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Reproductive aspects of *Macrobrachium amazonicum* (Decapoda: Palaemonidae) in the State of Amapá, Amazon River mouth

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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 to investigate general aspects of population structure and reproductive characteristics (size at first maturity, fecundity and reproductive output) of *M. amazonicum* from two important areas to artisanal prawn fishing located at the mouth of the Amazon River, State of Amapá. The specimens were captured using 20 handcrafted traps called "matapi". A number of 5,179 prawns were captured, 2,975 females and 2,195 males resulting in 1.35:1 female to male ratio. Santana Island and Mazagão Velho showed females predominated in the population. A reproductive peak period was observed from January to April/2009 and in December/2010, coinciding with the period of higher rainfall. The recruitment peak occurred in June and July/2009. Egg-bearing females ranged in size (carapace length) from 11.10 to 29.6 mm. Fecundity increased with female size and reached up to 7,417 eggs. This amount of eggs is considered low if compared with other *Macrobrachium* estuarine species. Mean egg volume increased gradually from 0.121 to 0.24 mm³ during embryogenesis, representing 68.5% of overall increase from Stage I to Stage III. Eggs of *M. amazonicum* are small; this is typical for *Macrobrachium* species, which depends on brackish water to complete the larval development. Irrespective of female size, reproductive output of *M. amazonicum* varied between 4.8 and 21.85% of their body weight into eggs production.

KEYWORDS: Palaemonid eggs, first maturation, fecundity, morphometric relationships, reproduction

Aspectos reprodutivos do camarão *Macrobrachium amazonicum* (Decapoda: Palaemonidae) no estado do Amapá, foz do rio Amazonas

RESUMO

Macrobrachium amazonicum é uma espécie nativa vastamente distribuída nas bacias da America do Sul, sendo largamente explorada por pescadores artesanais no Norte e Nordeste do Brasil e com grande potencial para aquicultura. O objetivo deste trabalho foi abordar aspectos gerais da estrutura populacional e biologia reprodutiva (tamanho de primeira maturação, fecundidade e investimento reprodutivo) de *M. amazonicum* de duas importantes áreas de pesca artesanal de camarão localizada na foz do rio Amazonas, no Estado do Amapá. Os exemplares foram capturados usando 20 armadilhas artesanais, conhecidas localmente como matapi. Um total de 5.179 camarões foi capturado, dos quais 2.975 eram fêmeas e 2.195 eram machos, dando uma razão sexual geral de 1,35: 1 em favor das fêmeas. As proporções sexuais nas áreas de Ilha de Santana e Mazagão mostraram fêmeas predominando na população. Os picos reprodutivos nas duas áreas ocorreram de Janeiro a Abril/2009 e em Dezembro/2010, coincidindo com o período mais chuvoso. Os picos de recrutamento foram observados em junho e julho de 2009. O tamanho das fêmeas ovígeras variou de 11,10 mm a 29,6 mm de comprimento de carapaça. A fecundidade aumentou com o tamanho das fêmeas, chegando até 7.417 ovos, podendo ser considerada baixa comparada a outras espécies estuarinas de *Macrobrachium*. Volume médio dos ovos aumentou gradualmente durante a embriogênese saindo de 0,112 para 0,220 mm³, representando um aumento global de 68,5% do I ao III estágio embrionário. Os ovos de *M. amazonicum* podem ser considerados pequenos, típicos de espécies de *Macrobrachium* que dependem de água salgada para completar seu desenvolvimento larval. Independente do tamanho da fêmea, o investimento reprodutivo de *M. amazonicum* variou entre 4,8 e 21,85% do seu peso corporal para a produção de ovos.

PALAVRAS-CHAVE: ovos de palaemonideos, primeira maturação, fecundidade, relações morfométricas, reprodução.

INTRODUCTION

Prawns are decapods restricted to freshwater or need brackish water on the onset of life cycle (New 2002). Unlike marine shrimp, female prawns carry their eggs until spawning time. Among palaemonid 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).

The knowledge of reproductive biology (fecundity and fertility) of palaemonid prawns is an important tool to evaluate the potential candidates for aquaculture and define strategies for biodiversity preservation (Mossolin and Bueno 2002). Therefore, understanding the reproductive periodicity of this group is imperative for developing management and culture programs with obvious consequences for species conservation policies (Fransozo et al. 2004).

