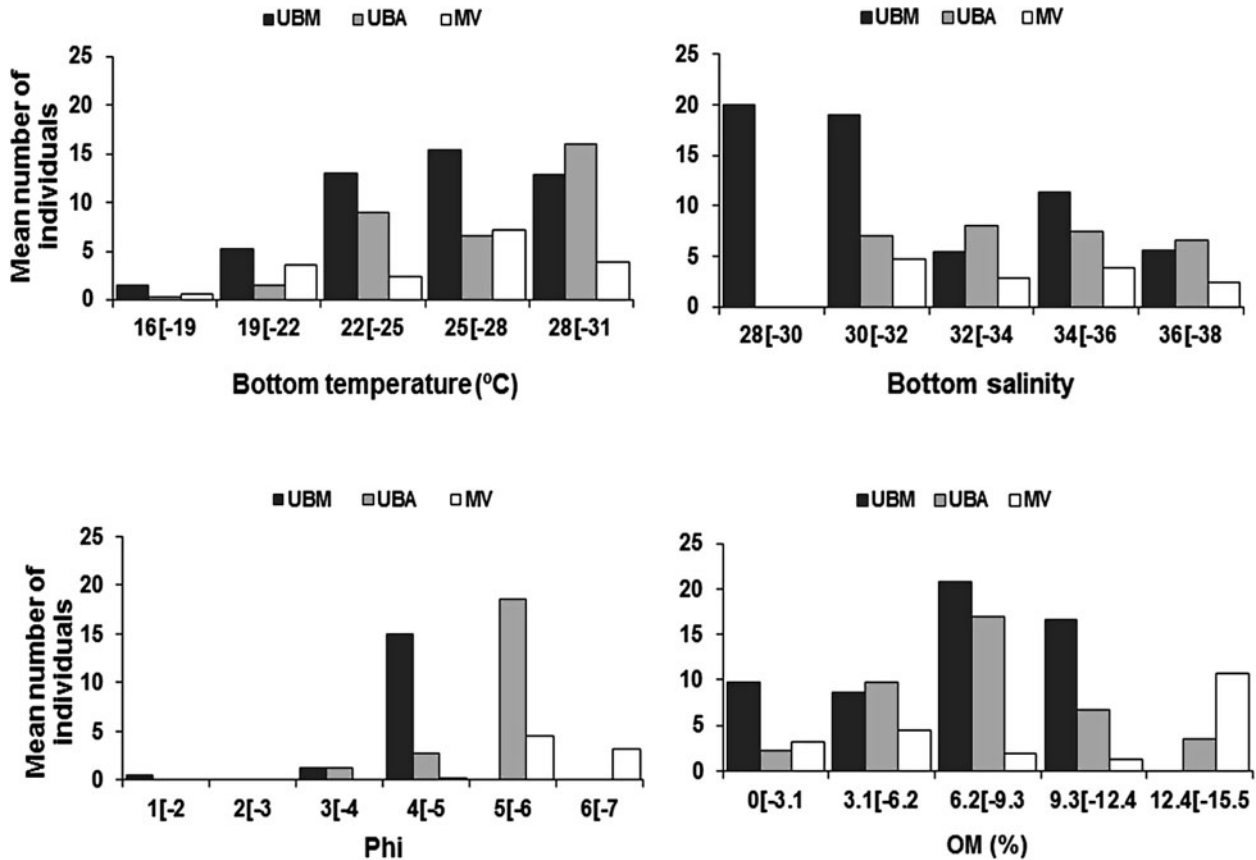


Figure 4. *Callinectes danae* Smith, 1869. Mean number of individuals per trawl for each class of environmental factors in Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV), São Paulo State, southeastern Brazil (January 1998–December 1999). OM = organic matter.

