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Population structure of *Macrobrachium amazonicum* (Heller, 1862) (Decapoda: Palaemonidae) in Miranda Hydroelectric Plant Reservoir, Araguari river, Minas Gerais, Brazil

Estrutura Populacional de *Macrobrachium amazonicum* (Heller, 1862) (Decapoda: Palaemonidae) no reservatório da Usina Hidrelétrica de Miranda, rio Araguari, Minas Gerais, Brasil

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Abstract: Aim: The present study aimed to analyze a *M. amazonicum* population structure in a reservoir of the "Triângulo Mineiro", Brazil. **Methods:** Monthly surveys were carried out from April/2012 to May/2013 at the Miranda Hydroelectric Plant Reservoir located in Araguari river, state of Minas Gerais. A sampling section of 100 m long, 5 m wide and depth not exceeding 1 m was defined on the banks of the reservoir. Sampling consisted on two persons quickly passing a 2 mm sieves in partially submerged marginal vegetation, for one hour. The sampled specimens were identified, sexed and measured. **Results:** A total of 2,584 specimens were analyzed, of which 64.62% were females (3.93% ovigerous, 5.94% non-ovigerous and 54.75% juveniles), 29.16% males (21.41% adults and 7.76% juveniles) and 6.22% juveniles of undetermined sex. The sex ratio (1:2.21) indicated a clear deviation for females, for the whole sampling period, monthly and for each size class. Males had an average carapace length (CL = 4.50 ± 0.71 mm) significantly lower than females (CL = 4.64 ± 1.47 mm) and the size frequency distribution revealed a unimodal pattern, with peaks occurring in 4.0 - 4.9 mm size class for males and in 3.0 - 3.9 mm size class for females. The relation between total and carapace length was significant, indicating a negative allometric growth. No males' morphotypes were found. The population presented a continuous reproduction with a gradual increase between April and June/2012. Female sexual maturity was determined for 6.3 mm of CL, while for males was estimated for 4.0 mm. **Conclusion:** The Miranda reservoir population had a body size variation similar to the continental populations of Pantanal. The sexual dimorphism observed may be related to the absence of male morphotypes and to the "pure search" reproduction strategy. The deviated sex ratio for females may increase the chance of fertilization and the reproductive success. The presence of juveniles and ovigerous females throughout the year indicates a continuous reproduction pattern of the population.

Keywords: Amazonian prawn; Benthos; Crustacea; population dynamics.

Resumo: Objetivo: O presente estudo analisou a estrutura populacional de *M. amazonicum* em um reservatório no "Triângulo Mineiro", Brasil. **Métodos:** Coletas mensais foram realizadas de abril/2012 a maio/2013 no reservatório da Usina Hidrelétrica de Miranda localizado no rio Araguari, estado de Minas Gerais. Um setor de amostragem de 100 m de comprimento, 5 m de largura e profundidade não excedendo 1 m foi definido nas margens do reservatório. A amostragem consistiu em duas pessoas passando rapidamente peneiras de malha de 2 mm na vegetação marginal, parcialmente submersa, por um período de 1 hora. Os espécimes amostrados foram identificados, sexados e medidos. **Resultados:** Foram analisados 2.584 espécimes, dos quais 64,62% eram fêmeas (3,93% ovígeras, 5,94% não ovígeras e 54,75% juvenis), 29,16% machos (21,41% adultos e 7,76% juvenis) e 6,22% juvenis de sexo indeterminado. A razão sexual (1:2,21) indicou desvio a favor das fêmeas, para todo o período amostral, mensalmente e por classe de tamanho. Os machos tiveram um comprimento de carapaça médio (CL = 4,50 ± 0,71 mm) significativamente menor que das fêmeas (CL = 4,64 ± 1,47 mm) e o padrão distribuição de frequência nas classes de tamanho foi unimodal, com picos ocorrendo em 4,0 - 4,9 mm para machos e 3,0 - 3,9 mm para fêmeas. A relação entre comprimento total e carapaça foi significativa, indicando um crescimento alométrico negativo. Não foram encontrados morfotipos de machos. A população apresentou reprodução contínua, com um aumento gradual entre abril e junho/2012. A maturidade sexual feminina foi determinada para 6,3 mm de CL, enquanto para machos foi estimada em 4,0 mm. **Conclusão:** A população do reservatório de Miranda teve uma amplitude de tamanho similar às populações continentais do Pantanal. O dimorfismo sexual observado pode estar relacionado à ausência de morfotipos de machos e com a estratégia de reprodução de busca ativa. A razão sexual desviada para fêmeas pode potencializar a chance de fertilização e sucesso reprodutivo. A presença de juvenis e fêmeas ovígeras ao longo de todo ano indicam um padrão de reprodução contínua da população.