In Palaemonid species fecundity can be defined as the number of eggs laid per hatching that can be found adhered to the female pleopods. According to Valenti et al. (1989), the knowledge of species fecundity is important to evaluate their potential for commercial farming, as well as estimating the reproductive potential and stock size of natural population. In addition, it can also be used to determine the minimum number of adults necessary to maintain the recruitment and egg survival rates until adulthood (Da Silva et al. 2004).

Macrobrachium amazonicum (Heller 1862) is an indigenous species vastly distributed in many basins of South America (Gamba 1997). This prawn species had great economic importance. It is widely exploited by artisanal fisheries in northern and northeastern Brazil, and it is broadly consumed by indigenous people and Brazilians of all economic groups (Moraes-Riodades and Valenti 2002). Because of its potential for aquaculture, intense research effort has been made elsewhere to determine the general reproductive aspects of this species, especially for the North region of Brazil (Chaves and Magalhães 1993; Silva et al. 2002; Da Silva 2011). Moreover, in these reports neither the authors provide information on female energy investment per egg clutch, nor they consider the different developmental stages of eggs.

Despite the high biological and economic importance of *M. amazonicum* in the Amazon region, its life history is poorly understood especially in the region of Amapá state, Brazil. Therefore, studies on this species are necessary to develop appropriate farming technology for Brazilian North region and thus, enabling farmers to have alternative species for culture. This study aimed to investigate general aspects population structure and reproductive biology (reproductive period, size of sexual maturity population, fecundity individual and population, reproductive output and recruitment) of *M. amazonicum* from two important areas to artisanal prawn fishing located at the mouth of the Amazon River, State of Amapá.

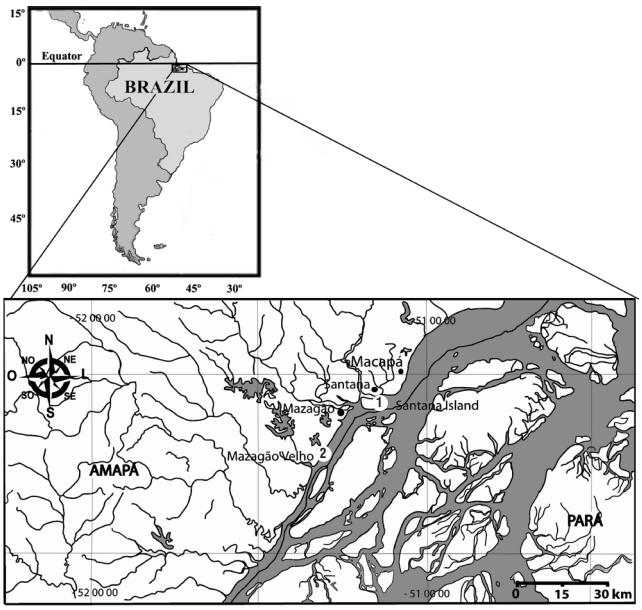

Figure 1 - Study area location - 1) Santana island, 2) Mazagão Velho.

MATERIALS AND METHODS

Study Area

The study area comprised the regions of Santana Island (00º03'40.9"S and 051º08'46.6"W) and Mazagão Velho (00º15'39.9"S and 051º20' 42.3'W) located in the estuary of the Amazon River, State of Amapá (Figure 1). The areas are relatively similar and important to artisanal prawn fishing. Santana Island is more exploited than Mazagão Velho. These islands have various drainage channels with different sizes and depths influenced by the tidal flooding, generating a wide diversity of microhabitats. In Santana Island, vegetation is open and sparse, with the presence of a narrow border of macrophytes. In Mazagão Velho, the vegetation is strongly dense with great and wide bands of macrophytes along the river.

Samples collection and Rainfall data

Samples were collected monthly from January 2009 to January 2010 by using an artisanal trap called "matapi" (25 cm in diameter and 50 cm in length, spacing of cracks between 3 to 5 mm), baited with flour of babaçu (Orbignya speciosa.) palm fruit as reported by Simonian (2006). Twenty matapis were used at each collection site. Traps were set at depths of 1 to 2 meters during on average 12 hours of immersion. The sampling method is equivalent to the capture performed by artisanal fishermen every tidal cycle (12h, twice daily). All

Table 1 - Distribution frequency and grouped percentage of adult (males, non-ovigerous females, ovigerous females) and juvenile prawns (males, females and undifferentiated sex) of *Macrobrachium amazonicum* sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010.

