Abstract

The present research, undertaken in a mangrove swamp in northeastern Brazil (Mamanguape River Estuary), examined the factors that led to the overwhelming acceptance of the tangle-netting technique by crab harvesters in detriment to the now illegal tamping technique. Both techniques are the only ones currently used at our study site and in many other areas in Brazil, despite being prohibited by law. Data were collected through direct observations to determine capture efficiency, productivity, daily production, selectivity, and harvesting effort, and through interviews with crab harvesters, focusing on their perceptions of the capture techniques, the conditions of crab stocks and the sales price of a dozen crabs. Our results indicated that the two capture techniques did not significantly differ in terms of their efficiency or productivity, but daily production rates differed significantly, being greater using tangle-netting. The tangle-netting permits a greater harvesting effort (6 hours and 34 min) compared to tamping (4 hours and 19 min). Tangle-netting is also less selective than tamping indicated by the larger number of captured smaller specimens, including females. This results in a lower average sales price for a dozen crabs caught by tangle-netting (US$ 0.95) compared to tamping (US$ 1.02). The greater daily production of crab harvesters using the tangle-netting technique nevertheless increased their net gain, explaining their preference for this method, Given that tangle-netting results in greater harvesting pressure but lower selectivity compared to tamping, it may potentially be less sustainable. All of the crab harvesters interviewed having more than 20 years of experience (n = 34) stated they perceived that stocks of *U. cordatus* had become reduced over the last 20 years, together with average crab sizes. It is now important to examine the structure of the local *U. cordatus* population and to assess its fishery to allow evaluating whether the illegal, but prominent tangle-netting and tamping mangrove crab capture techniques are sustainable or not. We further suggest improving the dialogue between decision makers and fishermen, which barely exists to date, to initiate a discussion about possible ways of resolving the current situation of illegality of the fishermen. This will be key to achieving effective sustainable co-management of this important natural mangrove forest resource.

Key-words: artisanal fishing, crab harvesters, crustaceans, sustainability.

1. Introduction

The mangrove crab *Ucides cordatus* (“caranguejo-uçá”) is found in intertidal zones of mangrove swamps from Florida (USA) through Santa Catarina State (Brazil) (Chace and Hobbs, 1969; Manning and Provenzano Jr., 1961; Rathbun, 1901) in burrows that vary in depth from 0.5 to 1.5 m (Alcântara-Filho, 1978; Castro, 1986; Puelmanns et al., 2014). This species has numerous ecological functions in mangrove ecosystems. Its burrows provide oxygen and help drain the sediments (Aller and Aller, 1998; Puelmanns et al., 2015) and its dietary preference for plant material (Nordhaus and Wolff, 2007) accelerates the breakdown of organic material and nutrient recycling (Nordhaus et al., 2006). In the food chain it is prey of diverse predators such as other crustaceans, fish, birds, and mammals (Pinheiro et al., 2005; Wunderlich et al., 2008), including humans.

U. cordatus is one of the most heavily exploited natural resources in mangrove swamps in Brazil, generating jobs and income for coastal communities (Alves et al., 2005; Alves and Nishida, 2002; Capistrano and Lopes, 2012; Nascimento et al., 2012; Nordi et al., 2009; Passos and Di Beneditto, 2005). Boeger et al. (2005) stated that destruction of mangrove habitats, and diseases threaten local crab populations. Overfishing is also frequently suggested as a risk in many places, however for most Brazilian mangrove swamps available stock data are insufficient to confirm populational declines.

Decreases in *U. cordatus* populations represent a threat to the sustainability of their harvesting, which can cause detrimental socio-economic impacts for thousands of people who depend on this resource for financial subsistence (Alves and, Nishida 2003). As a response to problems encountered in the harvesting of *U. cordatus* in Brazil, the Environmental Ministry elaborated a proposal in 2011 to help guarantee its sustainable use, as well as that of other crustaceans such as *Cardisoma guanhumi* and *Callinectes sapidus*, and fisheries resources in general.

The harvesting techniques used to capture *U. cordatus* have been intensively discussed in proposals for management plans, in light of the fact that some capture strategies are considered more detrimental than others. Historically, mangrove crabs have been harvested using various different techniques, one of them being the widespread and more traditional *braceamento*. When applying the braceamento technique, the crab harvester will simply introduce his arm into the crab's burrow and grab the creature with his hand, dragging it to the surface (Diele et al., 2005; Nascimento et al., 2012). *Tapamento* (tamping) is another traditional technique used in many areas of Brazil, including Paraíba State, and consists of blocking the crab’s burrow with mud (pushing it into the burrows using one's feet). This technique predominated among indigenous populations for many centuries (Nordi, 1992).