7.5 m transect of the sheltered area in UBM and MV bays. In UBM bay, the abundance was significantly the highest at the 7.5 m transect (865 specimens;  $H = 109.540$ ,  $DF = 5$ ,  $p < 0.001$ ), whereas in UBA bay, the highest abundance of swimming crabs for both years occurred at the 5 m transect (738 specimens,  $H = 75.140$ ,  $DF = 5$ ,  $p < 0.001$ ), (Figure 5). Regarding the season, the highest number of individuals was recorded in the autumn (1246), which differed from the other seasons in all the sampled bays ( $H = 13.832$ ,  $DF = 3$ ,  $p = 0.003$ ) (Figure 6).

The abundance of ovigerous females and the remaining demographic groups was significantly higher at transects from sheltered areas ( $H = 1827.500$ ,  $DF = 23$ ,  $p \leq 0.001$ ) (Figure 7), whereas related to the seasons, ovigerous females occurred mainly during the spring and summer. The other demographic groups were observed at a higher abundance during the autumn, but the difference in the values was not significant (Figure 8).

The CCA revealed that among all environmental factors analysed, the temperature and phi values were significantly correlated with the abundance of the distinct demographic groups for *C. danae* at UBM and UBA, and only the bottom temperature at MV (Table III). The first two canonical variables, when summed, explained 83% of the variance of the distribution of *C. danae* in relation to the environmental factors at UBM, 86% at UBA and 81% at MV.

Considering the axis of the first canonical variable, the abundance of the juvenile swimming crabs was positively associated with the phi value at UBM and with the bottom temperature at MV,

where this relationship was also positive for adult males (Figure 9).

## Discussion

Based on the T-S diagram, it was observed that CWa was prevalent in the study area and that was characterized by a salinity value below 36 and temperature usually higher than 20°C (Castro-Filho et al. 1987), and this water mass exerted a greater effect, mostly during the autumn and winter, while the pronounced effect of the SACW occurred in the spring and summer (Costa et al. 2007).

The highest values of crab abundance during the autumn coincided with the incursion of CWa, which occurred at the transects located in the shallower areas with higher temperature values (5, 7.5 and 10 m), not influenced by the SACW (Costa et al. 2007; Castilho et al. 2015) and near to the influx of freshwater from the rivers, which contributed to the lower salinity values (Bertini et al. 2010).

The literature presents evidence of the great influence of the SACW on the populations of decapod crustaceans along the southeastern coast of Brazil (Furlan et al. 2013; Bochini et al. 2014; Andrade et al. 2015; Castilho et al. 2015). However, this influence was not relevant for this study, even with an abundance of *Callinectes danae* reported in spring, because the entrance of the SACW is mainly evident in exposed areas (15 and 20 m) (Costa et al. 2007), where few individuals were found.

Benthic swimming crab communities of Ubatuba clearly followed a depth gradient, probably related to changes in the sediment (Sumida & Pires-Vanin 1997). Differences in sediment grain size and organic matter content among bays and transects