Study site	Adult prawns						Juvenile prawns							
	Male		Non-ovig. Female		Ovig. Female		Male		Female		Und. sex		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Santana Island	1,537	29.7	1,328	25.6	684	13.2	161	3.1	236	4.6	3	0.06	3,949	76.3
Mazagão Velho	426	8.2	346	6.7	206	4.0	71	1.4	175	3.4	6	0.11	1,230	23.7
Total	1,963	37.9	1,674	32.3	890	17.2	232	4.5	411	7.9	9.00	0.17	5,179	100

captures occurred at daybreak. The caught specimens were properly labeled and preserved in plastic bags containing 4% formalin + 70% ethanol (1:1) solution. 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).

Laboratory work

In the laboratory, prawns were sorted into species and identified according to Melo (2003). Carapace length and total length were measured with digital caliper (Absolute 500-196-20, Mitutoyo, Tokyo City, Japan) at 0.01 mm precision, and the body wet weight of each individual was determined by a semi-analytic scale with 0.01 g precision (BL 320H, Shimadzu, Harbour City, Hong Kong). Carapace length was measured as the distance from the inside of the eye socket to the center of the dorsal margin of the carapace, whereas total length was measured as linear distance from the rostrum extremity to the telson tip. Prawns were grouped into the following demographic categories: adult males, non-ovigerous adult females, ovigerous and juveniles (smaller prawns than the smallest ovigerous female and undifferentiated sex). Sexual differentiation was assessed by observing the secondary sexual characteristics, such as male appendix in the second pleopods, which is absent in females.

Reproductive aspects

The reproductive period was determined by the presence of ovigerous females during the sampling period. Size at first individual maturity was determined between the size classes with smaller ovigerous female. The size for sexual maturity population was determined among size classes with 50% of ovigerous females. The fecundity was obtained by direct counting the eggs of 49 ovigerous females that were randomly selected considering the integrity of eggs and collection months. The entire egg mass was carefully removed under a dissecting binocular stereo microscope (K 400L, Motic, Causeway Bay, Hong Kong) and all eggs were counted. The development stages of eggs was sorted as follows (Wehrtmann 1990): Stage I: eggs recently extruded; uniform yolk; no eye pigments visible; Stage II: eye pigments barely visible, and Stage III: eyes clearly visible and fully developed. The recruitment was assessed by the presence of juvenile individuals in the sampled population.

To determine the egg volume, a total of 10 eggs were separated from each ovigerous female to measure the length (longest axis) and width (shortest axis) under a compound binocular microscope equipped with calibrated ocular micrometer. Egg volume was calculated according to Wehrtmann (1990) by the following formula:

$$v = \pi * l * h * (h)^2$$

Where "l" is length; "h" width in mm e π =3.14

For reproductive output (RO), the dry mass of each ovigerous female was determined with a digital balance without regard to the developmental stage of the embryos; subsequently, the RO was calculated by dividing the total egg wet mass by the female wet mass that were determined by analytic scale (0.0001 g precision).

Statistical analysis

The differences in monthly abundance between areas were analyzed using the Student test (Zar 1999). The differences in sex ratio were analyzed and tested for significant divergence from the expected 1:1 ratio by using the Chi-square ($\chi 2$) goodness off it test (Zar 1999). Pearson linear regression model with a posteriori Student t test was used to demonstrate the correlation between total weight and total length and, total length and carapace length. Other Pearson linear regression model with a posteriori Student t test was used to demonstrate the correlation between body size and number and, mass volume of incubated eggs for each embryonic stage. For each of the three embryonic stages, the mean egg volume with standard deviation was calculated and the Analysis of variance (ANOVA, $\alpha = 0.05$) with a posteriori Tukey test was applied to identify significant differences between stages (Zar 1999). The mean egg volume was subsequently multiplied by the total number of eggs per female to obtain the total egg mass; linear regressions were prepared for each embryonic stage to depict

Table 2 - Chi-square values and sex ratio of *Macrobrachium amazonicum* sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010.

