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Density, abundance and extractive potential of the mangrove crab, *Ucides cordatus* (Linnaeus, 1763) (Brachyura, Ocypodidae): subsidies for fishery management

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ABSTRACT

Ucides cordatus is a relevant fishery resource of Brazilian mangroves and requires legal normative to sustainable use based on stock assessment and management. This study evaluated some population parameters (structure, density, abundance, fishery potential and stock) of this crab species in Brazil Southeast (São Paulo, State), discussing the use of the results to delineate fishery management strategies. Density was monthly evaluated (September 1998 to August 1999), using five sample quadrats of 2x2 m. Density (ind.m^{-2}) was indirectly estimated by counting the opened (with biogenic activity) and closed galleries, and contrasted with flooding level by tides using the vertical distribution of macroalgae in the base of trees. Density of *U. cordatus* ranges from 2 to 11 ind.m^{-2} (6±2 ind.m^{-2}) and statistical difference occurred among monthly means (F=11.58; *p*=0.000). The relationship density vs. tidal flooding indicated a decrease of *U. cordatus* density in mangroves with higher levels of tidal flooding (r=−0.94; *p*=0.001). The total abundance of *U. cordatus* was estimated in 63.7 millions of crabs in 10.61 km^2, with a reduction of 34.9% due to total mortality discount. Estimates like that are uncommon in literature, and could be used for fishery forecasts, allowing improvement by the introduction of new variables to be known in the future.

Key words: crab, crustacean, fishery, management, mangrove, population.

INTRODUCTION

Ucides cordatus (Linnaeus, 1763) is a semi terrestrial crab endemic of mangrove forests, and distributed along the tropical and sub-tropical mangroves of the eastern Americas from southern Florida to southern Brazil (Bright and Hogue 1972, Melo 1996), where it is popularly called 'uçá'-crab. In mangrove ecosystem this crab develops a major ecological function, consuming 81 to 98% of leaf litter available on mangrove sediments (Koch 1999, Nordhaus et al. 2006). According to

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Wolff et al. (2000), 75% of the Brazilian mangrove biomass is composed by macrofaunal organisms, as *U. cordatus* (84%) and *Uca* spp. (16%), preventing an exportation of leafs/propagules with ebb tides to adjacent coastal areas. These vegetal items are converted in particulate organic matter (Nordhaus and Wolff 2007) and, then incorporated in mangrove sediments by these crabs when they dig their galleries (bioturbation) (Kristensen 2008). Therefore, leaf recycling by *U. cordatus* is the principal retention factor of carbon and nutrients in mangroves, and responsible by the high productivity of this ecosystem (Jennerjahn 2012, Koch and Wolff 2002, Nordhaus et al. 2006).

Due to the expressive size in adult phase, the 'uçá'-crab is used as human food and it is very commercially explored in many Brazilian regions, mainly in North and Northeast (Blandtt and Glaser 2000, Diele et al. 2005, Ibama 1994, Monteiro and Coelho-Filho 2004, Santos et al. 2016). Wolff et al. (2000) mentioned this crab species as a principal fishery resource in some mangroves of Brazilian North, with an annual capture estimated in 1,500 tons, in an area of 100 km^2. Due to the intense exploration of *U. cordatus* in Brazil its mean size and weight have annually decreased in some Brazilian mangroves (Alves and Nishida 2004, Amaral and Jablonski 2005), as a result of their reduced growth (Pinheiro et al. 2005), use of non selective traps to capture this crustacean (Fiscarelli and Pinheiro 2002, Nordi et al. 2009, Pinheiro and Fiscarelli 2001), no compliment of the closed fishing law (Rodrigues et al. 2000), and an increase of mortality due to improper transport (Legat et al. 2006).

Brazilian mangroves occupies the second largest extent in the world (13,000 km^2), corresponding to 8.5% of the global mangrove area (Spalding et al. 2010). Despite this, mangrove areas worldwide have been decreased, particularly due to intensification of the anthropogenic activities (Polidoro et al. 2010), in special those related to agriculture, aquaculture, property expansion, exploitation of coal/wood, among others (FAO 2007). This habitat loss directly impacts the mangrove macrofauna, especially *U. cordatus* which shows biologic limitations as slow growth and high fishery exploitation. This scenario has drawn the attention of researchers that previously studied the abundance and density of this crab species in Brazilian mangroves of the north-northeastern (Alcântara-Filho 1978, Amaral et al. 2014, Costa 1979, Santos et al. 2016) and south-southeast (Blankensteyn et al. 1997, Sandrini-Neto and Lana 2012, Wunderlich et al. 2008), as well as national environmental agencies responsible for the conservation and sustainable fishery of this species (e.g., Dias-Neto 2011).

Density estimates in crustaceans can vary in function of their activity, spatial distribution and habitat. In semi terrestrial crabs these estimates could be indirect, conducted by counting the number of active individuals or using the number of galleries/area, for non digging and digging species, respectively (Macia et al. 2001). For *U. cordatus*, it is known the existence of only one exemplar/gallery (Costa 1979, Pinheiro and Fiscarelli 2001), a fact that makes possible more reliable evaluations, mainly considering the discount of galleries without biogenic activities (abandoned) and those with more of one aperture, which percentage is still unknown in the literature. Therefore, information about crustacean density is relevant to crustaceans with economic importance (Pérez-Chi 2005, Saher and Qureshi 2011, Waiho et al. 2015), although there are few quality data in the literature about this subject (Alberts-Hubatsch et al. 2016), specially for *U. cordatus*, preventing accurate estimates of abundance.