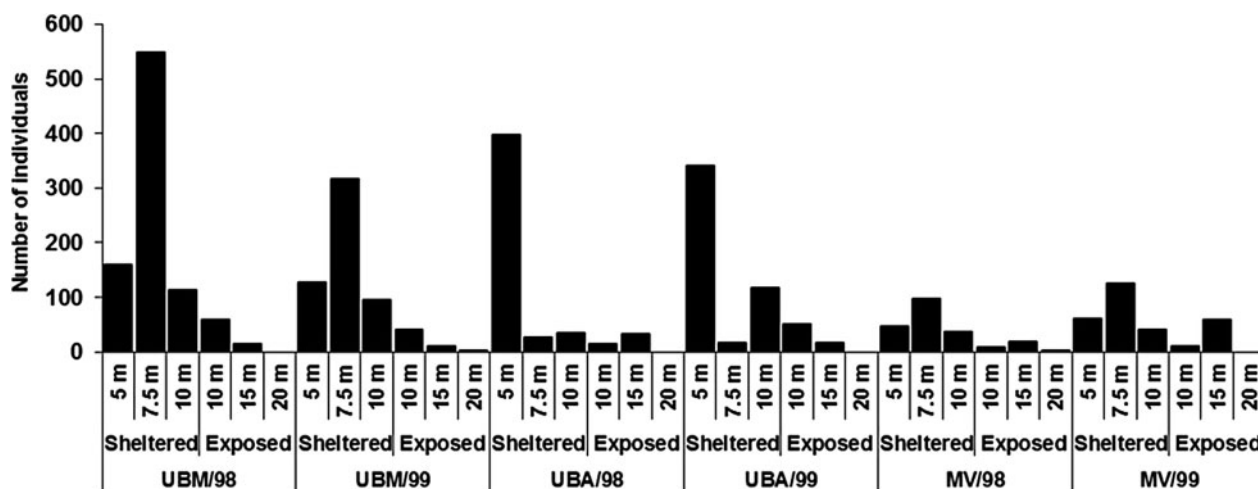


Figure 5. *Callinectes danae* Smith, 1869. Number of individuals in six different transects in Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV), São Paulo State, southeastern Brazil (January 1998–December 1999).



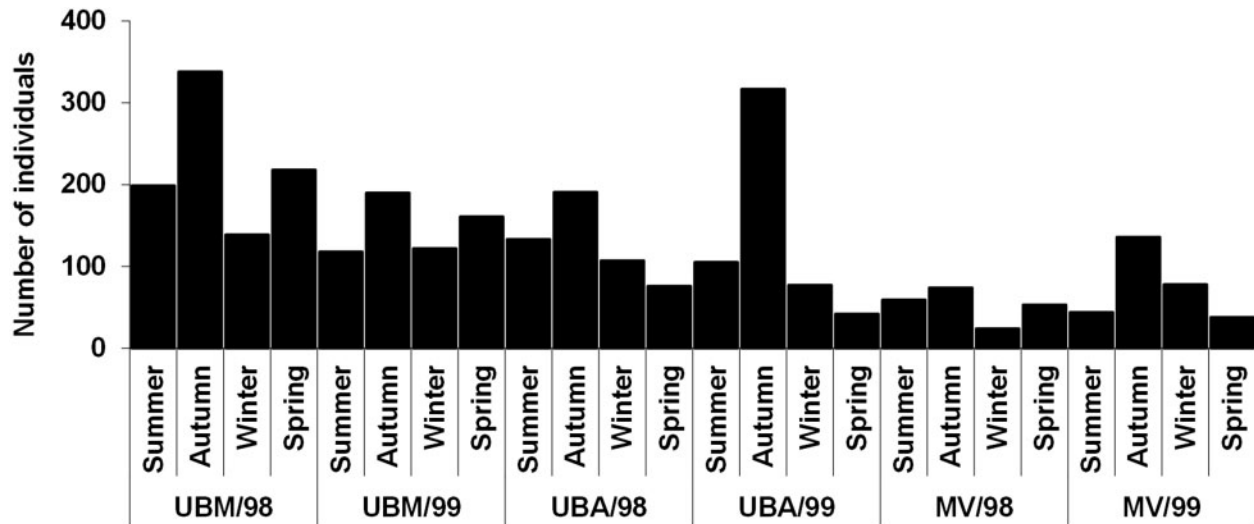


Figure 6. *Callinectes danae* Smith, 1869. Number of individuals in relation to the season sampled from January 1998 to December 1999 in São Paulo State, southeastern Brazil. UBM = Ubatumirim; UBA = Ubatuba; MV = Mar Virado.

also result from the local sediment dynamics, affected by the direction of ocean currents, wind and waves (Mahiques et al. 1998). The sediment texture was also an important factor that modulated the spatial distribution of *C. danae* throughout the study period. The abundance was higher in transects where the granulometric fractions were smaller,

and the predominance of fine and very fine sand at UBM and UBA created more favourable conditions for the establishment of the species.