According to the harvesters, the crab will then move to the upper part of the burrow and attempt to dig itself out - becoming exhausted by the effort and the lack of oxygen, so that it can be taken with little resistance (Nascimento et al., 2012). There is no information available in the scientific literature, however, to corroborate this assumption.

Within the last three decades (probably since the 1980's), however, a new technique called "tangle-netting" (*redinha*) has rapidly spread among crab harvesters in many areas of Brazil (Nunes and Samain, 2004), with reports of its use in Paraiba State (Alves and Nishida, 2003; Nascimento et al., 2012; Nordi et al., 2009); Rio de Janeiro (Jablonski et al., 2010; Passos and Di Beneditto, 2005); Pernambuco (Botelho et al., 2000); São Paulo (Mendonça and Lucena, 2009); Sergipe (Santa Fé and Araújo, 2013); and Rio Grande do Norte (Capistrano and Lopes, 2012). This technique consists of placing polypropylene threads across the opening of the burrows of *U. cordatus* fixed to pieces of broken prop roots or branches of the mangrove tree *Rhizophora mangle* (Nascimento et al., 2012). When leaving their burrows, the crabs become entangled in the threads and can easily be captured. According to these authors, these traps are set and then removed during the same low tide period, although unsuccessful traps can be left and then checked again the next day.

The Brazilian Institute of the Environment and Natural Resources - IBAMA (2011), the Brazilian Federal Environmental Agency, considers the tangle-netting technique to have much greater environmental impacts than the traditional braceamento, and in 2003 prohibited its use as well as the use of the tamping technique in Brazil (Decree Nº 034 /03-N of June 24, 2003). Potential environmental impacts related to the use of tangle-netting technique include: less size selective captures, larger yields, mangrove swamp pollution, and the cutting of the roots of *R. mangle* (Nascimento et al., 2012). According to Santa Fé and Araújo (2013), this prohibition was implemented without detailed prior monitoring and comparison with the braceamento technique (the only legally permitted method), and without consulting the crab harvesters, key stakeholders.

The prohibition of the use of tangle-netting did not, however, inhibit the spread of this new technique which has displaced older traditional techniques in many areas of Brazil. In light of this situation, the present research, undertaken in a mangrove swamp in northeastern Brazil (Mamanguape River Estuary), examined the factors that led to the overwhelming acceptance of the tangle-netting technique by crab harvesters in detriment to the braceamento, which is no longer used in the study area, and tamping technique. Based on earlier qualitative information supplied by local crab harvesters (see Nascimento et al., 2011; Nascimento et al., 2012), we hypothesized that the tangle-netting technique creates more harvesting pressure

than tamping in terms of factors such as efficiency (capture success), selectivity (considering the sizes and sexes of the harvested crabs), productivity (crabs/man/hour), and harvesting effort (time spent for capturing).

2. Material and Methods

2.1. Study area

The Mamanguape River estuary (06º 43’ 02” - 06º 51’ 54” S x 35º 07’ 46” - 34º 54’ 04”W) is the second largest estuary in the northeastern Brazilian Paraíba State (16,400 ha), with a mangrove swamp covering 45.7 km^2 (Maia et al., 2006) (Fig. 1). The environmental protection area (APA) “Barra do Rio Mamanguape” and the area of relevant ecological interest (ARIE) “Manguezais da Foz do Rio Mamanguape” are located in the area, as well as several indigenous (Potiguara ethnicity) areas and villages.