In Brazil Southeast, the mangroves of Iguape municipality are part of the Environmental Protected Area (EPA) from Cananéia-Iguape-Peruíbe (EPA/CIP), and are characterized by a good conservation status, assuring a sustainable extraction of the 'uçá'-crab and others estuarine fishery resources. Density estimates and characterization of population structure of this crab are scarce in this region (e.g., Hattori 2006), but they are essential aspects to evaluate the crab extractive potential and quantity of the stocks. This information could be a temporal mark to monitor this species, thus very important to be considered in the Proposal of a National Management Plan for the Sustainable Use of *Ucides cordatus*, in the light to designate mangroves areas for exclusion and crab extraction (Dias-Neto 2011). This study evaluates the population structure, density, abundance and extractive potential of *U. cordatus* at Iguape mangroves, using percentages of bias and mortality pre-established. Based on this, it was discussed possible projections about sustainable extraction of this species at local scale and the applicability of these parameters at the national scale for the crab fishery management.

MATERIALS AND METHODS

The density, abundance and extractive potential of *U. cordatus* were estimated in mangrove areas with predominance of the white-mangrove *Laguncularia racemosa* (L.) Gaertn.f., (>80%), in an estuarine island near to Icapara Foz, Iguape Municipality, São Paulo State, Brazil (Figure 1). During one completed year (September 1998 to August 1999), a same mangrove area was monthly sampled to obtain data about population density of *U. cordatus*. A sample unit measuring 2x2 m was considered the ideal quadrat due to minimize the product between the variance and time, according Wiegert's method (e.g., Krebs 1999).

The density of *U. cordatus* was monthly represented by the average of five 2x2 m sample quadrats totalizing 20 m^2, with the first of them placed 10 m from the mangrove margin and the others contiguous and perpendicularly placed inside to the mangrove forest (Figure 1). In the first month the quadrats were positioned 50 m from the NE (Northeast) island edge, and in the subsequent months they were disposed in direction to SW (Southwest), always with 20 m of distance each month (Figure 1). The crab density was registered by counting of numbers of galleries/m^2, considering

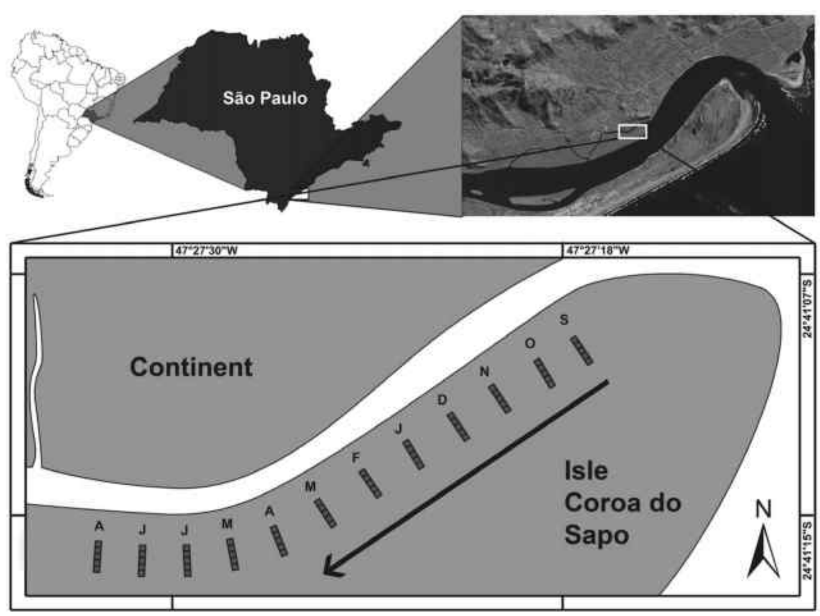

Figure 1 - Location and execution sequence (arrow) of the mangrove areas monthly sampled from September 1998 to August 1999, at 'Coroa do Sapo' Island, Municipality of Iguape, São Paulo State, Brazil. Where letters correspond to initial of each month; and art design by Gustavo Pinheiro based on Ikonos IV image.

the occurrence of only one exemplar/gallery (Costa 1979, Pinheiro and Fiscarelli 2001). To minimize the estimative bias of density (and other population parameters to be evaluated) only the crab galleries with a sloping position in relation to the sediment surface were counted, which characterize *U. cordatus* gallery (see Santos et al. 2009). It was used the method established by Pinheiro and Almeida (2015), by which only opened galleries with biogenic activity (e.g., presence of traces and/or with mud near the gallery overture) or closed (gallery overture recently occluded by mud or not removed) were counted, discarding those without biogenic activities (abandoned). The duct of each gallery was also accompanied by hand to verify the existence of one or more overtures, aiming to minimize this bias at the final counting.

To compare the density among mangrove areas (treatments) it was applied ANOVA considering five quadrats as replicates, with contrast 'a posteriori' by Tukey test in a 5% significance level. To use ANOVA it was verified the assumptions by the normality Shapiro-Wilk test and regression residue analysis (Quinn and Keough 2002). Monthly in the same mangrove area where the quadrats were installed, the flooding level by tides (*F*) was measured based on the vertical distribution of the macroalgae ("Bostrychietum") on the base of the mangrove tree trunks (n=15), using a measuring tape (in centimeters). The flooding tide average was associated with the average of crab density, using Spearman's correlation coefficient with 5% of significance level. To verify a possible heterogeneity of flooding among the mangrove areas monthly sampled, the data were firstly submitted to a normality test (SW, Shapiro-Wilk) and then to a homoscedasticity test of variances (L, Levene's test), used as assumptions to apply a statistical test evolving averages (ANOVA) or, in antagonism, a non parametric test (KW, Kruskal-Wallis) (Sokal and Rohlf 1995).

