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Population structure and relative growth of freshwater prawn *Macrobrachium amazonicum* (HELLER, 1862) (Crustacea, Palaemonidae) in two regions of the State of Amapá, Amazon River mouth, Brazil

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ABSTRACT: *Macrobrachium amazonicum* is an indigenous prawn vastly distributed in basins of South America, widely exploited by artisanal fisheries in northern and northeastern Brazil and, with great potential for aquaculture. This study aimed at examining the population biology with emphasis on the sex ratio and size frequency distribution. The specimens were analyzed in terms of population structure, sexual ratio, size frequency distribution, recruitment and the relative growth was compared by sex and seasons. A number of 5,179 (2,977 females and 2,192 males) were collected monthly using 20 matapis. The sex ratio in both areas was favorable to females with 1:1.36 in Santana Island and 1:1.41 in Mazagão Velho. The monthly distribution of absolute frequency of juveniles, adult males and females varied according to the season in the two areas studied. Adult females were more abundant in the rainier period; while the adult males and females were similarly abundant in the less rainy period. In Santana Island, females were significantly larger than males, while the sizes were similar between sexes in Mazagão Velho. The regression equations applied to the data shown positive allometry in all relations, with r^2 more than 0.94 in both sex and sites.

Keywords: morphometric relationships, sex ratio, matapi.

Estrutura populacional e crescimento relativo do camarão de água doce *Macrobrachium amazonicum* (HELLER, 1862) (Crustacea, Decapoda, Palaemonidae) em duas regiões do estado do Amapá, foz do rio Amazonas, Brasil

RESUMO: *Macrobrachium amazonicum* é um camarão nativo vastamente distribuído em bacias da América do Sul, largamente explorada por pescadores artesanais no Norte e Nordeste do Brasil e com grande potencial para aquicultura. Este estudo teve como objetivo analisar a biologia da população, com ênfase na razão sexual, distribuição de frequência de tamanho e descrever as equações matemáticas referentes ao crescimento relativo. Os espécimes foram analisados em termos de estrutura da população, razão sexual, distribuição de freqüência de tamanho, recrutamento e o crescimento relativo sendo comparado por sexo e estações. Um número de 5.179 (2,977 femeas e 2.192 machos) foram coletados mensalmente, utilizando 20 matapis. A proporção entre os sexos em ambas as áreas foi favorável às fêmeas com 1:1,36 na Ilha de Santana e 1:1,41 em mazagão Velho. A distribuição mensal de frequência absoluta de juvenis, machos e fêmeas adultas variou de acordo com a estação nas duas áreas estudadas. As fêmeas adultas foram mais abundantes no período mais chuvoso; enquanto na estação menos chuvosa os machos e fêmeas adultas foram igualmente abundantes. Na Ilha de Santana, as fêmeas foram significativamente maiores que os machos, enquanto em Mazagão Velho os tamanhos foram semelhantes entre os sexos. As equações de regressão aplicada aos dados demonstram alometria positiva em todas as relações, com r^2 mais de 0,94 em ambos os sexos e locais.

Palavras-chave: relações morfométricas, razão sexual, matapi.

1. Introduction

Studies on crustacean populations provide important information on species dynamics and preservation of natural biodiversity. Population studies on freshwater caridean prawns are less numerous than those on the remaining decapods, especially with respect to the marine enviromnment and considering the species described thus far (MANTELATTO; BARBOSA, 2005).

Prawns are decapods restricted to freshwater or need brackish water on the onset of the life cycle (NEW, 2002). Among Palaemonidae prawns, the genus *Macrobrachium* (BATE, 1868) is one of the most important groups worldwide with many species of scientific and commercial interest distributed in tropical and subtropical regions (DA SILVA et al.,2004; SILVA el al., 2007).

Macrobrachium amazonicum (HELLER, 1862) is a widely distributed species in South America, in the basins of the Orinoco, Amazon and Paraguay (HOLTHUIS, 1952). It also focuses on the economy as one of the most exploited resources in the Amazon estuary (Lower Amazon) by artisanal fishermen and coastal communities (MACIEL; VALENTI, 2009; BENTES et al., 2011; LIMA et al., 2014).