	Santana Island				Mazagão				Sites Grouped			
Months	♀	♂	X^2	Ratio	♀	♂	X^2	Ratio	♀	♂	X^2	Ratio
Jan/09	105	31	40.3	3.4:1*	8	4	1.3	2.0:1	113	35	45.7	3.3 : 1 *
Feb	288	75	125.0	3.8:1*	124	84	7.7	1.47:1*	412	159	226.1	2.6 : 1*
Mar	175	71	44.0	2.5:1*	52	90	10.2	0.57:1*	227	161	75.1	1.4 : 1*
Apr	51	59	0.58	0.9:1	13	22	2.3	0.59:1	64	81	0.1	0.8 : 1
May	145	165	1.3	0.9:1	20	17	0.3	1.18:1	165	182	0.0	0.9 : 1
Jun	43	26	4.2	1.6:1*	40	26	3.0	1.54:1	83	52	27.9	1.6 : 1*
Jul	242	82	79.0	2.9:1*	155	82	22.5	1.89:1*	397	164	188.2	2.4 : 1*
Aug	280	258	0.9	1.1:1	60	45	2.2	1.33:1	340	303	10.9	1.1 : 1
Sept	359	329	1.3	1.1:1	35	8	16.9	4.37:1*	394	337	4.4	1.2 : 1*
Oct	275	223	5.4	1.2:1*	62	75	1.2	0.83:1	337	298	22.9	1.1 : 1
Nov	58	81	3.8	0.7:1	11	15	0.6	0.73:1	69	96	1.0	0.7 : 1*
Dec	214	281	9.1	0.8:1*	104	17	62.5	6.12:1*	318	298	0.1	1.1 : 1
Jan/10	13	17	0.5	0.8:1	44	12	18.3	3.66:1*	57	29	11.5	2.0 : 1*

*Significant data, $P<0.05$.

the relation between fecundity and females' size (FS). Linear regressions were prepared to analyze the relation between RO and female size (TL). All statistical analyses were conducted using the Biostat 5.0 software at $\alpha= 0.05$.

RESULTS

In the present study 5,179 specimens of *M. amazonicum* were captured, 2,975 females and 2,195 males, resulting in a female to male sex ratio of 1.35:1. Global number of prawns caught in Santana was higher than in Mazagão ($P < 0.05$) (Table 1). The Chi-square test showed that the ratio was significantly different from that (1:1) in Santana Island ($X^2 = 76.66$; $P< 0.001$) and Mazagão Velho ($X^2 = 43.56$; $P < 0.001$), with 1 ♂: 1.46 ♀ and 1 ♂: 1.32 ♀, respectively. M. amazonicum showed significant differences from a 1♂:1♀ ratio except in April, May, August, October and December 2009 (Table 2).

There was increased capture rate during summer (August to October), particularly for adult prawns, matching with the period of higher fish production in the region (Figure 2). Ovigerous *M. amazonicum* females were found throughout the year; however, the reproductive peak period was from January to April 2009 and December 2009, coinciding with high rainfall (Figure 2). Juvenile prawns were found in most months of the year; but the recruitment peak was observed in June and July, with capture of 76.7% of juveniles.

The largest female showed 29.6 mm of carapace length or it was 146.48 mm total length, whereas the largest male was 32.92 mm or 165.11 mm total length. The biometrical relationships between the total weight (TW) and total length (TL), and between the TL and carapace length (CL) of both sexes were statistically significant ($P = 0.95$) (Figures 3A and 3B).

Among females sampled, 890 or 31.56% carried eggs in their abdomen and 1,930 or 68.44% did not. Ovigerous females ranged in carapace length from 11.10 to 29.6 mm, out of which 52.5% are distributed between classes of 11.10 to19.09 mm, suggesting that the first gonad maturation of M. amazonicum populations from Santana Island and Mazagão occurs between these classes (Table 3).

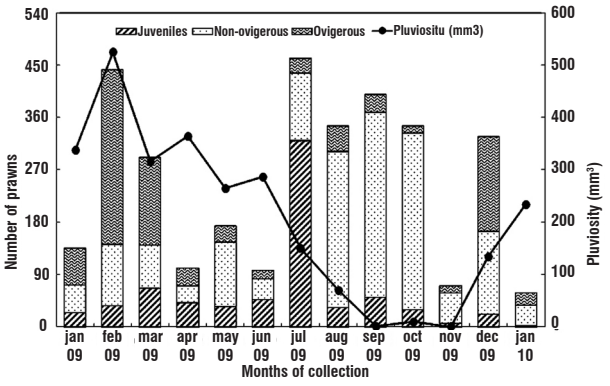

Figure 2 - Absolute frequency distribution of ovigerous, non-ovigerous females and juveniles of *Macrobrachium amazonicum* sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010.