Palavras-chave: Camarão-da-Amazônia; Bentos; Crustacea; dinâmica populacional.

1. Introduction

Although Brazil's freshwater prawn farming is world-wide known, in continental waters is predominantly made with an exotic species - *Macrobrachium rosenbergii* De Man, 1879 (Palaemonidae) (FAO, 2014). The native species *M. amazonicum* (Heller, 1862), however, may in future be exploited on a large scale, since it is widely distributed throughout South America and has high commercial value (Mantelatto et al., 2016). The poor knowledge about the natural biology of Brazilian inland populations of *M. amazonicum* can be one of the reasons of this little explored market. It is endemic in South America and distributed in the main river basins of the continent, like the Amazon River in the state of Pará and Paraná River in the states of Minas Gerais, São Paulo and Goiás (Vergamini et al., 2011; Pileggi et al., 2013; Pantaleão et al., 2014; Silva et al. 2017; Silva et al., 2018).

Macrobrachium amazonicum species are divided into two main populations: those living in coastal regions, which inhabit the river estuaries and depend on brackish water to complete their life cycle, and continental populations that live in rivers, lakes and other inland water bodies (Moraes-Valenti & Valenti, 2010). Variations between these populations occur regarding environmental characteristics, behavioral and life histories (Hayd & Anger, 2013), in addition to physiological and morphological characteristics (Charmantier & Anger, 2011; Boudour-Boucheker et al., 2013). These variations can be exemplified by the different osmoregulation and survival skills among larval and adult stages (Augusto et al., 2007), and changes in reproductive strategies and size reached by individuals of these continental and estuarine populations (Odinetz-Collart & Magalhães, 1994; Silva et al., 2004).

This species is the main native freshwater prawn commercially exploited in Brazil by artisanal fishing in the Amazon region, especially in the states of Pará and Amapá where there is a significant consumption, in addition to the Northeast region (Moraes-Valenti & Valenti, 2010). Among the native species, *M. amazonicum* is the most recommended for cultivation in Brazil (New, 2005). It has important characteristics that indicate its potential for aquaculture, such as the ability to adapt to intensive or extensive farming, its low aggressive behavior, rapid growth, great hardiness, easy captive breeding and maintenance (Maciel & Valenti, 2009; Machado et al., 2018), besides being resistant to diseases (Lobão & Rojas, 1991; Araújo & Valenti, 2007). There is currently a favorable scenario for the expansion of freshwater prawn farming in Brazil, mainly due to growing demand and better organization of the production chain (Marques & Moraes-Valenti, 2012).

Despite all utilities and advantages, researches related to natural populations of *M. amazonicum* are concentrated in the north of Brazil (Odinetz-Collart & Rabelo, 1996; Nóbrega et al., 2014; Taddei et al.,

2017) with few studies in the northeast (Sampaio et al., 2007; Rocha et al., 2015) and southeast region (Pantaleão et al., 2012, 2014; Silva et al., 2017). In the southeast region, most studies are related to *M. amazonicum* culture and were developed in São Paulo at the Aquaculture Center of Universidade Estadual Paulista - CAUNESP (Araújo & Valenti, 2007, 2011; Santos et al., 2016).

Crustacean population studies provide important information on species dynamics and contribute to the preservation of its natural biodiversity (Mantelatto & Barbosa, 2005). There is no knowledge on population structure of *M. amazonicum* in the "Triângulo Mineiro" in the west part of state of Minas Gerais, although the species has been recorded in several dams in the region (Silva et al., 2017).

The construction of dams for hydroelectric power generation promotes substantial changes, not just in the original aquatic fauna of dammed rivers, but also micro-climatic changes and social impacts (Alves et al., 1999; Sanches & Fisch, 2005). One way to minimize these environmental effects is to enable the sustainable use of these artificial aquatic environments (Freire et al., 2016). Traditionally, the dams have been used in Brazil in leisure activities, including recreational activities, sport and artisanal fishing and most recently as areas for the development of fish farming enterprises (Vilas Boas, 2006; Freire et al., 2016). Prawn populations, like *M. amazonicum,* present in dams can also be an important environmental resource for the inhabitants of regions located on its banks, either directly through artisanal fisheries, but also as a food item for fish species of sport and/or commercial interest.