In Amazon estuary an imminent overfishing has been signaled by Lucena-Fredou et al. (2010) in bay Guajará (Pará), Freire et al. (2012b) in Bragança Peninsula (Northeast Pará) and Lima et al. (2014) in foz Amazon river (Amapá), indicating the necessity of management fishery for M. *amazonicum*. Despite its economic value and cultural importance as ingredient in regional recipes, management of the species is nearly non-existent due to, among other reasons, the gaps in the knowledge regarding its biology and fishing efforts in the natural environment (BENTES et al. 2011). In this way, this study was conducted to examine the population structure with emphasis on the sex ratio, size frequency distribution and relative growth.

2. Material end Methods

Samples of M. *amazonicum* were collected monthly from January 2009 to January 2010 from Santana Island (00°03'40.9"S and 051°08'46.6"W) and Mazagão Velho (00°15'39.9"S and 051°20' 42.3'W), located at the mouth of the Amazon River, state of Amapá (Figure 1). Specimens were caught with 20 traps locally known as matapis. The traps were set at the depths of 1 to 2 meters for on average

12 hours of immersion. This sampling is equivalent to the capture performed by artisanal fishermen, which occurs every tidal cycle (12h, twice daily). All captures occurred at daybreak. The monthly rainfall data in the region was obtained at the Nucleus of Hydrometeorology and Renewable Energy of Institute of Scientific and Technological Research of the State of Amapá - IEPA (NHMET/IEPA). Rainy period was considered from January to June and the dry period from July to December.

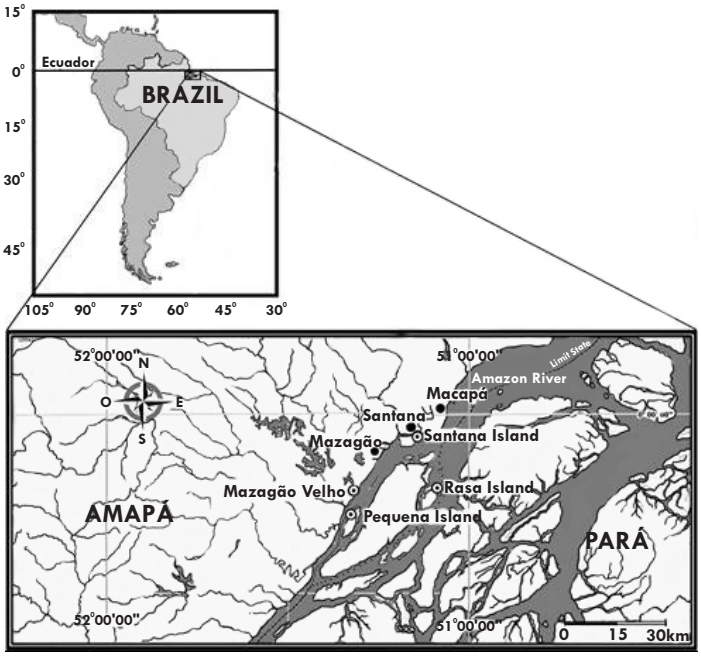

Figure 1. Location of the two study areas - 1) Santana Island, 2) Mazagão Velho.

The specimens were properly labeled and stored in plastic bags containing solution of 4% formalin + 70% ethanol (1:1). Animals identified, counted and sexed. Sex was verified by the presence of masculine appendix on the second pleopod. The male/female ratio was analyzed based on the frequency of individuals captured during the study period. Standard length (SL - linear distance from the base of ocular orbit to the base of the telson), carapace length (CL-measured in mm from the posterior portion of the orbit to the posterior extremity of the carapace) and abdomen length (AL - measured in mm from the anterior portion of the abdomen to the base of the telson) were recorded using a digital caliper (0.1 mm minimum unit). Specimens will be deposited in the collection of crustaceans from the Scientific and Technological Research Institute of the State of Amapá (IEPA) under the accession number 01488.

Morphometric relations were used to apply the power function ($Y = a+b.x$), which was fitted to the data. The CL and AL dimension were used as independent variables because it is used to indicate the size in prawn studies. The pattern of allometry was established for each parameter by the b-value slop ($b = 1$, isometry; $b < 1$, negative allometry, $b > 1$: positive allometry) (HARTNOLL, 1982; RODRIGUES, 1985). To detect the b-difference from unit, the b value was tested by Student t-test (ZAR, 1999). Standard length was compared separately between months, sex and area using analysis of variance with multi factors (ANOVA; $a = 0.05$) and the posteriori Tukey test (ZAR, 1999). The sex proportion was determined per month and collection site using the chi-square test (X^2; $a = 0.05$) according to ZAR (1999). To verify that there is a relationship between rainfall and the number of ovigerous females, one regression analysis was performed (ZAR, 1999).