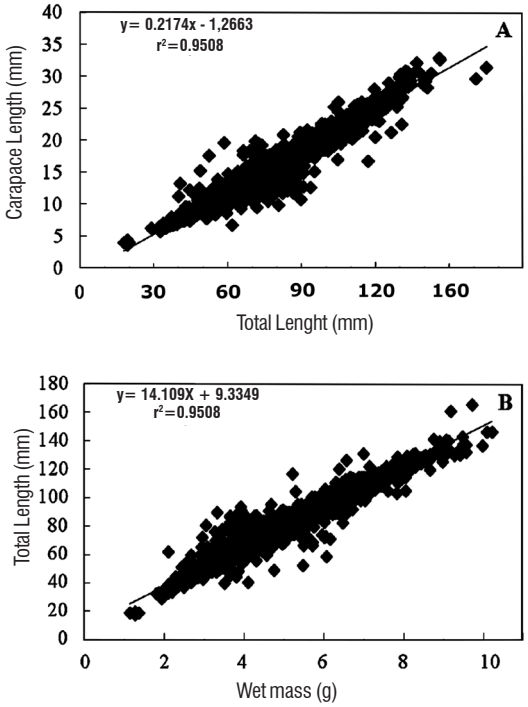

Figure 3 - Biometric ratios between male and female of *Macrobrachium amazonicum* sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010. A - total length and total weight; B - carapace length and total length.

The estimated fecundity of *M. amazonicum* varied between 1,099 and 7,417 eggs per specimen for individuals of 15.38 – 29.6 mm carapace length or 75.30 – 146.48 mm total length. The body size parameter was considered more suitable than body weight as the independent variable for correlation with egg number because the latter parameter may be significantly influenced by the loss of one or both second of pereiopods that occurred in some females during transportation from the collecting site to the laboratory. The relationship between fecundity (egg number and mass volume) and female size (carapace length) can best be described by a positive linear correlation for Stage I (egg number with $P < 0.001$ and egg mass volume with $P < 0.001$); Stage II (egg number with $P = 0.00024$ and egg mass volume with $P = 0.00049$) and Stage III (egg number with $P = 0.0018$ and egg mass volume with $P = 0.0032$) (Figure 4).

The ANOVA test showed significant difference between egg stages ($P < 0.001$), with mean egg length having increased from 0.38 at Stage I to 0.48 mm at Stage III (Table 4). Mean egg volume increased significantly during embryogenesis ($P < 0.001$) from 0.121 to 0.204 mm³, representing 68.6% the overall global increase, approximately 30% at each stage (Table 4). There was no statistically significant relationship ($P = 0.92$) between RO and CL in *M. amazonicum*, indicating

Table 3 - Distribution frequency of *Macrobrachium amazonicum* according to the size classes (Carapace Length) sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010.

Size Classes (SL, mm)	Adult prawns						Juvenile prawns							
	Males		Non-ovig. females		Ovig. females		Males		Females		Und. sex		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
3.09 -|5.09	0	0	0	0	0	0	0	0	0	0	4	0.08	4	0.08
5.09 -|7.09	0	0	0	0	0	0	10	0.19	15	0.29	5	0.10	30	0.58
7.09 -|9.09	0	0	0	0	0	0	26	0.50	131	2.53	0	0	157	3.03
9.09 -|11.09	0	0	0	0	0	0	196	3.78	265	5.12	0	0	461	8.90
11.09 -|13.09	535	10.3	366	7.07	19	0.37	0	0	0	0	0	0	920	17.7
13.09 -|15.09	586	11.3	424	8.19	60	1.16	0	0	0	0	0	0	1070	20.6
15.09 -|17.09	352	6.8	354	6.84	172	3.32	0	0	0	0	0	0	878	16.9
17.09 -|19.09	191	3.7	235	4.54	217	4.19	0	0	0	0	0	0	643	12.4
19.09 -|21.09	113	2.2	165	3.19	239	4.61	0	0	0	0	0	0	517	9.98
21.09 -|23.09	70	1.4	83	1.60	130	2.51	0	0	0	0	0	0	283	5.46
23.09 -|25.09	48	0.9	33	0.64	41	0.79	0	0	0	0	0	0	122	2.36
25.09 -|27.09	27	0.5	13	0.25	10	0.19	0	0	0	0	0	0	50	0.97
27.09 -|29.09	22	0.4	1	0.02	1	0.02	0	0	0	0	0	0	24	0.46
29.09 -|31.09	15	0.3	0	0.00	1	0.02	0	0	0	0	0	0	16	0.31
31.09 -|33.09	4	0.1	0	0.00	0	0	0	0	0	0	0	0	4	0.08
Total	1,963	37.9	1,674	32.3	890	17	232	4.5	411	7.94	9.0	0.17	5,179	100