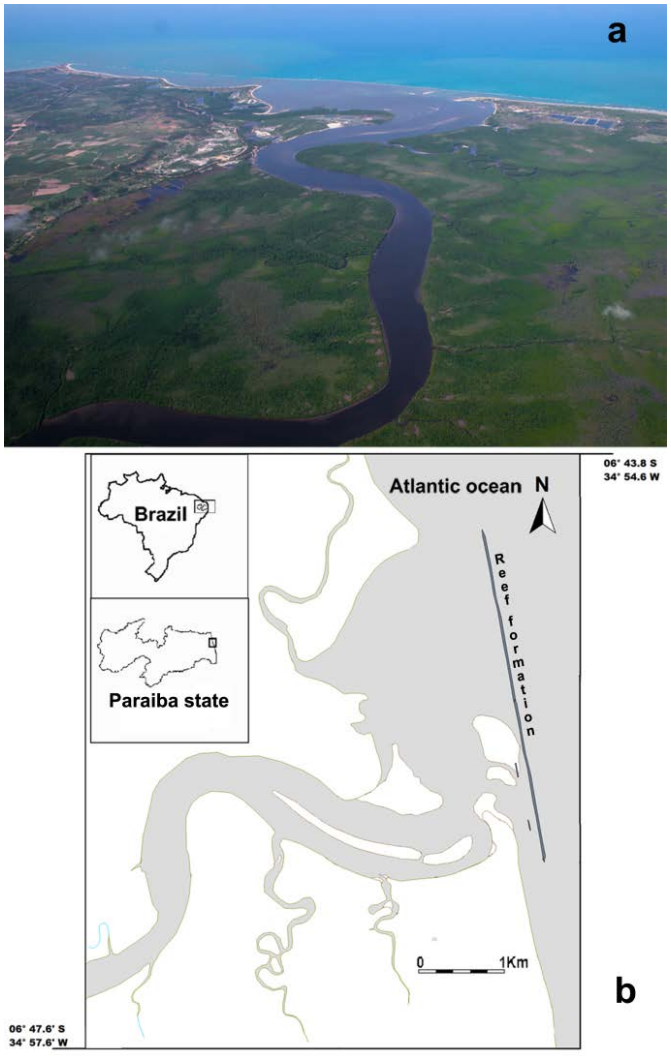


Fig. 1. The Mamanguape River estuary – PB, Brazil. A: Aerial view (photo: Dirceu Tortorello, 2008); B: Geo-referenced map (Figure adapted from Xavier et al. 2012).

The Potiguara Amerindians are part of the Tupi linguistic group that currently occupies portions of the northern coast of Paraíba State, with a total population of approximately 19,000 inhabitants in villages and towns in Baía da Traição, Marcação, and Rio Tinto (Cardoso and Guimarães, 2012). These villages constitute three contiguous Indigenous Reservations - IRs (the Potiguara, Jacaré de São Domingos, and Potiguara de Monte-Mor IRs), comprising a total of 33,757 hectares (Cardoso and Guimarães, 2012). The Potiguara economy is based on agriculture and fishing (Cardoso and Guimarães, 2012).

The harvesting of *U. cordatus* is the most important economic activity in the estuary (Paludo and Klonowski, 1999) and is concentrated in the four localities Jaraguá, Marcação, Camurupim, and Tramataia (Institute of Biodiversity Conservation Chico Mendes – ICMBio, 2014). The village Tramataia has the largest number of crab harvesters, which was the principal motivation for choosing this community for study. The community of Tramataia is a Potiguara Amerindian settlement situated within the municipality of Marcação - PB. The community comprises 243 families occupying 230 residences, with a total population of 1110, of which 877 (452 men and 425 women) are Amerindians (Source: SIASI - FUNASA/MS, 07/04/2011). The socio-economic profiles of these *U. cordatus* harvesters demonstrate precarious living, health, and educational conditions, and very low incomes - putting them at the very margin of modern society (Alves and Nishida, 2003).

2.2. Research permit and design

Scientific research in the Barra do Rio Mamanguape Environmental Protection Area was authorized by the Institute of Biodiversity Conservation Chico Mendes (ICMBio) through the Automated System of Biodiversity Authorization (SISBIO) (numbers: 36974-1 and 36974-2); the Research Ethics Committee (CEP) of the University of Pernambuco (UPE) conceded authorization for research with humans (authorization number 359.093); the National Institute of Historical and Artistic Heritage (IPHAN) conceded authorization to investigate traditional knowledge without access to any genetic patrimony (authorization number 019/2014); and the National Indian Foundation (FUNAI) authorized access to the Potiguara indigenous lands for purposes of scientific research (authorization number 97/AAEP/PRES/2014).

The technique of direct observation, the equivalent of non-member participatory observation (Sttebins, 1987), was used to collect qualitative and quantitative data while accompanying the harvesting activities of the crab harvesters during low tide periods between September/2013 and October/2014. The tangle net and tamping techniques, both illegal, are the only crab capture techniques currently used in the Mamanguape River estuary, and individual harvesters in the region always use only one of these capture techniques, never both. The legal technique of braceamento has fallen into disuse in the study area and it was therefore impossible to include it in the analyses for comparative purposes. Our fieldwork included 37 harvesting days accompanying professional fishers that only use the tamping technique, and 37 harvesting days with crab harvesters using exclusively the tangle-netting technique. In the first nine months of our fieldwork at least six harvesting days/month occurred (three for each technique) and four harvesting days/month occurred (two for each technique) for the last five months of our research. The crab harvesters were individually accompanied and interviewed. Each day of fieldwork consisted of accompanying one crab harvester (using one of the two different harvesting techniques) during low syzygy tides during the day.