3. Results

A total of 5,179 prawns was collected, out of which 2,977 (57.48%) were females and 2,192 (42.32%) males, the rest (10) were of undetermined sex (four in Santana Island and six in Mazagão Velho). The ratio between males and females in the population was 1:1.36 in Santana Island ($X^2 = 76.66$; $P < 0.001$) and 1:1.47 in Mazagão Velho ($X^2 = 43.56$; $P < 0.001$) for 3,944 and 1,225 prawns sampled, respectively. Significant differences in the sex ratio were not observed in April, May, August, and November 2009 (Table 1). Ovigerous females accounted for 725 individuals (28.7%) versus 1802 (71.3%) non-ovigerous adult females, with 11.09-31.09 mm carapace length (total length = 49.9-142.08 mm) and 11.09-29.9 mm (total length = 49.9-136.94 mm), respectively. Adult male carapace length ranged from 11.09 to 33.09 mm (total length = 49.9-151.08).

Global number of prawns caught in Santana Island was higher than in Mazagão Velho ($P < 0.05$) (Figure 2). There was increased capture rate during less rainy period (August to October), particularly for adult prawns, matching the period of higher fish production in the region. Monthly distribution of juveniles, adult males and females varied depending on the season in the two areas (Figure 3A, B). In Santana Island, adult females were more abundant that males during rainier period (January to June) and similarly abundant in the less rainy period (July to December), while in Mazagão Velho male and female showed alternated dominance in both seasons. Juvenile prawns were found in most months of the year, but the recruitment peak was observed in July with capture of more 40.0% of juveniles in Santana Island and June, July and September in Mazagão Velho (Figure 3A, B).

Table 1. Number of *Macrobrachium amazonicum* collected from Jan/2009 to Jan/2010 in the Island of Santana and Mazagão Velho, state of Amapá considering sex and sex ratio.

		Santana Island				Mazagão			
Season	Months	Females	Males	X^2	Ratio	Females	Males	X^2	Ratio
Rainy	jan/09	105	30	41.67	3.5:1*	8	4	1.33	2.0:1
Rainy	feb/09	288	75	124.98	3.8:1*	124	84	7.69	1.4:1*
Rainy	mar/09	175	71	43.97	2.4:1*	54	90	9.00	0.6:1*
Rainy	apr/09	51	59	0.58	0.8:1	13	22	2.31	0.59:1
Rainy	may/09	145	165	1.29	0.87:1	19	17	0.11	1.1:1
Rainy	jun/09	43	26	4.19	1.65:1*	40	26	2.97	1.5:1
Dry	jul/09	242	82	79.01	2.9:1*	155	81	23.20	1.9:1*
Dry	aug/09	279	258	0.82	1.08:1	60	44	2.46	1.3:1
Dry	sep/09	359	329	1.31	1.09:1	36	8	17.82	4.5:1*
Dry	oct/09	275	223	5.43	1. 23:1*	62	75	1.23	0.8:1
Dry	nov/09	58	81	3.81	0.7:1	11	15	0.62	0.7:1
Trans	dec/09	214	281	9.07	0.76:1*	104	17	62.55	6.1:1*
Rainy	jan/10	13	17	0.53	0.76:1	44	12	18.29	3.6:1*

(*) X^2 values with asterisk are statistically different at 5% significance.

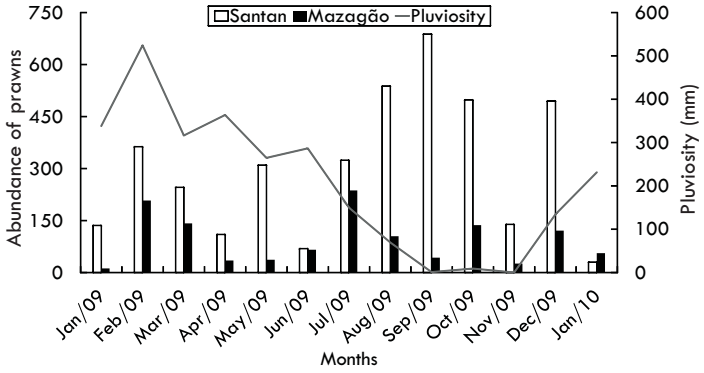

Figure 2. Abundance of *M. amazonicum* (Heller 1862) sampled from Jan/2009 to Jan/2010 in the Island of Santana and Mazagão Velho, state of Amapá and their relationship with rainfall.