The instantaneous total mortality rate (Z) and survival annual tax (S) were obtained based on the monthly distribution of frequency by the crab size class (CW, carapace width). The calculation of 'Z' was obtained using the method of length-converted catch curves (Pauly 1983, 1984a, b), while 'S' was calculated by the equation *exp(-Z)* (Ricker 1975). These values were used to improve the abundance estimates with the necessary discounts. The population abundance of *U. cordatus* was based on the product between the estimated mangrove area and the average crab density. The estimated mangrove area was obtained in the study of Herz (1991), who elaborated mangrove maps for the study area occurring between 'Icapara' Foz (24º37'30'' S) and 'Boqueirão' Island (24º45'30'' S), using synthetic aperture radar images from 1985.

The diameter of the opened galleries (DG) inside the quadrats was measured with a vernier caliper as indicated by Pinheiro and Almeida (2015) and converted to carapace width (CW) using the equation $CW=13.21+0.9602 \cdot DG$ ($R^2= 0.73$), established to Brazilian southeastern-south regions for *U. cordatus*. These data were used to characterize the crab population structure (mean size and size-frequency distribution) and to calculate the immediate extractive potential (IEP) which is the percentage of crabs with carapace width equal or higher than 60 mm (CW≥60 mm) and the future extractive potential (FEP) which is the percentage of crabs with carapace width lower than 60 mm (CW<60 mm) (e.g., Wunderlich et al. 2008). These parameters were established based on the Brazilian legal minimum market size of *U. cordatus*, which is 60 mm of carapace width (IBAMA 2003a, b).

RESULTS

A total of 1,411 crabs were recorded in the mangroves of Iguape, with a density ranging from 2 to 11 ind.m^{-2}, and an average of 6±2 ind.m^{-2} (Table I and Figure 2a). The density data showed normal distribution (SW=0.976, p=0.285), leading to an analysis of variance in function of the mangrove sampled area. The ANOVA reveled that 72.7% of the total crab density variance was explained by the mangrove areas which significantly differed among them (F=11.63; p=3.68 10^{-10}). Based on the differences of mean crab density among the areas, they were grouped and divided into three groups: A (areas 01 to 03), B (areas 04 to 08 and 12) and C (areas 09 to 11). This new arrangement was again assessed by ANOVA (F=53.3; p=8.27 10^{-14}), which confirmed a significant difference on the crab density among the groups (Table II, Figure 2b). The highest difference occurred between groups A and B (Table II), which showed the lowest and highest crab densities, respectively (Figure 2b).

TABLE I
Flooded height (cm) of tides estimated based on the vertical distribution of 'Bostrychietum' on mangrove arboreal base, in each mangrove area monthly sampled during one year (September 1998 to August 1999), and respective densities of *U. cordatus*, based on gallery number in function of its condition (O, opened; C, closed; T, total).

Mangrove Area	Month/Year	Flooded height (cm)		Mean of galleries.m^{-2}		
		Mean ± SD	CV (%)	O	C	T
A01	Sep/1998	23.3 ± 8.7	37.2	2	0	2
A02	Oct	14.8 ± 2.2	14.8	3	1	4
A03	Nov	19.4 ± 3.2	16.3	2	1	3
A04	Dec	18.4 ± 3.3	17.8	7	0	7
A05	Jan/1999	17.1 ± 2.9	17.1	6	1	7
A06	Feb	17.2 ± 3.5	20.3	6	2	7
A07	Mar	14.8 ± 3.8	25.4	5	3	8
A08	Apr	11.4 ± 4.4	38.6	5	3	9
A09	May	21.9 ± 3.0	13.9	5	0	5
A10	Jun	10.4 ± 3.7	35.3	4	1	5
A11	Jul	23.1 ± 4.7	20.3	5	1	6
A12	Aug	14.8 ± 3.2	21.8	7	1	7
Mean ± SD		**17.2 ± 4.2**		**5 ± 2**	**1 ± 1**	**6 ± 2**
CV (%)		**24.6**		**36.5**	**92.0**	**34.6**