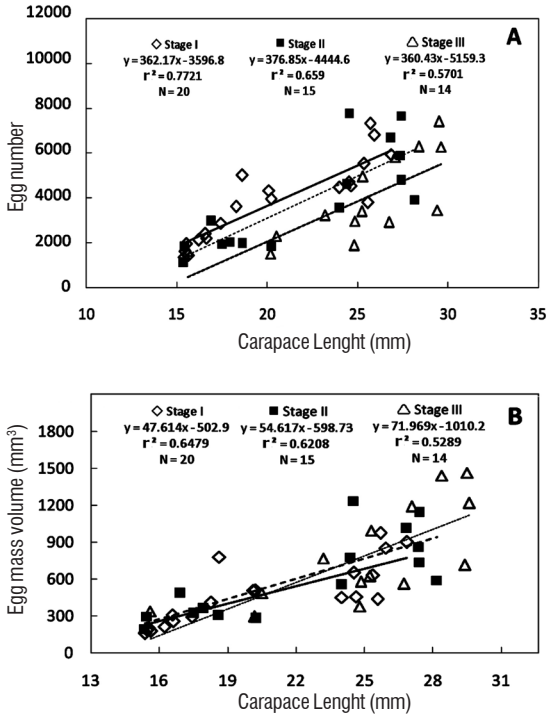

Figure 4 - Ratio between fecundity and female size for each of the three embryonic stages of *Macrobrachium amazonicum* sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010. A - carapace length (mm) and egg number (mm); B - carapace length (mm) and egg mass volume (mm 3). Stage I: solid line; Stage II: dashed line; Stage III: dotted line.

that RO is not determined by size (Figure 4). Females of this species converted on average 11.74% of their body weight into the eggs production, and RO varied between 4.8% and 21.85% (Figure 5).

DISCUSSION

In this study females predominated in the population. This biased-female ratio seems to be common in caridean prawns, particularly in species of the *Macrobrachium genus*. For example, high proportion of females has also been reported in *M. olfersii* (Mossolin and Bueno 2002), *M. potiuna* (Antunes and Oshiro 2004) and *M. iheringi* (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 *M. hainanense* in Hong Kong streams by Mantel and Dundgeon (2005) and (Parisi 1919) that deviations at sex ratio were in favor of males. Moreover, identical proportion of males and females was recorded by Mattos and Oshiro (2009) for *M. potiuna* (Müller 1880), in which the sex ratio did not differ from the expected 1♂:1♀. Deviations in the sex ratio could be a consequence of differences in size, mortality and birth rates between males and females or other factors, such as

Table 4 - Egg volume (mm³) and Egg size (mm) with mean, minimum and maximum values for three embryonic developmental egg stages of *Macrobrachium amazonicum* sampled in Santana Island and Mazagão Velho from Jan/2009 to Jan/2010. N = number of observations; SD = standard deviation.

Egg stage	N	Mean egg volume (mm³)	± SD	Minimum	Maximum
I	20	0.121	0.016	0.101	0.156
II	15	0.158	0.009	0.146	0.178
III	14	0.204	0.015	0.184	0.238
Egg stage	N	Mean egg length (mm)	± SD	Minimum	Maximum
I	20	0.383	0.016	0.354	0.407
II	15	0.435	0.023	0.386	0.478
III	14	0.480	0.019	0.464	0.536

molt rates, dispersal, reproduction and differential migration (Botelho et al. 2001).

Among populations of a same species, the sex ratio also may be influenced by environmental conditions, geographical characteristics and anthropogenic interferences. For example, Odinetz-Collart (1991) clearly shows the effects of a dam construction on *M. amazonicum* population from the lower Tocantins (State of Pará), with reduced specimens' size and sex ratio. Similarly, Silva et al. (2002) suggest a possible overexploitation affecting the population dynamics of this prawn species on the island of Combú (State of Pará).

Bentes et al. (2011) showed that abundance of *M. amazonicum* of 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 *M. amazonicum* specimens between areas probably may not be related to the food availability, once the areas are relatively similar, with the same tidal dynamics and food resources. 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.

The *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 and Valenti 2009). According to the local fishermen, 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 low water, when they are migrating from the lowland (present study). Similar data are presented by Bentes et al. (2011), suggesting that these prawns catches are strongly influenced by rainfall on the lower Amazon River estuary.