The ages of the interviewees (n = 74) varied between 19 and 62 years, with a mean age of 34. The mean ages of the fishermen that used the tamping and tangle-net techniques were 52 and 30.7 respectively. Of the total interviewees, thirty-four had more than 20 years of experience and forty had less than 20 years of experience. Semi-structured interviews (Huntington, 2000) were conducted while accompanying crab harvesters in the field, during which they stated their perceptions of the work involved in capturing *U. cordatus* and any changes in the availability of stocks of these animals during last 20 years. The crab harvesters answered questions concerning their perceptions of crab populations over time, harvesting efforts, the differences of the impacts of the two studied techniques, and market benefits. Questions concerning crab stocks and general and personal harvesting efforts during the last 20 years were only directed at fishermen with at least 20 years of experience (n = 34). All other questions were directed to all of the interviewees. Specific questions were: 1) How do you perceive the crab stocks over the last 20 years? 2) How do you compare your current harvesting effort over that of 20 years ago? 3) What is your relationship with the environmental agencies? 4) What would be your suggestions for improving controls on *U. cordatus* harvesting? 5) What is your selling price (US$) for a dozen crabs?

Field observations covered all steps involved in the harvesting of the crabs in the mangrove forest: (i) preparation (mounting the tangle-netting, or tamping the crab burrows),

(ii) the subsequent “waiting interval” during which the crabs entangled in the nets or emerged to the upper part of the tamped burrows, and, finally, (iii) the collection of the crabs. The total numbers of burrows covered with tangle nets or tamped, and the numbers of unsuccessful captures were noted, as well as the time spent for each of the harvesting steps. The efficiencies (capture success) and harvesting effort (time invested in capture) of the two techniques were compared.

Data concerning daily production (quantities of crabs, crab sizes, and sex) were collected as soon as the harvesters returned to their homes. Productivity, represented by the Catch per Unit Effort (CPUE), was estimated by determining the numbers of crabs captured per hour (crabs/man/hour). This calculation is controlled by the relationship between capture (resource abundance) and effort (a function of the behavior of the harvesters) (Voges et al., 2005), with the latter being influenced by both economic and social factors (Lopes and Begossi, 2011).

Biometric data of the crab carapaces were taken using a digital caliper (precision 0.01 mm) measuring the following parameters: length (measured along the sagittal plane on the dorsal part of the animal's body), width (measured transversely at the level of the first pair of pereiopods, corresponding to the widest dimension of the body), and height (the dorsal-ventral dimension, measured at the central portion of the carapace).

The standard measure used by environmental control agencies is carapace width (CW), and current legal capture size is 60 mm carapace width, for both sexes (Decree IBAMA/PB n.º 34 of 03 June, 2003). Therefore, the proportion of legal-sized crabs from the total catch was determined for each capture methods.

The sexes of the captured specimens were determined by the shapes of their abdomens. The number of captured ovigerous females, recognizable by egg clutches under their abdominal flap, was noted. Ovigerous females were always released in the mangrove.

2.3. Data analysis

Efficiency, productivity, harvesting effort, and selectivity of each capture technique were compared. The data were tested for normality using the *Shapiro-Wilk* test, and for *homocedasticity* using the Levene test. Student t test comparisons were made to determine if there were significant differences between the productivities (CPUE) and efficiencies of the two harvesting techniques. Statistical analyses were also employed to analyze the degree of capture selectivity (sizes and sex ratios). Comparisons of the sizes of the captured crabs

(median values of CW) were performed using the Student t test; comparisons between the numbers of captured females were performed using the chi-square test (X^2). All analyses were conducted using the R statistical program (R Development Core Team, 2011) and Excel.

The captured specimens were grouped into carapace width, length, and height classes according to the capture technique used. The classes were calculated using Sturges' formula (1926): K = 1 + 3.3222logN, where K represents the number of classes and N the total number of samples.

Qualitative data analysis considered emic perceptions (Toledo, 1991). Emic approaches consider the manner in which the members of the culture being studied perceive, structure, classify, and articulate their universe (in this case, faunal resources) (Posey, 1987).