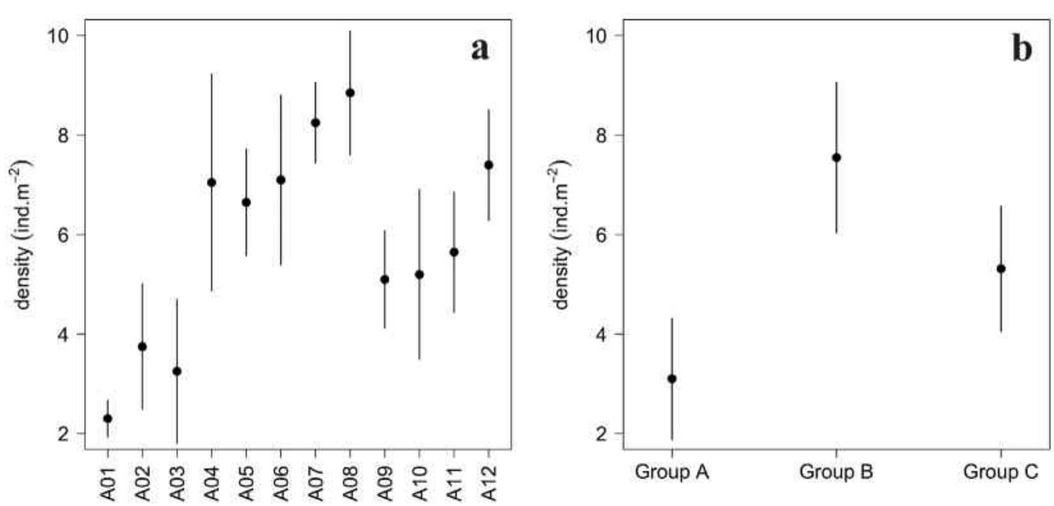

Figure 2 - Mean (± standard deviation) of *Ucides cordatus* density in Iguape (SP) mangroves, in each sampled area (**a**), and based on three groups (**b**) established. Where: Group A (areas A01 to A03); Group B (areas A04 to A08 and A12); and Group C (areas A09 to A11).

This analysis revealed a spatial pattern in which the crab population occurs at lower densities in the extremities NE (group A) and SW (group C) of the isle, and at higher densities in the central region of the isle (group B).

On the assumption that the flood influences the density of crabs, a simple regression model was tested, considering the means of flood (*F*) and the density of the crab in the twelve mangrove areas (*D*). The initial model for the relationship *D vs. F* showed a moderate negative correlation between these variables (Figure 3a) (r=−0.50, df=10, *p*=0.09), but it slightly explained the variation of density due to flooding (R^2=0.25). In the residual analysis, it was identified the presence of four outlier points (areas 01, 02, 03 and 10) (Figure 3a) which were removed for a further evaluation of the model. In this second analysis the model showed a high negative correlation between the variables (Figure 3b) (r=−0.94, df=6, *p*=0.0003) and significantly explained the variation of density areas due to flooding (R^2=0.89). Therefore, the relationship *D vs. F* indicated that *U. cordatus* density tend to decline in mangroves with higher level of flooding by tides, which correspond to the mangrove areas distributed at the extremities of the isle.

The total mortality rate (Z) of *U. cordatus* in Iguape mangroves was estimated in 1.05±1.15 yr^{-1}, resulting in 34.8% survivors/year (Figure 4). The natural mortality (M) was estimated in 0.49 yr^{-1}, while the fishery mortality (F) was 0.56 yr^{-1}, with an exploitation rate of 0.533, therefore, the fishery of this resource is responsible for 53.3% of the crab mortality. The mean size of *U. cordatus*, estimated in terms of carapace width, was 49.6±10.5 mm. Most of the crabs were in the class size of 40 to 50 mm (40.3%), followed by the class of 50 to 60 mm (24.4%) and 30 to 40 mm (16%) (Figure 5a). Thus, small to medium sized crabs (30 to 60 mm) were the most frequent in the mangroves of the Iguape. Larger crabs (60-70 mm: 14.2%; 70-80 mm: 3.7%;

TABLE II
Differences in crab density (ind.m^{-2}) among the groups of mangrove areas (A, Areas 01-03; B, Areas 04-08 and 12; and C, Areas 09-11) using information of Tukey test.

Group	Mean difference	Confidence interval		*p*-adjusted
		Lower	Upper	
B – A	4.45	3.39	5.50	0.000
C – A	2.21	1.00	3.43	1.46 10^{-4}
C – B	-2.23	-3.28	-1.18	1.17 10^{-5}

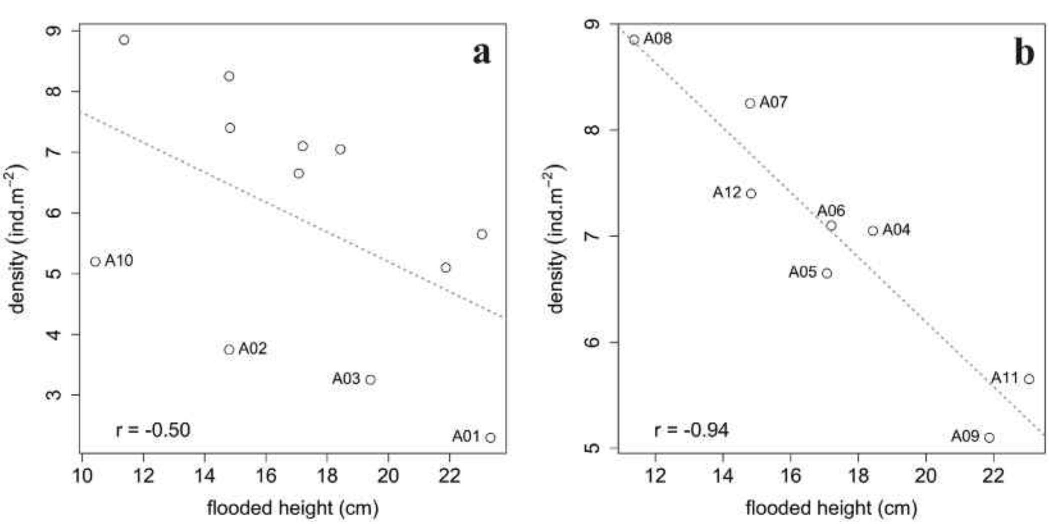

Figure 3 - Relationship between *Ucides cordatus* density (ind.m^{-2}) and flooding height (cm), with identification of four outlier points removed of the analysis (**a**), and the remaining points used to data reanalysis (**b**).

and 80-90 mm: 0.39%) were less frequent in these mangroves (Figure 5a).