The molecular genetic diversity studies of Bastos (2002), the extensive morphometric analyzes of Porto (2004) and the differences in larval morphology and pattern of development described by Hayd & Anger (2013) suggest the possibility of an incipient speciation for some continental populations of *M. amazonicum*. In order to provide evidences for this possibility, the present study evaluated the population of *Macrobrachium amazonicum* in the reservoir of Miranda, describing its population structure (frequency distribution for size classes, sex ratio, sexual maturity and alometric growth) and some morphological characteristics of the individuals as total length and caparace length.

2. Materials and Methods

Samples of *Macrobrachium amazonicum* (Heller, 1862) were monthly collected from April/2012 to May/2013 in Miranda dam. This dam covers areas of Indianópolis, Nova Ponte, Uberlândia and Uberaba municipalities in Minas Gerais state. A sampling section of 100 m long, 5 m wide and depth not exceeding 1 m was defined on the banks of the reservoir (19°03'13.0"S - 047°59'25.5" W) (Figure 1). Sampling consisted on quickly passing a 2 mm sieves in partially submerged marginal vegetation. To standardize the capture effort, sampling was performed by two people over a period of 1 h. Samples were collected at the beginning of the evening period, as *Macrobrachium* Spence Bate, 1868 species are known to be more active at night (Mossolin & Bueno, 2002). The specimens captured were transferred to a plastic box, with water and ice, from the dam and immediately transported to the

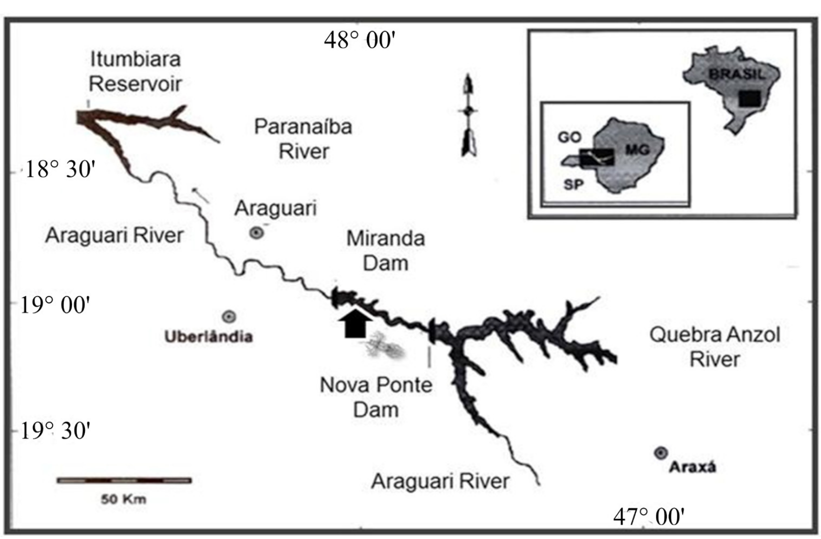

Figure 1. Miranda dam (arrow indicates sampling location) (adapted from Vono et al., 2002).

Laboratory of Aquatic Ecosystem Ecology of the Universidade Federal de Uberlândia (state of Minas Gerais), where they were stored in labeled bottles containing 70% EtOH.

In the laboratory, prawns were identified (Melo, 2003) and sexed, by observing under a stereoscopic microscope the presence or absence of male sexual appendage on endopod inside the second pair of pleopods (Rocha & Barbosa, 2017). The ovigerous condition also served for immediate recognition of females. There was a minimal size that allowed observing the male appendage and sex determination. Thus, the size of the lowest male individual found, determined the minimum size (CL) to verify sex, according to Bauer methodology (Bauer, 1989; Bauer & Vega, 1992). All specimens smaller than the smallest male were considered undetermined sex juveniles. Sexual maturity of males was determined according to Bauer (1989), using 25% of all size classes found, and for female was used the smallest ovigerous female.