3. Results

3.1. Efficiency and harvesting effort

During the 74 accompanied harvesting days, a total of 8.755 *U. cordatus* specimens were collected, 6.178 specimens by the harvesters using the tangle-netting technique (n = 37 harvesting days) and 2.577 by the harvesters deploying the tamping technique (n = 37 harvesting days). The CPUE of the two techniques, 24.3 crabs/man/hour for the tangle netting and 20.8 crabs/man/hour for the tamping, did not differ significantly (p> 0.05- [P(T<=t) bi-caudal = 0.2009885]). On the other hand, daily production, i.e. the respective median numbers of specimens captured per day, was significantly higher for tangle-netting than for tamping (166.9 versus 69.6 crabs per day, respectively) (p<0.05 [P(T<=t) bi-caudal = 0.0000]).

Both techniques demonstrated high capture success percentages, with 82.5% for tangle-netting and 79.3% for tamping. This small difference was not significant ($t_{17.189;\ 2\ (0.05)}$ = 0.7865; p = 0.5463).

The average daily time spent for capturing crabs by the harvesters was six hours and 34 minutes (preparation: 4h and 15 min. / waiting interval: 1h / harvesting: 1 h and 19 min.) for those using the tangle-netting technique, and four hours and 19 minutes (preparation: 2h and 11 min. / waiting interval: 1h / harvesting: 1 h and 8 min.) for those using the tamping technique. The waiting interval for both harvest techniques is determined by crab harvesters.

3.2. Capture selectivity: Sizes and sexual ratios of harvested crabs

The mean CW of the crabs captured using tangle-netting and the tamping techniques were 64.83 and 68.77 mm respectively, the former being significantly smaller than the latter ($t_{2256.70;\ 2\ (0.05)} = -23.29$; $p = 0.0000$) (Table 1). The percentage of crabs captured smaller than the legal carapace width of 60 mm was 21.5% (11.4% males and 10.1% females) and 5.3% (4.1% males and 1.2% females) for tamping and tangle-netting captures, respectively.

Most (71.6%) of the crabs harvested using tangle-netting belonged to the 60 to 70 mm width class, while 67.9% of the crabs captured by tamping fell within the 65 to 75 mm width class. The distribution of individuals into length, width and height classes (Fig. 2) confirmed that the crabs captured by tamping were larger. The average carapace width of females and males captured by tamping was 64.74 mm (±4.397) and 68.50 mm (±4.724), respectively, while for the tangle-netting technique it was 61.96 mm (±3.900) and 63.67 mm (±4.786), respectively.

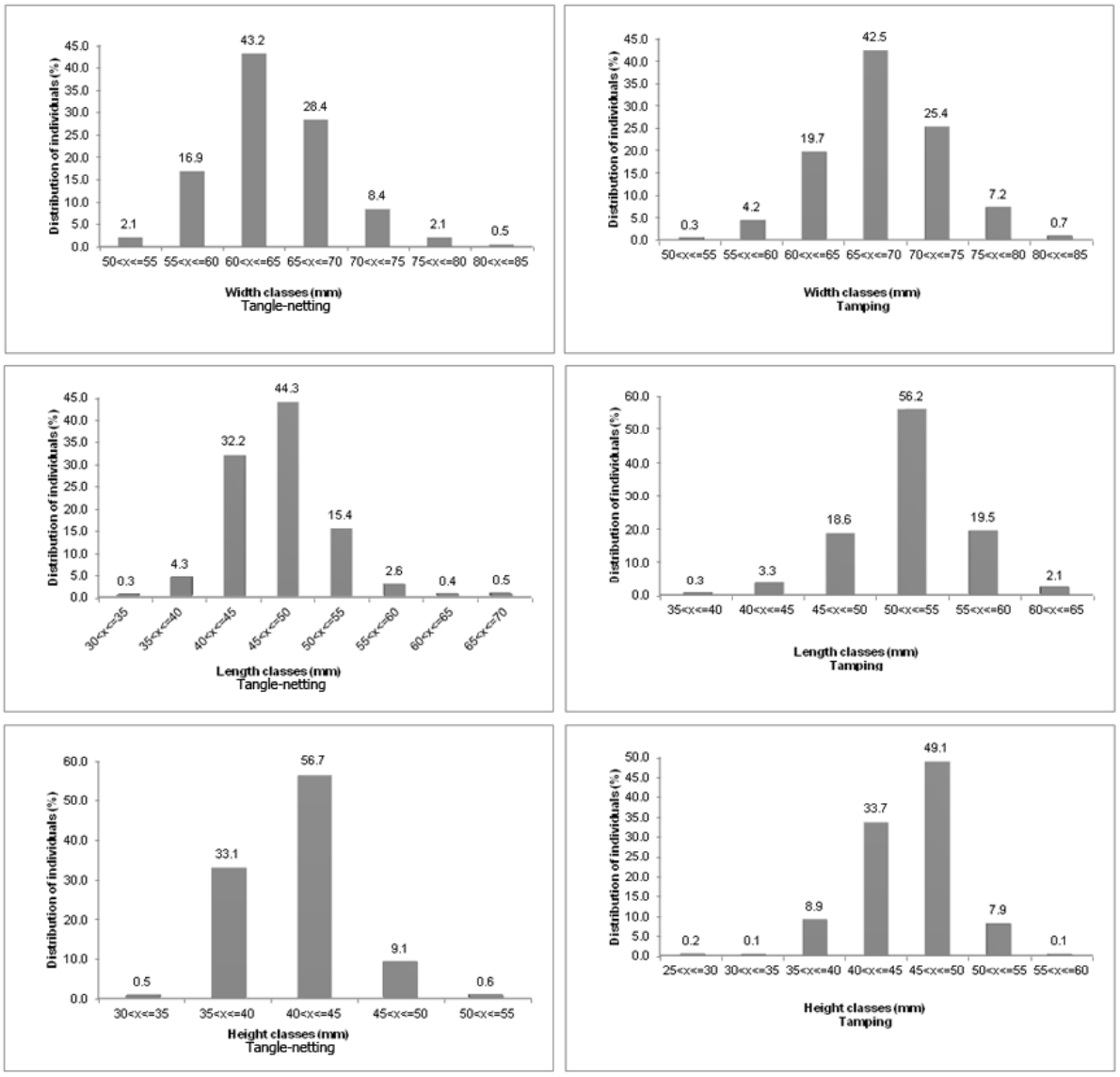
The proportion of females was significantly higher when capturing crabs with the tangle-netting technique than when using the tamping technique (Table 2; $\chi^2 = 203.1995$, df = 1, p-value < 0.0000). Of the total number of female crabs captured by the fishermen (n = 1918), 39 (2%) were ovigerous females, with 21 (1.1%) of them having been captured using tangle-nets and 18 (0.9%) by tamping.