In overall, only 18.2% of the total crabs were in commercial size (CW≥60 mm), while 81.8% were crabs that did not reach commercial size (CW<60 mm). Therefore, in the mangroves of the studied area the Immediate Extractive Potential - IEP of *U. cordatus* was significantly lower than the Future Extractive Potential - FEP (Figure 5b).

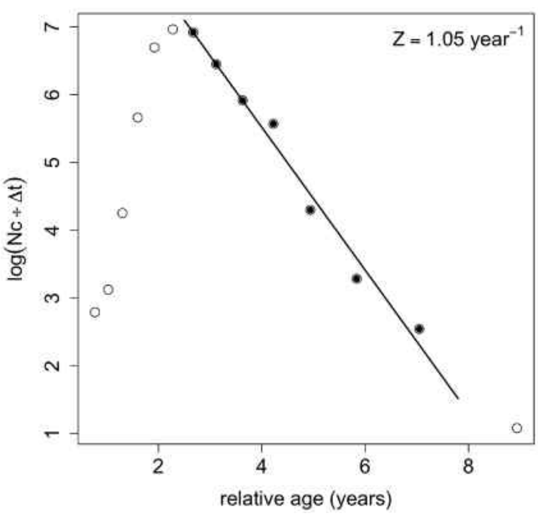

Figure 4 - Total mortality (Z) estimated to *U. cordatus* at Iguape (SP).

This indicates that the population of *U. cordatus* at the studied mangrove areas was most composed of small and juvenile crabs that did not reached the commercial size (Figure 5).

According to the data obtained by Herz (1991), the municipality of Iguape (SP) comprised a total mangrove area of 28.7 km^2 (Table III). Considering this fact and the mean density of *U. cordatus* in the study area (6±2 $ind.m^{-2}$), the total absolute abundance of *U. cordatus* in Iguape mangroves was 172.5 millions of crabs. However, this abundance was reduced to 60 millions of crabs if we considered the discount of 65.2% of mortality tax of this species (Table III).

Considering the mangrove forest status in Iguape, 68.8% were pristine areas, while 31.2% were anthropized (Table III). Based on this, the total and corrected crab abundances were extremely higher in the pristine areas than in the anthropized mangroves (Table III). In regard to mangrove forest categories, most of them (50.7%) were located in less-flooded areas (high mangroves), which showed higher values of total and corrected crab abundances than the more-flooded areas (low mangroves - 18.2%) (Table III). On the other

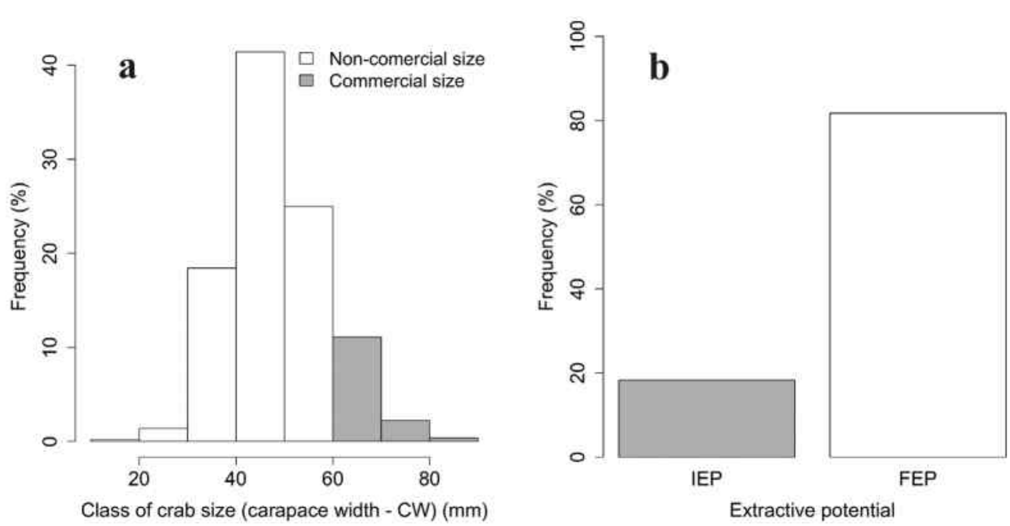

Figure 5 - Population and fishery parameters of *U. cordatus* in the mangroves of Iguape. (**a**) Size-frequency distribution by carapace width classes. (**b**) Immediate Extractive Potential (IEP) and Future Extractive Potential (FEP).

TABLE III
Areas and status of mangrove forests related to the absolute abundance of *U. cordatus*, using the mean density (6±2 ind.m^{-2}) without correction (TCA, total crab abundance), and discounting 65.2% of mortality (CCA, corrected crab abundance). Source of mangrove categories and status from Herz (1991), where: H, high; L, low; D, degraded; and A, altered.