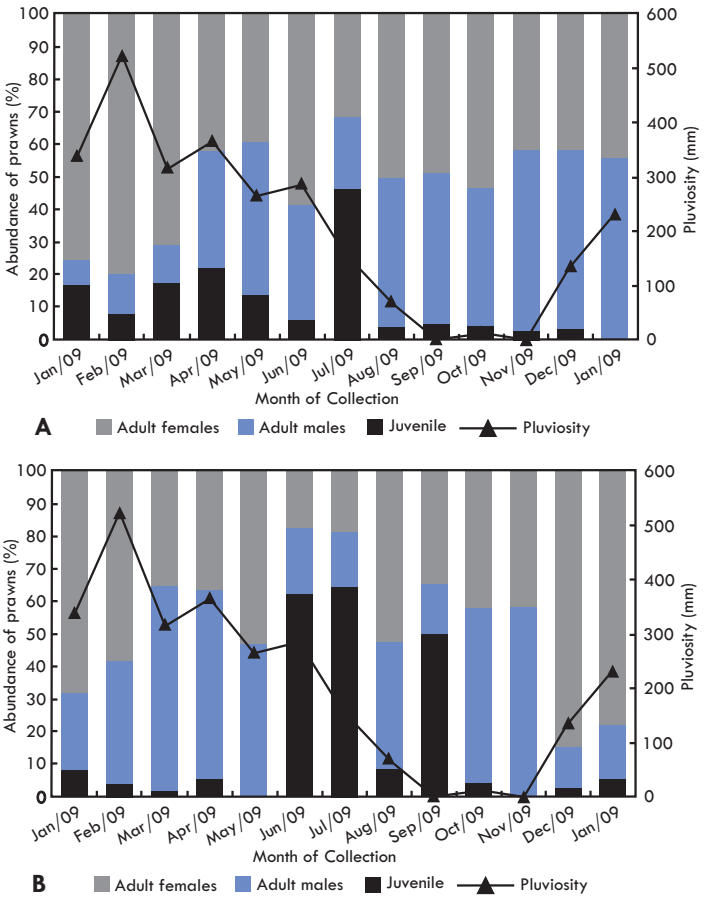

Figure 3. Monthly absolute frequency distribution of juvenile, adult males and adult females of *M. amazonicum* (Heller 1862) sampled from Jan/2009 to Jan/2010 in the Island of Santana (A) and Mazagão Velho (B), state of Amapá and their relationship with rainfall.

A strong dependence between the number of ovigerous females and rainfall was observed in Santana Island shown by the coefficient of determination ($R^2 = 0.6788$), while a moderate dependence was observed in Mazagão Velho ($R^2 = 0.3481$) (Figure 4A, B).

Males had size-frequency distribution concentrated at the 33-48 mm interval of standard length, while females' size-frequency distribution assumed a bell-shape pattern in which the specimens are concentrated around 33-58 mm in the Santana Island, while males had size-frequency distribution concentrated at the 33-43 mm interval of standard length and females' size-frequency distribution assumed a bell-shape pattern in which the specimens are concentrated around 33-53 mm in the Mazagão Velho (Table 2).

The analysis of variance showed differences between the lengths to sexes, sites, month and interaction among the factors.

According to ANOVA females are larger than males. The Mazagão Velho shrimp are larger than those of Santana Island. When analyzed overall by month and location, we found that the shrimps were higher in Mazagão Velho in March, April and May 2009, while in September 2009 and January 2010, the shrimp Santana Island were higher.

Females are larger than males in the rainiest months (January, February, March and April 2009). In Santana Island females are larger than males, while in Mazagão Velho, there was no difference between the lengths. Males of Mazagão Velho were larger than males of Santana Island, while females Santana Island were larger than females of Mazagão Velho.

The interaction between the three factors showed that in Santana Island females were larger than males in the rainy season, while for Mazagão Velho females were higher in March and April 2009 and the males were higher in May and June 2009 (Figure 5).