Table 1

Carapace width (CW), carapace length (CL) and carapace height (CH) of the crabs captured by the tangle-netting and tamping techniques in the Mamanguape River estuary mangrove swamp – PB, Brazil. The number of accompanied harvesting man days was 37 for each technique.

TANGLE-NETTING (n = 6.178 CRABS)				TAMPING (n = 2.577 crabs)		
CARAPACE DIMENSIONS						
VALUES (mm)	CW	CL	CH	CW	CL	CH
Maximum	82.01	66.89	53.38	85.31	64.17	59.48
Minimum	52.14	32.56	33.98	52.59	36.13	32.46
Mean	64.83*	45.92	42.02	68.77	53.62	47.11
Standard error	4.668	3.901	3.055	4.814	3.7	3.659

*Statistically significant ($p < 0.05$)



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298 **Fig. 2.** Distributions of the crabs (both sexes) captured by tangle-netting and tamping in the
299 Mamanguape River estuary mangrove swamp - PB, Brazil, into carapace width, length, and
300 height classes, in 5 mm intervals. The numbers above the bars means distribution of
301 individuals (%).

302

303 **Table 2**

304 Percent of male and female crabs captured using the tangle-netting and tamping techniques in
305 the Mamanguape River estuary mangrove swamp - PB, Brazil

	Sex ratio (%)*	
	Males (n = 6837)	Females (n = 1918)
Tangle-netting	71.6	28.4
Tamping	93.7	6.3

306 *Statistically significant ($p < 0.05$)

307

308 3.3. Ethno-ecological information

309

310 All of the crab harvesters were men. According to those workers themselves, the
311 participation of women in the production chain of *U. cordatus* is restricted to crab meat
312 processing, labor for which the latter are informally employed by middlemen. There were no
313 female crab harvesters or women that took on the roles of buyers in the community.

314 All crab harvesters interviewed with more than 20 years of experience (n = 34) stated
315 their perception that *U. cordatus* stocks in the Mamanguape River estuary had become
316 reduced over the last 20 years as they must now work for longer periods of time to gain the
317 same harvest quantities of the past. These professionals also noted that the average size of the
318 harvested crabs has decreased over time, although sex ratios have remained stable, despite the
319 fact that more males than females are harvested.

320 According to the interviewees, the principal factor limiting their capture times using
321 either the tangle-netting or tamping technique is the daily tidal cycle, as harvesting can only
322 be performed during low tide, when the mangrove substrate is exposed. The physical effort
323 involved was another limiting factor cited by those employing the tamping technique, as the
324 effort spent during their work is greater than that required by the tangle-netting technique.