The biometrics of individuals was obtained using a digital caliper (precision: 0.01 mm). The following dimensions were measured: Total Length (TL), distance between the tip of rostrum to the distal end of telson (mm), and Carapace Length (CL), distance between post-orbital margin to the posterior margin of the carapace (mm). The rostrum or telson of some specimens was broken, thus the use of the CL was preferred for most analyzes.

The number of size classes was calculated by means of the Sturges' formula but the population structure was not well described. So we grouped the individuals into eight different CL size classes by 1.0 mm intervals. The first class grouped individuals from 2.0 to 2.9 mm of CL and the last class grouped individuals between 10.0 to 10.9 mm. Individuals smallest than 2.9 mm de CL was considered juveniles of undetermined sex. As it was impossible to normalize the data with the transformations, the difference between CL males and females was compared by Mann-Whitney test (Zar, 1996).

The morphometric relations between TL and CL were described for males, and females, using linear regression. TL was considered as independent variable and CL as dependent variable. The linear regression was expressed by the equation: $Y = a + bX$. Y defines growth classes (Fonteles-Filho, 1989) as: negative allometric growth ($b < 1$), positive allometric growth ($b > 1$) and isometric growth ($b = 1$). Analysis of Variance (ANOVA) was used to check linear regression significance, while Analysis of Covariance (ANCOVA) tested the difference between regression lines for males and females. The "b" coefficient which expressed growth allometric levels was tested using Student t test (Zar, 1996).

The presence of ovigerous females was evaluated monthly, the months in which this presence was detected, were considered as breeding periods of the species. The sex ratio was measured by calculating the abundance of males in relation to the total of sexed individuals. The sex ratio in each CL class was compared to the expected sex ratio of 1:1 using the Binomial Test (SISA, 2018). The sex ratio recorded in each month and in the total sampling period was compared with the expected proportion (1: 1) using Chi-square test (χ^2).

3. Results

During this study, 2,584 individuals were captured and analyzed. Minimal size to check individual sex was 3.0 mm resulting in 2,423 individuals (93.8%) with their sex defined, and 161 with undetermined sex individuals. From this total, 1,668 individuals were female (102 ovigerous, 1417 juveniles and 149 adults) and 755 were male (201 juveniles and 554 adults). Juvenile males were included in CL size classes lower than 4 mm, while juvenile females in size classes lower than 6.3 mm.

Specimens of *M. amazonicum* were collected in 13 of the 14 months in which samples were taken. No individuals were sampled in May/2012. The highest frequency of individuals was observed in January, April and May/2013 with the highest number of individuals (573) sampled in May/2013. In October/2012 the lowest number of individuals (39) was recorded.

The population had an average CL of 4.48 ± 1.32 mm and CL amplitude varying from 2.0 to 10.6 mm. Females were larger than males ($U = 566339.5$, $p < 0.01$) and presented CL range from 3.0 to 10.9 mm, while males from 3.0 to 8.1 mm CL (Table 1). Ovigerous females was recorder in CL size classes from 6.3 to 10.7 mm.

Table 1. Number of individuals (N), minimal (Min) and maximal (Max) length, mean and standard deviation (SD) of length carapace of *M. amazonicum* specimens in a population sampled in Miranda dam (MG), between April/2012 and May/2013 (CL: carapace length).

Sex	CL (mm)			
	N	Min	Max	Mean ± SD
Males	755	3.0	8.1	4.50 ± 0.71
Females	1,668	3.0	10.6	4.64 ± 1.47
Undetermined sex juveniles	161	2.0	2.9	2.72 ± 0.19

Linear regression showed significance for the relationship between TL and CL for males and females ($p < 0.001$), with negative allometric growth, indicating that CL increased to a lesser extent than TL (Table 2). The relationship between TL and CL of males and females specimens differed significantly when submitted to Analysis of Covariance (ANCOVA) ($F_{1, 2,420} = 67.365.17$, $p < 0.001$).

The highest frequencies of occurrence were recorded in the 4.0 - 4.9 mm size class for males and in the 3.0 - 3.9 mm for females. These size classes represented 70.41% of the individuals sampled. The size distribution presented a unimodal pattern for both sexes (Figure 2A).