Portunids usually burrow in the sediment for protection against predators or to facilitate the capture of agile prey (Schöne 1961), such as fishes. The substrata which are predominantly mud

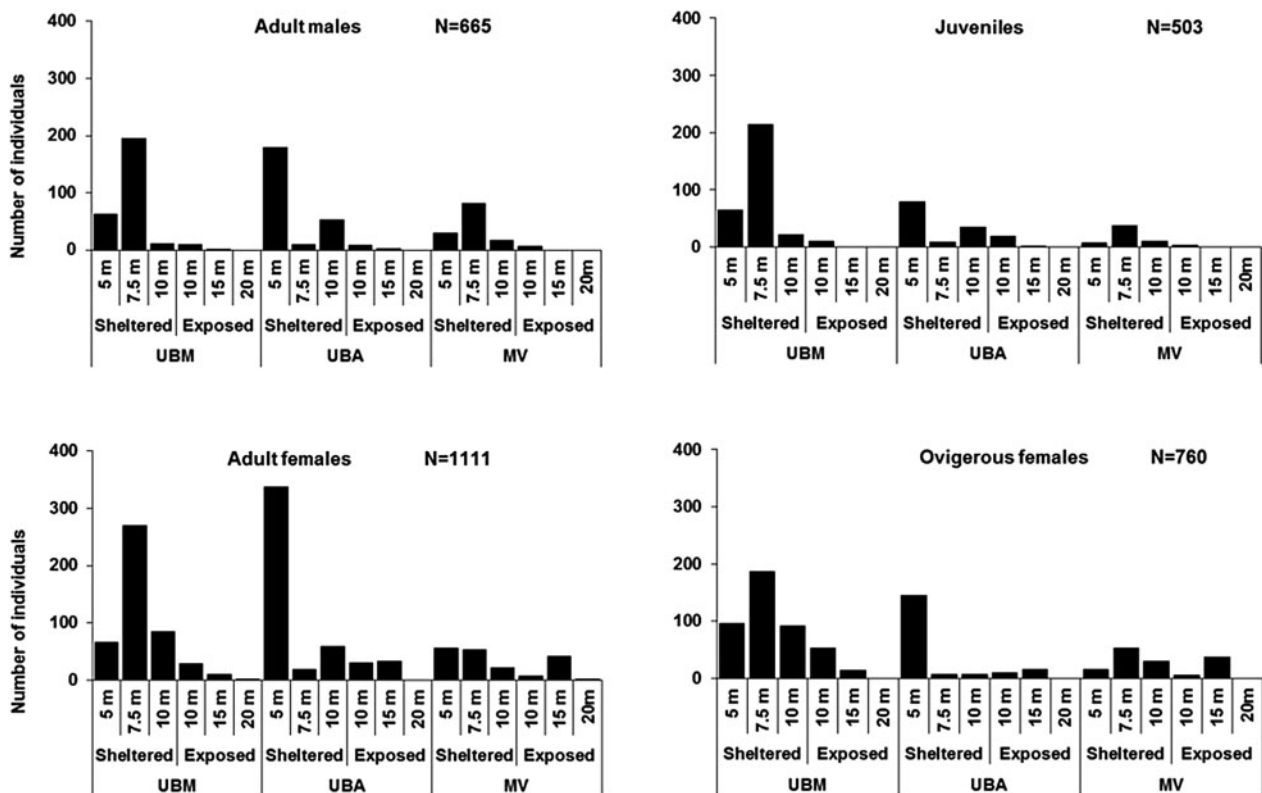


Figure 7. *Callinectes danae* Smith, 1869. Abundance of adult males (A), juveniles (B), adult females (C), and ovigerous females (D) in six different transects in Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV), São Paulo State, southeastern Brazil (January 1998–December 1999).