The regression equations applied to the data showed positive allometry in all relations, with r^2 more than 0.94 in both sex and sites (Table 3).

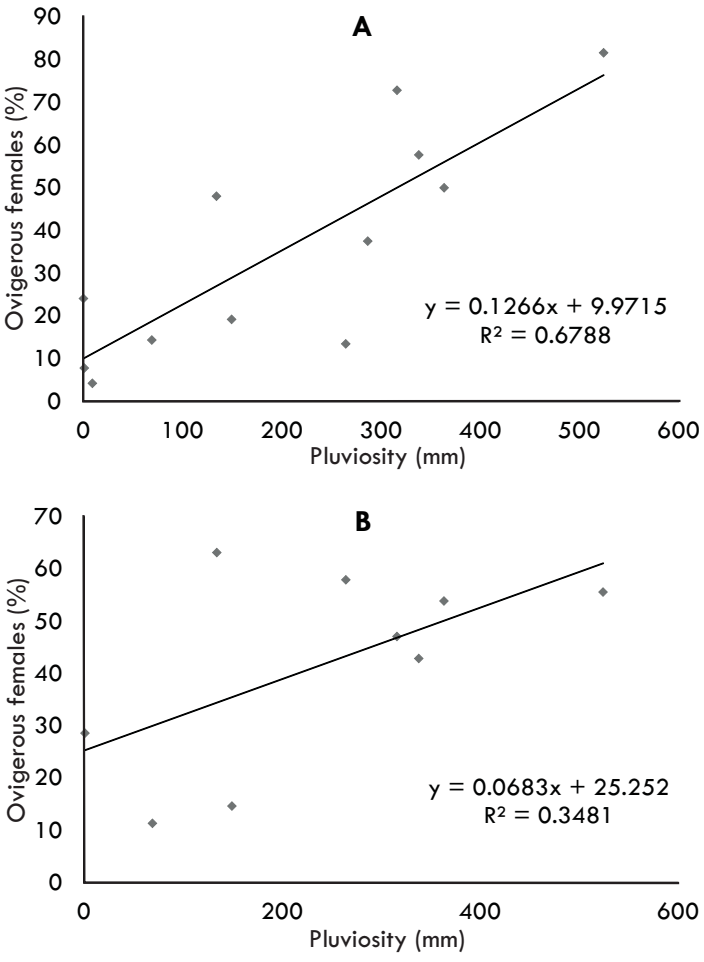

Figure 4. Regression between frequence of ovigerous females of *Macrobrachium amazonicum* and rainfall from Jan/2009 to Jan/2010 in the Santana Island (A) and Mazagão Velho (B), state of Amapá.

Table 2. Frequency distribution of the prawn *Macrobrachium amazonicum* in size classes (SL), collected from Jan/2009 to Jan/2010 in the Island of Santana and Mazagão Velho, state of Amapá.

	Santana Island				Mazagão Velho			
Size Class (SL, mm)	**Adult males**	**Adult females**	**Juveniles males**	**Juveniles females**	**Adult males**	**Adult females**	**Juveniles males**	**Juveniles females**
8--13	0	0	0	0	0	0	0	0
13--18	0	0	0	0	0	0	0	0
18--23	0	0	10	23	1	1	4	17
23--28	9	28	11	56	3	18	12	50
28--33	152	151	5	0	14	98	49	9
33--38	416	279	0	0	106	104	4	0
38--43	452	382	0	0	110	99	0	0
43--48	276	445	0	0	72	85	0	0
48--53	153	369	0	0	36	88	0	0
53--58	84	286	0	0	24	74	0	0
58--63	53	156	0	0	17	57	0	0
63--68	49	59	0	0	14	25	0	0
68--73	12	10	0	0	14	4	0	0
73--78	11	2	0	0	12	0	0	0
78--83	3	1	0	0	3	0	0	0
83--88	0	0	0	0	0	0	0	0
88--94	1	0	0	0	0	1	0	0
Total	1671	2168	26	79	426	654	69	76

Tabela 3. *Macrobrachium amazonicum* regression equations for the relationships: SL= Standard length, CL = carapace length, AL = abdomen length, (N = number of individuals; R^2 = coefficient of determination; A = allometry: (=) isometrics, (+) positive allometry, (-) negative allometry; t = Student t-test value).