For analysis of the sex ratio by size classes, the Binomial Test showed significant differences in all classes, except in class 5 - 5.9 mm ($p = 0.1935$; IC_{female}: 185.32 <2 05 < 224.49). Significant deviation for female direction (Figure 2B) was detected. In the evaluation of monthly sex ratio, a significant difference was observed in relation to the expected 1:1 ratio. Differences in sex proportion were recorded for almost every month, except for October/2012. A dominance of females was also recorded considering the whole study period (1:2.21) ($\chi^2 = 343.27$; $p < 0.0001$) (Table 3).

In general, it is possible to notice a higher variation in the number of males sampled throughout the year, which is not observed among females. The presence of ovigerous females was observed during all over the year. Recruitment peaks were observed in January and May/2013 (Figure 3).

Table 2. Regression equation for relationship between total length (TL) and carapace length (CL) in both sex, in a population sampled in Miranda dam (MG), between April/2012 and May/2013. (N = number of specimens, Y = CL (mm), X = TL (mm), a = interception, b = line slope and determination coefficient (r^2), F= F-test for ANOVA).

Group	N	Y = b. X + a	r^2	F
Males	755	CL = 0.154CT + 1.124	0.916	8150.021*
Females	1,668	CL = 0.185CT + 0.572	0.974	61661.093*

*p < 0.001.

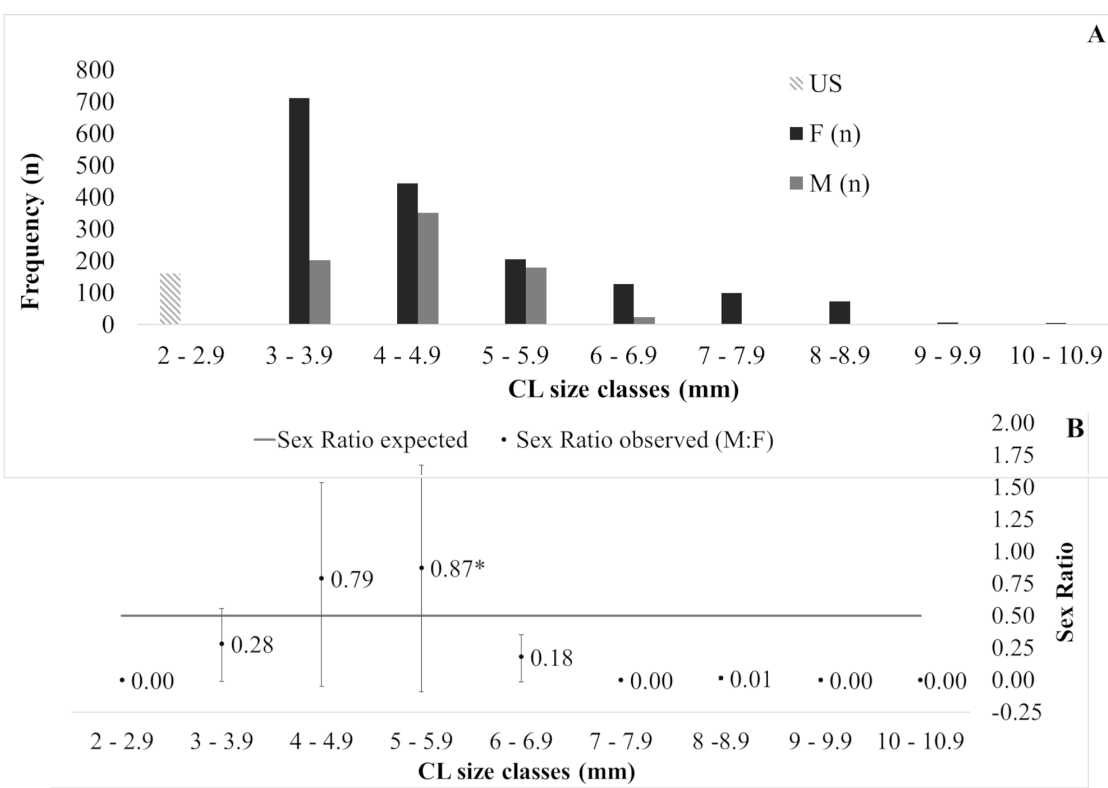

Figure 2. Frequency of individuals and sex ratio by size class in a population of *Macrobrachium amazonicum* in Miranda dam (MG) between april/2012 and may/2013. A: frequency distribution of males and females in Carapace Length size (US – undetermined sex; M – Male; F – Female). B: sex ratio by size class. *not significant difference.