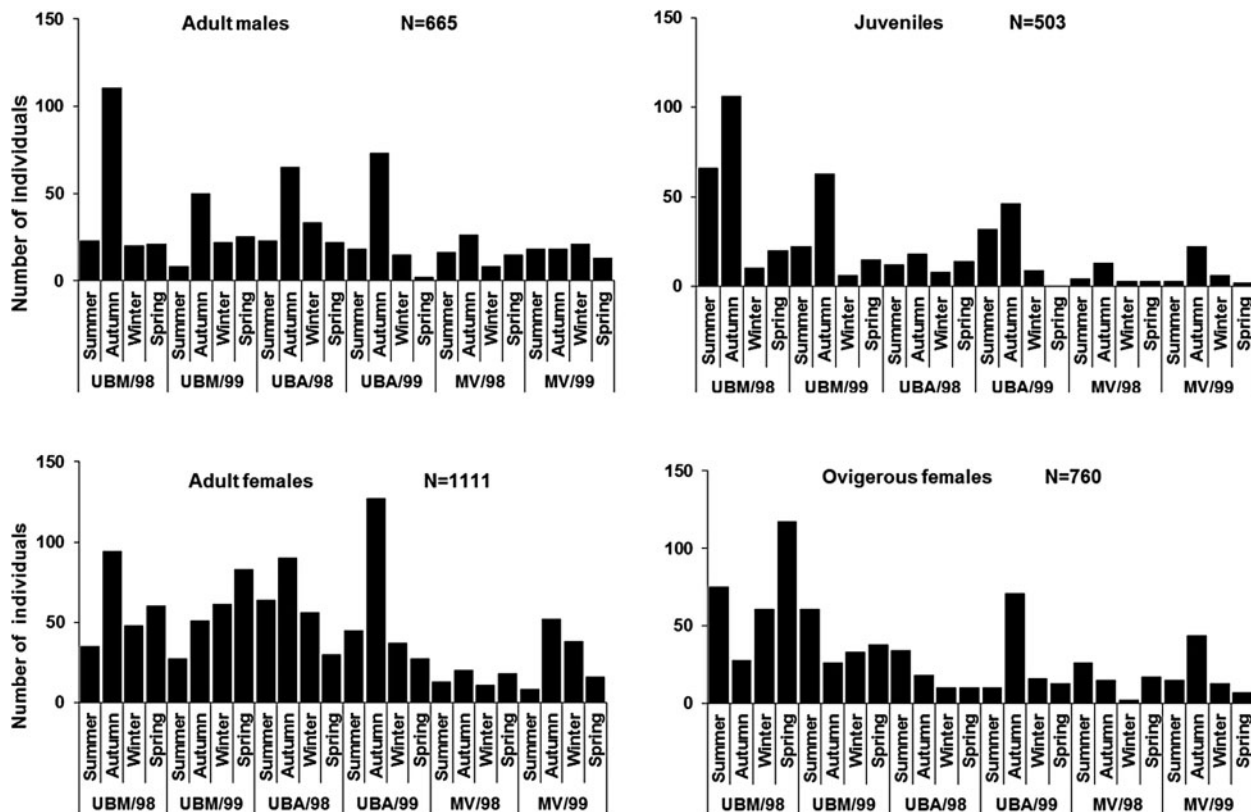


Figure 8. *Callinectes danae* Smith, 1869. Abundance of adult males (A), juveniles (B), adult females (C), and ovigerous females (D) in relation to seasons sampled in São Paulo State, southeastern Brazil (January 1998–December 1999). UBM = Ubatumirim; UBA = Ubatuba; MV = Mar Virado.

increase the difficulty of burrowing by swimming crabs, as well as the intake of water for gas exchange. Thus, the MV bay was not a favourable location for the establishment of *C. danae* because it contained the highest amount of silt and clay. According to Pires (1992), the bays located to the south (such as MV) are less vulnerable to the action of oceanic currents and are strongly influenced by the continent due to the physical barriers formed mainly by the São Sebastião Channel and Island, and also by Anchieta and Vitória Islands. Consequently, this area showed a sedimentary deposit composed mainly of silt and clay and a higher concentration of organic matter content in the sediment.