325 The fishing grounds are the same for both techniques, with the fishermen capturing
326 crabs in the same localities – with preference for areas with more solid mud (“mangue duro”),
327 as these are more amenable to human locomotion.

328 No physical damage was observed to crabs caught by either the tamping or tangle-net
329 techniques during the data collection phase, although some mutilations can occasionally
330 occur, such as autonomy of pereiopods. According to the interviewees, care is taken while
331 handling the captured crabs to avoid unnecessary damage, which would reduce their value on
332 the market.

333 Of the crab harvesters that use tangle-netting (n = 37), 49% believed that the technique
334 had greater impacts on crab populations than more traditional techniques such as braceamento
335 and tamping; 51% of the fishermen did not view the technique as more impacting than
336 traditional techniques. Ninety-three percent of the interviewees who use that (illegal)
337 technique were in favor of dialoguing with the appropriate environmental organs to discuss
338 the current legislation governing crab harvesting techniques. This type of conversation with
339 environmental administrators is not occurring, however, quite possibly because the crab

harvesters are technically violating environmental laws and thus do not participate in decisions in terms of the formulation of laws or management plans.

These harvesters have, however, articulated a series of suggestions for improving the resource management of the mangrove crab resource, including:

1) Receiving government aid during the reproductive period of *U. cordatus* when harvest is prohibited by law. Without such compensatory payments, they are economically obliged to continue crab harvesting, putting more pressure on the species. With secured rights to receive funds during this reproductive period, the fishermen indicated that they would gladly assist the government in enforcing those regulations.
2) The creation of a system of economic aid during the period of peak molting/ecdysis (September and October), as every year at that time *U. cordatus* crabs retreat to their burrows and plug them, making it difficult to capture them – and even if they are harvested, they are often tasting bad and are difficult to sell.

The middlemen, who purchase the harvesters' productions and resell them to market establishments, pay each fisherman for the sales unit of dozen crabs, according to the quality of the catch. Sales units composed of large male crabs are worth more (US$ 1.33) than sales units of females or small males (US$ 0.66). The average sales price of a dozen crabs during the research period was US$ 1.02 (tamping) and US$ 0.95 (tangle-netting), and the average daily profits of the crab harvesters using the tangle-netting and tamping techniques were US$ 13.30 and US$ 5.95 respectively.

4. Discussion

Greater production and more than two-fold higher financial returns appear to be the principal motives contributing to the abandonment of traditional techniques (braceamento and tamping) for the capture of the mangrove crab *Ucides cordatus* in the northeast Brazilian study area, in favour of the newer tangle-netting technique. Nascimento et al. (2011) showed that the tamping technique was employed by less than 9% of the crab harvesters in the Mamanguape River estuary in 2010, with the perspective of their total abandonment in the near future. The substitution of more traditional techniques by tangle-netting has also been observed by Cortês et al. (2014) in other regions of Brazil such as in Gargaú, Rio de Janeiro State, and by Santa Fé and Araújo (2013) in the coast of Sergipe State.

The harvesters using the tangle-netting technique captured 16.2% more crabs below legal minimum size (60 mm CW) than those using the tamping technique. The differences in crab harvest-sizes between the two techniques probably reflect the more selective choices of the tamping harvesters – as they must invest greater physical efforts in capturing each crab, and therefore seem to invest more time and effort in collecting larger specimens (principally males). Overall, the CW of the crabs captured using the tangle-netting technique was on average 3.94 mm smaller than those caught by tamping, due to the larger number of females captured. These females were about 4.83 mm (CW) smaller than the males captured with the tamping technique. Females are generally smaller than males, which also explains their lower market price compared to males (e.g. Diele et al., 2010). However, the mean price paid for a dozen crabs captured by harvesters using the tangle-netting technique was only 5% lower than for a tamping yield, but the greater overall production of the tangle-netting technique resulted in the twofold higher general income of the former compared to the latter. This significant economic advantage of the tangle-netting technique likely explains its popularity and its increasing use in our study areas as well as elsewhere in Brazil.

Despite the fact that the tangle-net technique facilitates crab harvesting, the socio-economic status of these fishermen and their families remains very low. According to Alves et al. (2005), the almost complete economic dependence of these fishermen on harvesting *U. cordatus* results in significant environmental pressure on those animals and the mangrove ecosystem itself. The lack of alternative income options and the limited economic gains of crab harvesting make this activity barely economically sustainable (Glaser and Diele, 2004).