Map Code Herz (1991)	Locality	Mangrove Categories[1] (Km^2)				Mangrove Status[2] (Km^2)		
		H	L	D	A	Pristine	Anthropized	**Total**
37647J1	Barra Ribeira	0.009	-	-	-	0.009	-	0.009
37647J2	Barra Ribeira	0.231	-	-	-	0.231	-	0.231
37647J3	Barra Ribeira	1.100	0.300	-	0.200	1.400	0.200	1.600
37647J4	Barra Ribeira	6.067	3.238	0.158	0.185	9.305	0.343	9.648
37647K3	Iguape	2.316	1.679	2.148	6.275	3.995	8.423	12.418
37647K4	Iguape	4.837	-	-	-	4.837	-	4.837
Mangrove Area (Km^2)		14.6	5.2	2.3	6.7	19.8	9.0	28.7
Mangrove Area (%)		50.7	18.2	8.0	23.2	68.8	31.2	100.0
TCA (x 10^6)		87.4	31.3	13.8	39.9	118.7	53.8	172.5
CCA (x 10^6)		30.4	10.9	4.8	13.9	41.3	18.7	60.0

hand, there were more altered mangroves (23.2%) that showed higher values of total and corrected crab abundances than the degraded mangroves (8%) (Table III). This scenario, in which 31.2% of mangroves were influenced by anthropogenic activities and sheltered *U. cordatus* populations, can have a directed impact in the quality of the resource found in these areas. Moreover, considering that only 18.2% of the *U. cordatus* in the study area is in commercial size, the total and corrected crab abundances drastically decreased to 31.4 and 10.9 millions of crabs, respectively.

DISCUSSION

DENSITY AND ABUNDANCE OF *U. cordatus*

The density of *U. cordatus* varied significantly between the mangrove areas (3 ind.m^{-2} in NE, 8 ind.m^{-2} in the inner, and 3 ind.m^{-2} in SW), with a mean of 6±2 ind.m^{-2}. Comparing these values with those recorded by studies in others Brazilian mangroves, it was found that the study area showed similar values of *U. cordatus* density of those recorded in North Brazilian, as by Piou et al. (2009), who recorded an average crab density of 6.02 ind.m^{-2}, in the mangroves of Pará state. Nevertheless, in overall, the mangroves of Iguape (study area) showed higher crab density than others mangroves along the Brazilian coast. For example in the northeast coast, the maximum crab density was between 4 to 5 ind.m^{-2} (e.g., Alcântara-Filho 1978, Blankensteyn et al. 1997, Costa 1979, Nascimento et al. 1982) while the minimum was between 1.2 to 1.7 ind.m^{-2} (Alves and Nishida 2004, Santos et al. 2016). It is interest to highlight that the mangroves of Iguape recorded higher values than those found in mangroves on the southeast coast, the region where the study area is located. For example, the maximum crab density of 3.7 ind.m^{-2} was recorded by Goes et al. (2010) in mangroves of the Espírito Santo State, while the smallest value of 0.85 ind.m^{-2} was recorded by Sandrini-Neto and Lana (2012), in mangroves of the Paraná State. In other location of the same study area Hattori (2006) recorded average densities of 3.9 ind.m^{-2}, which is lower than those in this study.

It is remarkable that *U. cordatus* density can vary between different mangrove areas as a result of their degradation (Duarte et al. 2014, Pinheiro et al. 2013), higher incidence of fishery (Pinheiro and Fiscarelli 2001), as well as due to intrinsic factors of a particular mangrove forest type as vegetation composition and flood degree (Conti and Nalesso 2010). Although Wolff et al. (2000) have indicated that predators of *U. cordatus* (e.g., raccoons, monkeys, and caracara hawks) generally occur in low abundance in mangrove areas and do not influence the abundance and density of this crab species, a different pattern is registered at Iguape mangroves. In this area, fisherman have report that raccoons are abundant and prey on *U. cordatus* crabs, therefore reducing the abundance and density of this crab species and influencing in the fishery activity, since the raccoons prey on the crabs captured by the tangle-netting traps.

In this view, the higher values of crab density recorded in the mangroves of Iguape during 1998 to 1999, can be correlated to three factors. Firstly, in the study area the fishery of *U. cordatus* during that period was almost non-existent and did not influence the observed crab abundance. This is not the reality of others Brazilian mangroves where the fishery is an intense activity (e.g., Alves and Nishida 2003, Firmo et al. 2011, Glaser and Diele 2004, Passos and Di Beneditto 2005, Santos et al. 2016, Souto 2007). Thus without fishery pressure on that period, the abundance of *U. cordatus* in Iguape was very high. Secondly, most of the mangroves of the study area during the final of 90's were pristine areas (68.8%), which provided a good habitat quality, food availability (vegetation litter) and high habitat extent for the development of *U. cordatus* population, thus supporting higher crab densities. Finally, the mangroves of the study area are dominated by the plant species *Laguncularia racemosa* (>80%), thus this can influence the crab population structure and density, leading to the higher densities here recorded. For example, Piou et al. (2009) showed that *U. cordatus* preferentially created their burrow entrances closed to *R. mangle* prop roots, in which is found lower total crab density, but of large crabs. Presence of *L. racemosa* in the neighborhood does not favor big crabs (Piou et al. 2009), thus small crabs in higher densities dominate these mangroves. This can be attribute to the morphological characteristics of *L. racemosa* which has cable roots that run under the surface of the mud and many pneumatophores coming up the surface, which can difficult the built of galleries by larger crabs, but are more appropriate for small crabs that can occur in high densities, as it was observed.