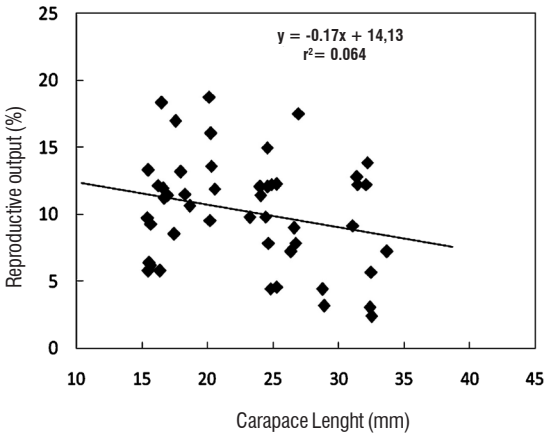

Figure 5 - Ratio between female carapace length (mm) and reproductive output of *Macrobrachium amazonicum* considering all developmental egg stages.

Regarding the ovigerous females, the smallest specimen was caught on Santana Island and had 11.10 mm of carapace length or it was 5.5 cm total length, being larger than that length described by Silva et al. (2002) in the municipality of Vigia (CT = 2.5 cm) and Bentes et al. (2011) on Combu Island. These results suggest that these areas are favorable to breeding and attract females of all sizes. The occurrence of ovigerous females in all monthly samples indicates that the *M. amazonicum* population from Santana Island and Mazagão reproduces continuously year-round. This observation is similar to that of Silva et al. (2002), Sampaio et al. (2007) and Bentes et al. (2011) for samples collected in various regions of Brazil.

The reproductive period of freshwater decapod crustaceans is closely associated with the rainy period, thermal variations and photoperiod of the region where it happens. Similar to the present study, ovigerous females of *M. amazonicum* have been found over the year with the reproductive peak in the rainy season, especially in estuarine populations (Silva et al. 2005; Silva et al. 2007, Bentes et al. 2011). In contrast, no relationship with rainfall was observed in populations from Jaguaribe River in northeastern Brazil by Sampaio et al. (2007), indicating atypical behavior of this species in the region, probably due to the local arid climate.

The size at first sexual maturity shown in the present work was similar to the standard range reported for the species, which is between 45-60 mm total length (Moraes-Riodades and Valenti 2002; Silva et al. 2005; Sampaio et al. 2007). In other estuarine area of Amazon River with intensive fishing activity, *M. amazonicum* ovigerous females have been reported with much smaller sizes than those in the present study (Silva et al. 2002; Silva et al. 2007), indicating that this species is overfished.

According to the local fishermen, the volume and size of prawns caught have decreased considerably in the last decade. Based on that, 30.1% of prawns caught in the matapis have 3.9 to 13.9 mm of carapace length (Table 3), and whereas up to 65.0 mm total length *M. amazonicum* is capable of performing at least one reproduction, one can infer that ideal size for first catch is 70.0 mm total length. Additionally, based on the data presented by Camargo et al. (2009) and Da Silva (2011), one can suggested adjustment in the spacing of cracks matapis, which currently present 2 to 3 mm for minimum distances of 8 and 10 mm. Once performed such adjustment, the number of juvenile prawns caught will probably decrease considerably.

Recruitment is a complex process involving a chain of events in the life cycle of the prawns (Deekae and Abowei 2010). The recruitment occurs when an age group integrates for the first time into the exploitable stock. In this context, about 70.7% of *M. amazonicum* juveniles caught in the present study integrated for the first time into the exploitable stock between sizes 9.09 and 11.09 mm of carapace length.

According to Lara and Wehrtmann (2009), caridean prawns are not as productive in fisheries and aquaculture as penaeids and fecundity is much higher in penaeids than in carideans. In the estuarine *Macrobrachium* species that depends on estuarine environments to complete the larval development, this generalization is not observed (Lara and Wehrtmann 2009; Bentes et al. 2011). These species can attain large sizes and produce much more eggs than the majority of other caridean prawns.

The highest fecundity in species of genus *Macrobrachium* is observed in *M. rosembergii* (De Man 1879) and *M. carcinus* (Linnaeus 1758), whose females can lay between 14,000 and 242,000 eggs in each spawning when they are complete mature (Lara and Wehrtmann 2009). Although *M. amazonicum* captured in Santana Island and Mazagão presents lower fecundity than those species; it has higher fecundity than *M. lanchesteri* with 58-580 eggs (Phone et al. 2005), *M. hainanense* with 20-75 eggs (Mantel and Dudgeon 2005), *M. brasiliense* (Heller 1862) with 15-168 eggs (Garcia-Dávila et al. 2000) among other *Macrobrachium* species reported by Lobão et al. (1986) whose absolute fecundity is lower than 200 eggs.

The intra- and interespecific differences in fecundity for representatives of the genus *Macrobrachium* are influenced by the differences in female size (Graziani et al. 1993; Da Silva et al. 2004) depending on temperature, food quality and quantity, which may vary along the latitudinal range of species distribution (Fransozo et al. 2004), proximity to estuarine regions.