The fishing efforts of crab harvesters were limited by two principal factors: the daily cycles of the tides and the physical effort required to perform each technique (especially the traditional tamping technique). Harvesters can only capture crabs during low tide periods when the mangrove swamp is not inundated, independent of the technique used. Since tampering a burrow takes longer than setting a tangle-net, harvesters using the former technique have potentially less effective time for crab harvesting during a given low-tide period than those deploying tangle-netting. Additionally, tamping burrows is physically quite demanding, so that tamping harvesters target fewer burrows and spend less time in the mangrove swamp than those that are tangle-netting. This explains the lower total production of the former harvesters, despite similar capture success and CPUE.

The yield of the crab harvesters using the tamping technique contains a higher proportion of male specimens (more commercially valued) compared to tangle-netting, probably to compensate their low production. Regardless of the technique used, crab

harvesters are able to distinguish between burrows occupied by male and female specimens, allowing them to optimize their harvest efforts by sex selectivity (Alves et al., 2005; Cortês et al., 2014). According to Alves et al. (2005), crab harvesters of both techniques have a success rate of up to 74% in identifying the sex of burrow inhabitants prior to their capture. They use the tracks in the mud to identify the sex of the crabs: males produce deeper marks with larger diameters than females, as they possess pereiopods bearing more hairs.

The crab harvesters stated that the growing use of tangle-netting in the Mamanguape River estuary, as opposed to traditional techniques, is due to a number of factors: smaller risk of work accidents (e.g., cuts on their hands and arms caused by oyster shells), a smaller risk of acquiring illnesses (such as skin problems caused by fungi), the ease of use of the tangle-netting - with less physical effort required and greater final production and financial gains (Nascimento et al., 2011). Crab harvesters using the braceamento and tamping techniques are more exposed to these risks as they come into more direct and sustained contact with the mangrove mud. Rosa and Mattos (2007) and Walter et al. (2012) classified crab harvesting as dangerous and a public health problem respectively. Furthermore, during periods of illness fishers may not be able to work, compromising their financial livelihoods.

Historically, the profession of harvesting mangrove crabs, *U. cordatus*, in the Mamanguape River estuary was male-dominated. Capture activities are considered, at least locally, as excessively rigorous for women to perform, even using the tangle-net technique. As such, the energetic costs of harvesting activities, added to the physical risks involved, makes the participation of women much less frequent, and for fact absent in the study area.

The crab harvesters interviewed were unanimous in recognizing decreases in crab abundance and average crab size over the years, and in attributing this to increased harvesting pressure. It must be noted however that crab stocks in the study area decreased significantly in 1998 due to significant die offs of *U. cordatus* (Alves and Nishida, 2002), probably due to the Lethargic Crab Disease (LCD) caused by the pathogenic fungus *Exophiala cf psychrophila* (see also Boeger et al., 2005). Alves and Nishida (2002) reported that after this event an average of only 48 crabs were captured per man per harvesting day, in contrast to the many fold higher production rates observed in the present study (> 100 crabs per harvesting day). Hence, stocks have been recuperating.

5. Conclusion

Our results show that the use of the tangle-netting technique does not guarantee greater efficiency and productivity as compared to tamping, but results in greater daily production, since the fishermen can harvest for longer periods of time, and therefore produce a more than twofold larger economic yield. The lower productivity and financial return of the more traditional tamping technique explains its substitution by tangle-net harvesting in the region for the harvesting of *U. cordatus*, an economic activity strongly influenced by local and regional commercial demands.

The tangle-netting technique is much less size selective than the tamping technique (22% versus 5% of total catch with illegal crab sizes), thus exercising a greater capture pressure on the crab population. The lack of (i) data on the structure and resilience of the *U. cordatus* population in the Mamanguape river estuary, (ii) fishery stock assessments and (iii) knowledge of the magnitudes of secondary impacts caused by tangle-netting (pollution through discarded nets, cutting of the prop roots of *R. mangle* while setting the traps), does not yet allow to unambiguously evaluate whether the use of tangle-netting (and tamping) poses a real threat to the crab resources in the Mamanguape River estuary, and in many places elsewhere. Nonetheless, the perception of local crab harvesters is that crab stocks have become reduced in the last 20 years, with decreasing average crab sizes suggesting overfishing. This perception of the crab harvesters, however, is based on long-term memories of harvesting stocks, memories that could well be exaggerated or otherwise inaccurate, and must be viewed with caution (Capistrano and Lopes, 2012). There is urgent need for the generation of above-mentioned data and the beginning of a dialogue between decision makers and stakeholders to exchange views and discuss the reasons for the non-compliance of the current fisheries legislation and possible ways to solve this conflict. The current situation of not only socio-economic marginalization of crab harvesters, but also their “environmental criminalization” needs to be resolved.

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