Table 3. Sex-ratio (M:F), Chi-square (χ^2) and significant probability by month (p), in a population sampled in Miranda dam (MG), between April/2012 and May/2013. (M: Male; F: Female; ns: non significant).

Month	M (n)	F (n)	M:F	χ^2	(p)
April/12	90	121	0.74:1	4.26	0.0389
May	-	-	-	-	-
June	25	79	0.32:1	27.01	< 0.0001
July	14	39	0.36:1	10.86	0.0010
August	44	108	0.41:1	26.11	< 0.0001
September	94	145	0.65:1	10.46	0.0012
October	19	20	0.95:1	0	ns
November	33	75	0.44:1	15.56	0.0001
December	31	99	0.31:1	34.53	< 0.0001
January/13	118	217	0.54:1	28.66	< 0.0001
February	23	52	0.44:1	10.45	0.0012
March	44	97	0.45:1	19.17	< 0.0001
April	82	202	0.41:1	49.86	< 0.0001
May	138	414	0.33:1	137.00	< 0.0001
Total	755	1668	0.45:1	343.27	< 0.0001

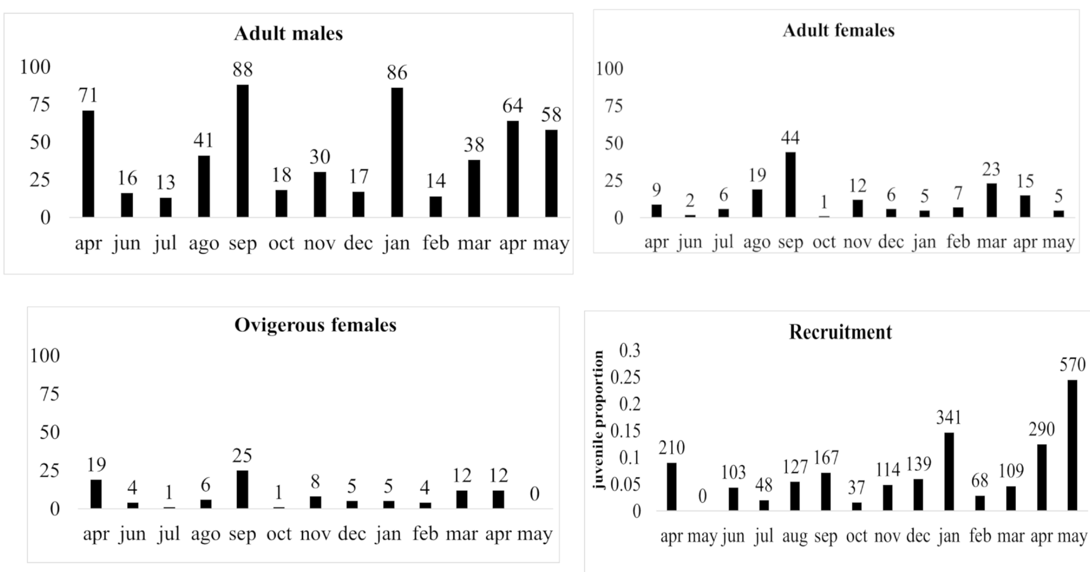

Figure 3. Monthly frequency of individuals in a population of *Macrobrachium amazonicum* in Miranda dam (MG) between april/2012 and may/2013 according to their population category and recruitment observed.

4. Discussion

Morphometric characteristics show important variations among different *M. amazonicum* populations (Porto, 2004). Variation in the biometry of males and females in the present study (males: 3.0 to 8.1 mm of CL and females: 3.0 to 10.6 mm of CL) was much lower than in populations of the same species studied in the estuaries and islands of Pará State (Bentes et al., 2011; Freire et al., 2012; Nóbrega et al., 2014). In the first paper, the authors found male lengths from 7.6 to 31.5 mm of CL and females lenghts from 5.0 to 32.5 mm of CL in one of the regions of the estuary, while Nóbrega et al. (2014) observed variation from 1.55 to 34.23 mm of CL for males and 2.57 to 44.72 mm of CL for females. In this study authors also reported that the high lengths of the observed individuals are due to local conditions, since the estuary offers better growth and protection conditions. Moreover, food such as microorganisms, phytoplankton and zooplankton are very abundant in this kind of environment. In addition, it may be due to the sampling section that offer full conditions for small individuals develop normally, including adults physiologically mature that already participate in the reproduction process.