In estuarine species, such as *M. carcinus* and *M. rosembergii*, there is a visible increased size of animals, number of eggs and larval stages; contrary to the typical species of continental waters, whose numbers of eggs and larval stages are quite low

as in *M. lanchesteri*, M. brasiliense and *M. hainanense*. In other species, whose populations can be found in estuarine and continental areas, such as *M. amazonicum*, the effects of the estuary proximity can be similarly detected. The specimens' size, number of eggs and larval stages produced in estuarine populations are greater than those observed in continental populations (Odinetz-Collart and Rabelo 1996).

In this paper, the number of eggs of *M. amazonicum* individually was higher than that reported by Lobão et al. (1986), Da Silva et al. (2004) and Da Silva (2011) for different Brazilian regions and Gamba (1997) and Medina et al. (2008) for Venezuela, indicating that *M. amazonicum* specimens with similar total lengths show variable fecundity. According to Lobão et al. (1986), fecundity variations may be attributed to the different conditions of female maintenance in the laboratory, female's physiological conditions and season, among others. Nazari et al. (2003) explained that the fecundity is extremely associated with the female age in *Macrobrachium* species, thus increasing as it becomes mature.

Numerous studies on different decapods have shown that fecundity is closely related to female size (Wehrtmann and Lardies 1999; Oh et al. 2002; Nazari et al. 2003). As a general rule, larger females of the same species have larger ovaries and larger physical space available for egg attachment; consequently beingcapable of producing more offspring than smaller individuals (Oh et al. 2002; Nazari et al. 2003, Lara and Wehrtmann 2009). Probably, larger individuals have low growth rates, indicating that much of the available energy is devoted to egg production if compared to smaller individuals in whom a large fraction of the energy may be devoted to growth rather than egg production. In the present study, fecundity of *M. amazonicum* increased linearly with the female's size being similar to that observed by Medina et al. (2008) and Da Silva (2011), especially when considering embryos in early developmental stages, suggesting differences in the pattern of allocation of food energy by the animals at different sizes. Such a positive linear relationship has also been described for M. acanthurus (Valenti et al.1989; Tamburus et al. 2012), M. olfersi (Mossolin and Bueno 2002) and *M. carcinus* (Lara and Wehrtmann 2009), indicating a common characteristic in the *Macrobrachium* species.

Differences in the maximum reproductive output among crustacean species seem to be primarily the result of differences in female body size; however, other biotic or abiotic factors, such as egg size, latitudinal and seasonal variations, and habitat adaptation (Mantelatto and Fransozo 1997) may also influence the reproductive output. In this study, females of *M. amazonicum* with medium size converted between 4.8 and 21.85% of their body weight into eggs production, similar result to that observed for the big prawn M. carcinus by Lara and Wehrtmann (2009). This agrees with the findings reported for other *Macrobrachium* species, such as *M. acanthurus* with 14-30% (Anger and Moreira 1998), *M. hainanense* with 4-17% (Mantel and Dudgeon 2005) and *M. olfersi* with 7 - 38% (Anger and Moreira 1998), indicating that reproductive output is variable in Macrobrachium species. The reproductive output of *M. amazonicum* was not related to the female size, and this finding is in accordance with the results reported for *M. hainanense* (Mantel and Dudgeon 2005) and *M. carcinus* (Lara and Wehrtmann 2009). Apparently, the reproductive output is associated with the individual condition of females and not size, since specimens of different sizes may have similar reproductive output.

CONCLUSION

Macrobrachium amazonicum females are more abundant that males in Mazagão and Santana Island and may be being affected by differences in the occurrence of macrophytes and opportunities for refuge from predation. In this study the prawns are caught in abundance along the banks during low water, when they are migrating from the lowland. In Santana Island and Mazagão *M. amazonicum* population shows a reproductive peak occurring in the rainy season, but reproduces continuously throughout the year. The number of juvenile prawns caught in this study indicates that the matapis in use has very closed cracks and can be affecting the local structure of *M. amazonicum* populations, given the considerably decreased volume and size of prawns caught reported by local fishermen.

Individual fecundity of *M. amazonicum* females is variable; it is higher in the Amazon River estuary than other Brazilian regions and is closely related to female size. The highest number of eggs of *M. amazonicum* produced individually indicates that specimens of Santana Island and Mazagão can be used as matrices in commercial larvae farming. The reproductive output was not related to the female size; there is a need for more studies to determine which factors actually affect the egg production in this species.

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