The UBA bay had a heterogeneous sediment similar to that of UBM, but with a higher concentration of organic matter, probably because this area received domestic waste from Ubatuba City (Rodrigues et al. 2002; Bertini et al. 2010). Although swimming crabs are considered vigorous predators that mainly consume bivalves and gastropods, they also consume decomposing organic matter (Warner 1977) and can extract organic matter from the sediment. Therefore, organic matter appears not to be a limiting factor to the distribution of *C. danae*, once the individuals have distributed uniformly with

respect to this environmental factor. Studies by Chacur & Negreiros-Fransozo (2001) revealed that *C. danae* were more abundant in areas with up to 10% organic matter in the sediment, which may explain the smaller number of individuals collected in MV.

According to Negreiros-Fransozo & Fransozo (1995), who examined the distribution of two swimming crab species of the genus *Callinectes*, and Pinheiro et al. (1997), who studied the portunid niche dimension and overlap, *C. danae* is preferentially found in shallow areas near estuaries, with low salinities. The large number of rivers or the large fluvial plan area can provide estuaries with favourable conditions mainly for the development of juvenile swimming crabs. The nature of the substratum, composed of finer grain sizes, food abundance and availability of refuges provided by the marginal vegetation, might favour the establishment of specimens at the transects near the mouth of such rivers (Orth & Montfrans 1987; Williams et al. 1990; Fitz & Wiegert 1991).

The largest estuarine area exists at UBM bay and the low anthropogenic influence might favour the high abundance of *C. danae* in this region, because this species is positively associated with freshwater

Table III. Results of the canonical correspondence analysis ordination for the first two canonical axes, with environmental variable data and demographic category abundance from Ubatumirim, Ubatuba and Mar Virado, São Paulo State, Brazil.

	Canonical coefficients		$R^2$	$p$
	Axis 1	Axis 2		
<i>(A) Ubatumirim</i>				
Environmental variables				
Bottom temperature (T)	0.554	-0.832	0.254	0.000***
Bottom salinity (S)	0.640	-0.768	0.009	0.645
Organic matter (OM)	0.975	-0.222	0.026	0.016
Phi	0.776	-0.629	0.088	0.015*
Demographic categories				
Juveniles (J)	0.948	-0.317	0.424	0.000***
Adult males (AM)	1.000	0.004	0.255	0.000***
Adult females (AF)	0.486	0.873	0.189	0.000***
Ovigerous females (OF)	-0.859	-0.511	0.203	0.000***
<i>(B) Ubatuba</i>				
Environmental variables				
Bottom temperature (T)	0.338	-0.941	0.100	0.015*
Bottom salinity (S)	0.991	-0.132	0.004	0.800
Organic matter (OM)	0.681	-0.731	0.019	0.499
Phi	0.872	-0.489	0.128	0.005**
Demographic categories				
Juveniles (J)	0.752	-0.659	0.371	0.000***
Adult males (AM)	0.757	-0.652	0.406	0.000***
Adult females (AF)	0.978	-0.204	0.082	0.042*
Ovigerous females (OF)	-0.765	-0.643	0.195	0.000***
<i>(C) Mar Virado</i>				
Environmental variables				
Bottom temperature (T)	0.838	0.545	0.142	0.003**
Bottom salinity (S)	-0.900	0.435	0.026	0.347
Organic matter (OM)	-0.253	-0.967	0.005	0.801
Phi	-0.854	0.519	0.042	0.156
Demographic categories				
Juveniles (J)	0.994	-0.103	0.297	0.000***
Adult males (AM)	0.987	-0.159	0.480	0.000***
Adult females (AF)	-0.717	-0.696	0.192	0.000***
Ovigerous females (OF)	-0.223	0.974	0.407	0.000***

$p$  = probability of significance based on 1000 permutations (Monte Carlo;  $\alpha = 0.05^*$ ).