Although Macia et al. (2001) and Skov et al. (2002) pointed out that the evaluation of crab density by counting galleries may overestimate this population parameter by 20%, these authors emphasize that this method is much more effective when compared to the gathering of the crabs. Advantages of this methodology includes: speed and consequent increase in sample size; conducting non-destructive sampling, important when work involves endangered species and the possibility of obtaining measures of all individuals within sampling units (Schmidt et al. 2008). Population estimations from gallery numbers and size have been widely used for mangrove crab species (e.g., Kent and McGuinness 2006, Macintosh 1988, Skov et al. 2002, Warren 1990), including *U. cordatus* (Alcântara-Filho 1978, Alves and Nishida 2003, Firmo et al. 2011, Hattori 2006, Piou et al. 2009, Sandrini-Neto and Lana 2012, Schmidt et al. 2008, Wunderlich et al. 2008) with high rates of accuracy.

A significant high negative correlation was found between the flood height and the crab density (Figure 3b). A spatial distribution pattern was observed with a zone of lower abundance (mean of 3 ind.m^{-2}) located in the NE of the island (more-flooded); followed by higher abundances (mean of 8 ind.m^{-2}) in the inner of the island (less-flooded), and lower abundances (mean of 5 ind.m^{-2}) in the SW of the island (more-flooded). Based on the regression model (Figure 3b) the effect of flooding on the crab abundance can be understood, since the more flooded areas showed low abundance of crabs, and the less-flooded areas higher abundance, showing a dependence of crab density on the flooding height (r=−0.94; df=6; p=0.0003). Therefore, 89% of the variation on crab density was explained by flood height (R^2=0.89). Corroborating with these results, Conti and Nalesso (2010) found that higher *U. cordatus* densities occur in mangrove areas with low salinity, showing a negative correlation between these variables. In this context, it is expected that more-flooded mangroves should present higher salinity, and therefore lower density of crabs.

Data from previous studies M.A.A. Pinheiro et al. (Unpublished results), Santos et al. 2016, Wunderlich and Pinheiro 2013) suggest that mangrove forests dominated by *L. racemosa* are those located in areas of high microtopography, thus with lower levels or frequency of flooding during neap and spring tides and are muddy areas showing more compacted sediment. Thus, in these areas, small crabs are more able to rebuild their galleries, than the large ones that preferably habit *R. mangle* dominated mangrove (e.g., Piou et al. 2009, Santos et al. 2016). Smaller crabs colonize *Laguncularia racemosa* less-flooded mangroves, therefore these mangroves are able to support higher crabs densities.

For the *U. cordatus* population of the Iguape mangroves, the total mortality (Z) was 1.05 y^{-1}, which is very higher than those estimated by Diele and Koch (2010) as 0.56 y^{-1} and 0.53 y^{-1} for females and males, respectively, in North Brazil and than those estimated by Farias (2009) as 0.60 and 0.57, respectively, in the Northeastern Brazil. The higher total mortality found in Iguape mangroves can be attributed to the structure of the crab population which is most composed by small sized crabs, 56.3% of crabs with carapace width between 30 to 50 mm, differing from the others studies (e.g., Diele and Koch 2010, Farias 2009). This high crab mortality causes a high reduction in the crab abundance and its stocks.

The mean size of *U. cordatus* recorded at the Iguape mangroves (49.6 ± 10.5 mm) was very similar to those recorded by other authors in the southeast Brazilian coast (45.9 mm - Conti and Nalesso 2010; and 48.9 mm - Hattori 2006). Nevertheless, this mean size was lower than those recorded by other authors in the north and northeast Brazilian coast (50.5 to 64.4 mm: Alcântara-Filho 1978, Alves and Nishida 2004, Amaral et al. 2014, Diele et al. 2005, Piou et al. 2009), as well as extremely lower than in the southeast coast (58.7 to 68 mm: Wunderlich et al. 2008). In the Iguape mangroves a dominance of small crabs (30 to 60 mm), mainly from the class of 40 to 50 mm, was found. This pattern differed from those recorded in other studies about *U. cordatus* in Brazilian mangroves (e.g., Dias-Neto 2011, Diele et al. 2005, Passos and Di Beneditto 2005, Santos et al. 2016), which found a dominance of adult medium size crabs (40 to 70 mm).

FISHERY POTENTIAL AND MANAGEMENT OF *U. cordatus*

Ucides cordatus is a species with low growth rate, high age of maturity, reaching the commercial size (CW = 80 mm) around 7 to 8 years (Pinheiro et al. 2005, Pinheiro and Fiscarelli 2001). These features indicate that the population stocks of the species are subject to significant reduction if submitted to high fishery pressure without adequate management, which would undermine the continuity of their extraction, and as a consequence, the economic subsistence of human populations along the Brazilian coast. This highlights the importance of stock assessments of this species, in the current and past periods, in order to generate data about the stock changes and status, which will allow the development of fishery management strategies.