Zimmermann et al. (2012) found differences in carapace shape of *Macrobrachium australe*

(Guérin-Méneville, 1838) related to water flow in the environment. In lotic habitats individuals with a robust carapace were recorded, while in lentic habitats prawns had slender carapaces. Considering the water flow characteristics of the Miranda dam, it is possible that this lentic environment, with very low water speed, is a response to the significant differences found in the carapace length of these animals in relation to other continental populations. It is essential to consider, however, that genetic characteristics could influence the expression of this character, being necessary an genetic comparison of these populations to answer of this question.

Similar biological differences between *M. amazonicum* populations from Pantanal (CLmax. 11.1 for males, 11.2 for females in lotic habitats and CLmax 10.9 mm for males 13.7 mm for females in lentic habitats) and those living in estuaries (CL_{max} 26.8mm, on average, for both sexes) has been showed by Hayd & Anger (2013) and were also detected in Miranda dam population (CLmax 8.1 mm for males and 10.6 mm for females). A maximum length of 33.09 mm has been recorded in the Santana Island (PA) (Lima e Silva, 2015), while in Tucuruí reservoir (PA) it was 18 mm (Odinetz-Collart & Magalhães, 1994). Individuals show up to 18 mm of CL in the Amazon River and up to 28 in the Tocantins River (Odinetz-Collart & Moreira, 1993; Flexa et al., 2005). Although significant differences were observed in several studies regarding morphological and morphometric characteristics, as well as in molecular genetics, these variations were not considered sufficient to justify a taxonomic division of the complex *M. amazonicum* (Porto, 2004; Maciel & Valenti, 2009; Vergamini et al., 2011; Hayd & Anger, 2013).

The relationship between TL and CL presented negative allometry for both sexes. This suggests that an increase in the proportion of the total length occurs faster than in carapace length as the animals grow. This result corroborates those obtained by Bentes et al. (2011), Freire et al. (2012), Hayd & Anger (2013) and Nóbrega et al. (2014).

The females were larger than males, which corroborates previous studies with *M. amazonicum* (Odinetz-Collart & Moreira, 1993; Silva et al., 2007; Bentes et al., 2011; Hayd & Anger, 2013). Population such as those observed in the Pantanal (Hayd & Anger, 2013), Tietê River (Pantaleão et al., 2012) and "Triângulo Mineiro" (present study; Silva et al., 2017), where males tend to be smaller than females, may be related to a promiscuous mating system, which in turn is associated with mobile and non-territorial species, with high density and few pre-copula interactions or agonistic behaviors among males. Thus, males would not need to invest in growth or defense structures against other males (chelipeds) in competition for females during reproduction. Staying small, agile, with high mobility and being less interesting for predators could be an efficient survival strategy (Bauer & Abdalla, 2001; Bauer, 2004; Correa & Thiel, 2003; Bauer & Thiel, 2011).

This variation in size between males and females is related to the presence or absence of male morphotypes (TC, CC, GC1, GC2). For *Macrobrachium* spp., the differentiation of males in morphotypes with very large chelipeds is associated to their guarding behavior, which guarantees intraspecific competition and domination of females during copulation process (Barki et al., 1991; Karplus et al., 1991; Moraes-Riodades & Valenti, 2004).

In our study, the presence of males with different morphological characteristics was not detected, such as in other studies (Pantaleão et al., 2012; Hayd & Anger, 2013; Rocha et al., 2015) with females larger than males. The weak expression of this sexual dimorphism associated with the absence of investment in the defense of potential females for mating make the males smaller. In this "pure search" mating system, small size is an advantage for males and they do not need to develop large chelipeds. The reproductive success depends on male ability to find and fertilize as many receptive females as possible (Correa & Thiel, 2003; Bauer & Thiel, 2011). In populations in which these morphotypes are absent females usually have larger sizes than males (Hayd & Anger, 2013). It becomes interesting for females to invest in body growth, since this ensures greater fecundity and increases the chance of reproductive success in interactions with males (Silva et al., 2004; Bauer, 2004; Correa & Thiel, 2003; Bauer & Thiel, 2011; Lima et al., 2013).