Sites	Relations	Groups	N	Y=a+b*X	r2	A	T
Mazagão	SL/CL	Female	730	SL=5.242+2.451*CL	0.96	+	78.23*
		Male	495	SL=6.376+2.387*CL	0.95	+	57.79*
	SL/AL	Female	730	SL=-1.628+1.616*AL	0.98	+	77.45*
		Male	495	SL=-2.029+1.628*AL	0.98	+	57.79*
Santana Island	SL/CL	Female	2247	SL=4.759+2.506*CL	0.95	+	123.05*
		Male	1697	SL=5.923+2.437*CL	0.94	+	100.35*
	SL/AL	Female	2247	SL=-0.671+1.578*AL	0.98	+	123.05*
		Male	1697	SL=-1.380+1.596*AL	0.98	+	100.35*

* Student test with significant value ($p < 0.05$).

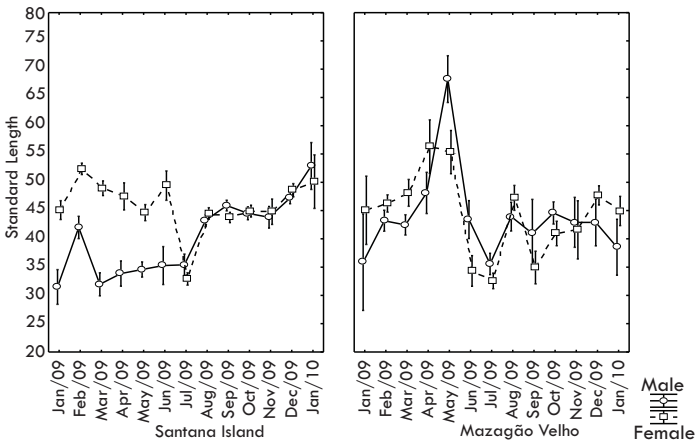

Figure 5. Monthly variation of standard length between male and females of *M. amazonicum* sampled in Santana Island and Mazagão from Jan/2009 to Jan/2010.

4. Discussion

The female predominance seems to be common in caridean prawns, particularly in species of the *Macrobrachium* (MOSSOLIN; BUENO 2003; ANTUNES; OSHIRO, 2004; FRANSOZO et al., 2004). However, the ratio in favor of males or identical proportion of males and females can also be observed in this genus. For example, *M. hainanense* (PARISI, 1919) in Hong Kong streams shows that deviations at sex ratio were in favor of males (MANTEL; DUNDGEON 2005), whereas *M. potiuna* (MULLER, 1880) had identical proportion of males and females in streams from Mangaratiba in Rio de Janeiro, Brazil (MATTOS; OSHIRO, 2009). In *M. amazonicum* the female predominance has been similarly reported (SILVA et al., 2007; SAMPAIO et al., 2007; MONTOYA, 2003 and FREIRE et al. 2012b and the present study).

Deviations in the sex ratio of crustaceans could be a consequence of differences in size, mortality and birth rates between males and females or other factors, such as molt rates, dispersal, reproduction and differential migration (BOTELHO et al., 2001). In *M. amazonicum* populations, the sex ratio also may be influenced by environmental conditions, geographical characteristics and anthropogenic interferences (LIMA et al., 2014). For example, Odinetz-Collart (1991) shows the effects of a dam construction on population from the lower Tocantins (State of Pará), with reduced specimens' size and deviations in the sex ratio. Other anthropogenic interferences were reported by Silva et al. (2002) and Lucena-Fredou et al. (2010) on the island of Combú (State of Pará), where a disordered and intensive exploitation of *M. amazonicum* has influenced the population dynamics of this species on the region.

The high abundance of adult females in Santana Island was occasioned by high occurrence of ovigerous females, more abundant and susceptible to fishing during the rainy period (January to June). As Santana Island is closer to water sea than Mazagão, it has more abundance of ovigerous females. According to Bentes et al. (2011), the abundance of *M. amazonicum* in two perennial creeks from Guajará Bay may be associated to the greater opportunities for refuge and availability of food sources. In the present study, differences in capture of this species between areas probably may not be related only to the food availability, once the areas are relatively similar with the same tidal dynamics. On the other hand, Mazagão area has greater abundance of macrophytes and greater opportunities for refuge from predation, consequently the prawns in this area can be less susceptible to capture than in Santana Island.