Since the end of 90's, the fishery of *U. cordatus* has been in the attention of Brazilian environmental agencies. To illustrate, in 1998 a management group of this resource was created for the south and southeast regions of Brazil, coordinated by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), when the first regional ordinance was published with a fishing closed season for this species. Since this ordinance has been published, it was subjected to four adjustments, and the last one was published in 2003 (IBAMA 2003b). From this, in 2004, *U. cordatus* was included in the list of overfished or endangered species of overexploitation by the Normative Instruction # 05/2004 of the National Environment Ministry. Despite this legal framework, published data (e.g., Alves and Nishida 2004, Boeger et al. 2005, Dias-Neto 2011, Diele et al. 2005, Jankowsky et al. 2006) have documented a significant reduction of the natural stocks, indicating the urgent need for population management of this crab. Consequently, in 2011, the IBAMA published a Proposal of a National Management Plan for the Sustainable Use of *Ucides cordatus*. More recently, in the end of 2014, the National Environment Ministry published the Ordinance # 445/2014, in which *U. cordatus* was listed in the "near threatened" (NT) category (Pinheiro et al. 2016). Finally, in 2015, this crab was included in the National Conservation Action Plan of Endangered Species and of Socioeconomic Importance in Mangrove Ecosystems (PAN Mangrove - Ordinance # 9 of January 29, 2015), as one of the nine species listed in the regional list of endangered species.

The Proposal of a National Management Plan for the Sustainable Use of *U. cordatus* (Dias-Neto 2011) aims to promote the sustainable use of this resources, ensuring the maintenance of populations at satisfactory levels, allowing the continuity of economic activity (Pinheiro and Rodrigues 2011). For this, it is necessary the evaluation of *U. cordatus* stocks and of its extraction potential, as estimated in this study.

Here it was found a high total and corrected absolute abundance of *U. cordatus* (172.5 and 60 millions of crabs, respectively), which is an estimate of the crab stocks for the entire area, in 1998/1999, considering the mangrove extent based on imagery from 1985 (Herz 1991). Nevertheless, more recently, an analysis of Landsat images from 2010, carried by Cunha-Lignon et al. (2011), for Iguape mangroves, with the exception of the Vila Subauma, estimated a total mangrove area much lower (10.61 km^2) than those recorded by Herz (1991), which was 28.7 km^2. This figure comprised 36.9% of the area estimated by Herz (1991), reflecting in lower values for TCA (63.7 millions of crabs) and CCA (22.2 millions of crabs).

In regard to the potential extraction, the IEP (18.2%) was extremely lower than the FEP (81.8%) in the study area. Therefore, considering that only 18.2% of *U. cordatus* population in the study area is in commercial size, the abundances have drastically decreased to $31.4 \cdot 10^6$ (TCA) and $10.9 \cdot 10^6$ crabs (CCA) according to mangrove extent data from Herz (1991); and to $11.6 \cdot 10^6$ (TCA) and $4 \cdot 10^6$ crabs (CCA), according to the data from Cunha-Lignon et al. (2011).

Hattori (2006) have recorded an IEP of 34.3% and a FEP of 65.7% for the same area in 2004/2005. These findings of Hattori (2006) and the results of the present study suggest that the study area mangroves tend to show a pattern of high FEP and low IEP. To illustrate, after having spent seven years (1998 to 2005), which is very close to the period that *U. cordatus* reaches the commercial size (7 to 8 years) (Pinheiro et al. 2005, Pinheiro and Fiscarelli 2001), the IEP had an increment of 16.1% (18.2% in 1998 to 34.3% in 2005). This configures an annual rate of 2.3% of increment in IEP. Based on these results, the study area requires a high attention, in order to protect the crab population that does not reach the commercial size.

Therefore, according to these features and the strategies stated in the Proposal of a National Management Plan for the Sustainable Use of *Ucides cordatus* (Dias-Neto 2011), it is suggested that the study area should be categorized as an exclusion area (e.g., Dias-Neto 2011), which is more suitable for the conservation of the crab population. In this area the crab fishery should be prohibited, in order to allow the conservation of adult crabs for reproduction, enabling the juvenile crabs to grow and reach the commercial sizes, which is very important to maintain the population stocks.

CONCLUSIONS

This study concludes that the density and abundance of *U. cordatus* in mangrove areas are influenced by abiotic, biotic and anthropogenic factors. Among them it is highlighted flood tide level, fishery pressure, mangrove conservation status and mangrove vegetation composition. The crab abundance and density tend to be higher in less-flood mangroves, when fishery pressure is low or absent, when mangroves show a good conservation status and their vegetation is dominated by *Laguncularia racemosa*. The flood tide level shows a negative correlation with the crab density; therefore, higher flood level is associated with lower crab density. Considering an isle of mangrove, which is very common in this ecosystem, this configures a spatial pattern wherein the crab population occurs at lower densities in the less-flood areas.

The study stresses the importance to consider the crab mortality tax in order to evaluate the corrected *U. cordatus* abundance, which is major for stock assessment. Decrease in mangrove extent due to anthropogenic factors has a direct impact in the crab abundance, causing a high reduction in total and corrected abundances, due to habitat loss. This highlights the need for the conservation of mangrove habitats in order to maintain *U. cordatus* stocks.

Mangrove areas most composed by small crabs of *U. cordatus*, with carapace width between 30 to 60 mm, tend to show high future extractive potential (FEP) and low immediate extractive potential (IEP). Since *Ucides cordatus* show low growth rate this pattern in extractive potentials tend to change at a low annual rate for IEP increment. Therefore, considering the Proposal of a National Management Plan for the Sustainable Use of *Ucides cordatus*, mangroves showing these features should be designated as exclusion areas in order to allow juvenile crabs grow and reach the commercial sizes, which is very important to promote a sustainable fishery. Finally, it was concluded the importance of long-term data about the population structure of *U. cordatus*, including comparison of past and current data, as base to designate exclusion and extractive areas in the National Management Plan for the Sustainable of this species.

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