Significance codes: 0.001\*\*\*; 0.01\*\*; 0.05\*.

inputs (Pita et al. 1985). The Ubatumirim and Fazenda Rivers are near the 7.5 m transect (58.2% of all individuals captured), the Iri and da Onça Rivers are near the 5 m transect (19% of all individuals), and Puruba and Quiririm Rivers are near the 10 m transect (sheltered area) (14% of all individuals).

In UBA bay, the highest abundance of all individuals of *C. danae* was recorded along the 5 m transect, situated near the Lagoa, Grande and Acaraú Rivers. Although UBA is considered to experience the highest anthropogenic influence of the bays studied, the estuarine area formed by these rivers favoured the abundance of *C. danae*, as 34.4% of the total swimming crabs sampled in this study

were obtained in this bay. Bertini et al. (2010) also noted a high occurrence of *C. danae* in the more sheltered transects of these bays and attributed this occurrence to the particular features of such places, which showed oscillations in salinity due to the flow of small rivers in the area, as well as facilitating the entrance of such organisms in the estuary, where they can grow and subsequently mate.

The migratory behaviour of ovigerous and adult females from shallower and estuarine regions to deeper sites was observed for *C. danae* for several regions of the Brazilian coast (Pita et al. 1985; Branco & Masunari 2000; Baptista-Metri et al. 2005) and is closely related to the reproductive success of this species that can vary depending on the size of the estuarine areas, as well as on the conservation status and the intensity of fishing in the area (Sforza et al. 2010; Sant'Anna et al. 2012).

In the Santos and São Vicente (State of São Paulo) estuarine areas, the highest exploitation of swimming crabs by fishing occurs in the inner region of the estuaries, by small artisanal fishery communities. In such activities, adult males represent the highest percentage of capture, followed by immature females (in the mature pre-moult phase) (Severino-Rodrigues et al. 2001). The ovigerous females remain concentrated in the deeper regions of the bays to ensure spawning and larval hatching (Pita et al. 1985). Additionally, Branco & Masunari (2000) reported that the Conceição Lagoon (State of Santa Catarina) also served as a spawning area for *C. danae*, and Baptista-Metri et al. (2005) reported that areas of shrimp exploitation also coincided with the spawning area for *C. danae* at Shangri-lá, Pontal do Paraná (State of Paraná).

In the three bays studied there was intensive artisanal fishing and this overlapped areas where there was a high abundance of ovigerous females. The fact that a large number of crabs are caught in the artisanal fishery might influence or modulate changes in abundance of the populations of *C. danae*. In agreement with Sant'Anna et al. (2012), special attention must be paid to the management of these estuarine areas, mainly during the reproduction peaks, due to the presence of a high concentration of pre-ovigerous and ovigerous females, which are positively associated with freshwater inputs (Pita et al. 1985). The preservation of these estuarine areas and adjacent bays is fundamental to the maintenance of population stocks of *C. danae*.

The complex life cycle of this swimming crab species in estuarine areas that are impacted by fishery and touristic development is a potential problem. The high abundance observed for this species at UBM might be related to the fact that