This study shows a clear relationship between abundance of ovigerous females and the rainy period, similar to that reported by Silva et al. (2005), Silva et al. (2007), Bentes et al. (2011) and Freire et al. (2012a), indicating that estuarine populations of *M. amazonicum* commonly has reproductive peaks in the rainy season. In contrast, no relationship with rainfall was observed by Sampaio et al. (2007) in the northeastern Brazil, indicating atypical behavior for this species due to the local arid climate.

The great abundance during dry or rainy seasons is a particular tendency of each species in the genus Macrobrachium. For example, M. brasiliense (HELLER, 1862) (MANTELATTO; BARBOSA, 2005), M. macrobrachion (HERKLOTS, 1851) and M. vollenhovenii (HERKLOTS, 1857) (LAWAL-ARE; OWOLABI, 2012) had greater abundance in the rainy season; differently of M. iheringi (ORTMANN, 1897) (FRANSOZO et al., 2004), M. ohione (SMITH, 1874) (TRUESDALE; MERMILLIOD, 1979), M. tenellum (SMITH, 1871) (ROMÁN-CONTRERAS, 1979); M. olfersi (WIEGMANN, 1836) (MOSSOLIN; BUENO, 2003) and M. amazonicum (present study) that are clearly more abundant during the dry season.

In the Amazon region, M. amazonicum fishery is characterized by periods of abundance and scarcity referred by local fishermen as "harvest season" (safra) and "slack" or "between-harvest season" (entressafra) (MACIEL; VALENTI, 2009; LIMA et al., 2014). Numerous local fishermen report that the capture of prawns is impaired during the high-water (flood) period, due to the strong currents and dispersal of prawns in the lowland. The prawns are caught in abundance along the banks of the Amazon River during the low water, when they are migrating from the lowland (present study). Similar data are presented by Bentes et al. (2011), Freire et al. (2012b) and Lima et al. (2014), suggesting that catches of estuarine populations are strongly influenced by the rainfall. According to Bentes et al. (2011), the greater number of individuals caught in the dry season may be related to the greater ease in catching specimens with the same fishing effort.

The mean size of specimens in the present study was similar to that reported by Silva et al. (2002), Silva et al. (2007) and Bentes et al. (2011) in others estuarine areas from the Amazon region. In the genus Macrobrachium, adult males generally reach larger sizes than females (SILVA et al., 2002). In this study, however, females had larger mean standard length than males in the rainy period; this variation is similar to that reported by Bentes et al. (2011). According to Silva et al. (2007), males that reach larger total lengths than females are caught with greater frequency, whereas the less aggressive females likely seek more protected areas. Thus, the largest individuals are removed in greater numbers, with smaller individuals remaining for recruitment. Santana Island has less protected areas than Mazagão, this characteristic can favor the occurrence of larger females. On the other hand, differences in prawn sizes between Santana Island and Mazagão Velho can be associated to the proximity with sea water, favoring the occurrence of great ovigerous females during the rainy season. For example, proximity with sea water was reported by Freire et al. (2012a) as the main factor for differences in sizes of M. amazonicum populations between two sites in the northeast Pará State.

Not enough data are available to allow generalizations about the morphometric patterns of prawn, particularly with regard to sexual dimorphism in the proportions of body dimensions (ANGER; MOREIRA, 1998). The sexual dimorphism in the proportions of body dimensions has showed clear sexual dimorphism in Macrobrachium species. For example, in M. brasiliense relationships between carapace length and highest propodus height, showed sexual dimorphism between male and females, with positive allometry in male growth and isometrics in female growth (MANTELATTO; BARBOSA, 2005). In this study, all morphometric relationships analyzed between sexes showed positive allometry with similar growth pattern presented by Moraes-Riodades and Valenti (2002). The abdomen is the largest body portion in males and females of M. amazonicum (SILVA et al., 2002; FLEXA et al., 2005).

5. Conclusions

Macrobrachium amazonicum populations of the Amazon River mouth shown female predominance as similar to other species of the Macrobrachium. The high abundance of adult females in Santana Island and Mazagão Velho was occasioned by high occurrence of ovigerous females during the rainier period. Differences in capture of this species between areas probably can be associated to the proximity with seawater and not only related to food availability greater and opportunities for refuge from predation. Macrobrachium amazonicum is more abundant during the less rainy period. Abundance of ovigerous females have a clear relationship with the rainier period in the sites.

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