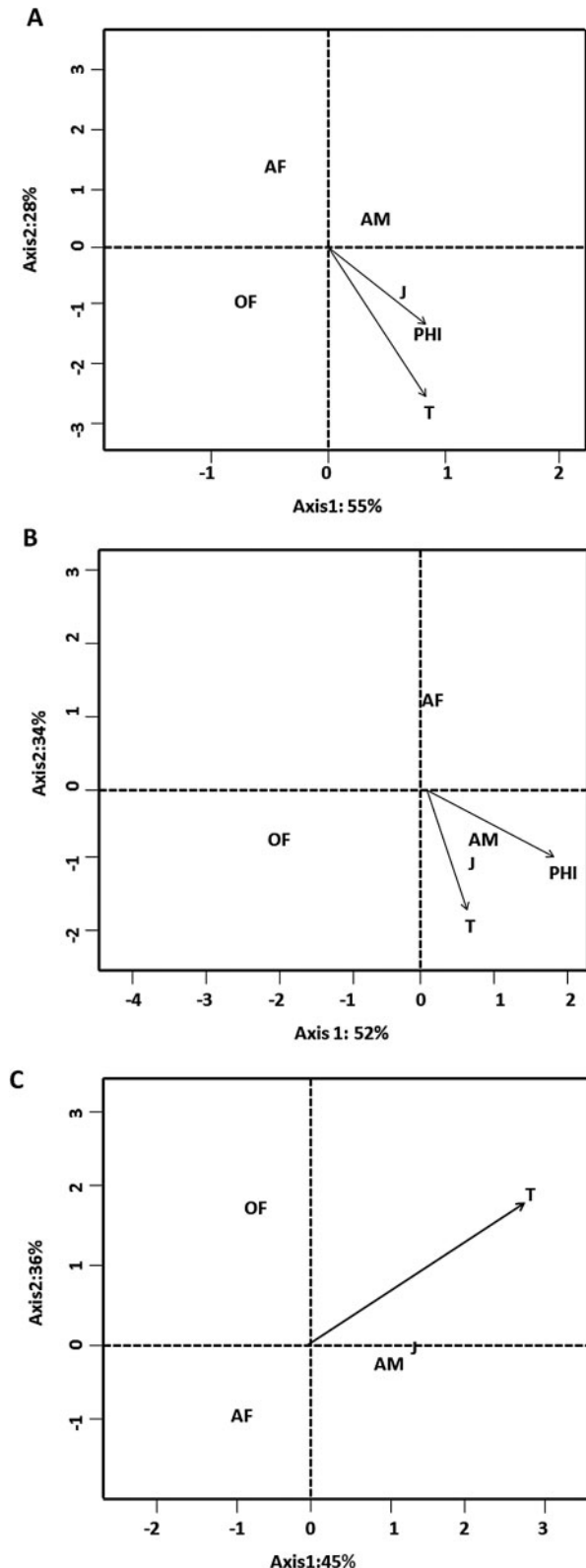


Figure 9. *Callinectes danae* Smith, 1869, from Ubatumirim, Ubatuba, and Mar Virado, São Paulo State, southeastern Brazil (January 1998–December 1999). Bidimensional graphics resulting from the canonical correspondence analysis between environmental variables and the abundance of demographic categories (J = juveniles; AM = adult males; AF = adult females; OF = ovigerous females; T = bottom temperature; S = bottom salinity; OM = organic matter).

this bay is an environment that has little impact by human occupation and anthropogenic activity (Rodrigues et al. 2002).

Several studies have shown evidence of the differential distribution of demographic groups of *C. danae*, especially ovigerous females and adult non-ovigerous females that probably migrated to deeper places with higher salinities to release their larvae. Larval dispersal is favoured in deeper waters due to the action of currents and winds (Hines et al. 1987; Chacur & Negreiros-Fransozo 2001; Sforza et al. 2010). Larvae in a more advanced stage of development return to shallow areas with lower salinity to complete their life cycles (Chacur & Negreiros-Fransozo 2001). However, in our study all groups were well represented, especially in shallow transects, indicating that the sampled areas provided adequate conditions for the presence of individuals at all benthic stages of the life cycle of *C. danae*.

The results of the present study showed that the migration of ovigerous females, mentioned by other authors, might occur only for a proportion of females of a particular area. Moreover, shallow estuaries and adjacent environments studied here provided conditions for the coexistence of all demographic groups of the *C. danae* population.

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