An increase in the total body length of females may be related to the growth in a greater proportion of the abdomen, since this part of the body of the prawn has an effective participation in the incubation of the eggs, which are adhered to the pleopods (Silva et al., 2007). In caridean shrimps, as in others crustaceans species, egg production can be limited by female's body size (Bauer, 1991), as Meireles et al. (2013) found in populations of states of Pará and Mato Grosso do Sul.

The frequency distribution of individuals in size classes was unimodal, with distinct modal classes for females and males. This pattern has also been verified for populations of *M. brasiliense* (Heller, 1862) (Mantelatto & Barbosa, 2005), *M. jelskii* (Miers,

1877) (Barros-Alves et al., 2012; Lima et al., 2013) and *M. amazonicum* (Silva et al., 2007). According to Díaz & Conde (1989), the unimodal pattern is common among tropical crustaceans, being the result of continuous patterns of spawning, recruitment, migration and mortality.

The sex ratio observed in the present study showed that the population was not stable in relation to the expected theoretical ratio of 1:1, since a favorable proportion to females occurred both monthly and in size classes, except in 5 - 5.9 mm size class. This favorable proportion of females in *M. amazonicum* was also verified in several studies (Odinetz-Collart, 1987; Hayd & Anger, 2013; Taddei et al., 2017) although Silva et al. (2002a, b) found dominance of males. Skewed sex ratios are widely diffused among crustaceans and are influenced by differences between males and females related to seasonal migrations, birth rates, mortality, longevity and predation (Wenner, 1972). For several species of the genus *Macrobrachium*, a favorable proportion of females was found, such as for *M. olfersi* (Wiegmann, 1836) (Mossolin & Bueno 2002), *M. jelskii* (Barros-Alves et al., 2012), *M. acanthurus* (Román-Contreras & Campos-Lince, 1993) and *M. brasiliense* (Mantelatto & Barbosa, 2005).

The larger proportion of females in the dam over the entire sampling period may also be related to the phases of the reproductive process in which females adopt an aggregate distribution pattern in the breeding areas and become more susceptible to be captured when the collection sampling is carried out in such places (Coelho & Santos, 1993).

For *M. iheringi* (Ortmann, 1897), it has been proposed that the dominance of females may be a reproductive strategy to compensate the low fecundity (Fransozo et al., 2004), a fact that also occurs with *M. amazonicum,* that has a lower fecundity when compared to other species of the same genus (Maciel & Valenti, 2009). In the same way, for the species *M. jelskii* and *M. brasiliense* (Heller, 1862), Taddei et al. (2017) mentioned that the higher number of females in the population favors a higher index of fertilization, mainly due to the characteristic of continuous reproduction of the species.

The occurrence of ovigerous females in the Miranda dam throughout the study period indicates the species can reproduce throughout the year, evidencing a continuous reproduction, also observed elsewhere (Freire et al., 2003, 2012). Freshwater prawns of the genus *Macrobrachium* present continuous or periodic reproduction, and in Brazil, most species have a long reproductive period that can extend throughout the year with a higher intensity period (Valenti & Lobão, 1986), as occurred in this study during the months of april and june/2012. The reproductive period of freshwater decapod crustaceans is associated with rainfall, thermal variations and photoperiod of the region (Pinheiro & Hebling, 1998). Odinetz-Collart & Rabelo (1996) add other influences such as water velocity, food availability, and population density.

Thus, this study confirmed the differences in population structure between the continental and estuarine groups of this prawn species. Females were larger than males and no male morphotypes were found either. The size frequency distribution revealed a unimodal distribution pattern, with peaks occurring in 4.0 - 4.9 mm size class for males and in 3.0 - 3.9 mm size class for females. The species presented a continuous reproduction with a gradual increase between april and june/2012. This study offered novel information to understand the life history of *M. amazonicum* in the "Triângulo Mineiro" region. The size differences recorded in relation to other studies suggests the possibility of an incipient speciation in this *M. amazonicum* population although genetic studies are necessary to provide more evidences on this. Besides, the data generated could be fundamental for defining strategies for the conservation and management of the species, including its potential for fishing and aquaculture exploitation. In addition, the information obtained is extremely important because it is a rich region of Brazil in water resources, with few studies of carcinology, and where other populations can be found and managed.

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References

ALVES, F.M., FISCH, G. and VENDRAME, I.F. Modificações do microclima e regime hidrológico devido ao desmatamento na Amazônia: estudo de um caso em Rondônia (RO), Brasil. *Acta Amazonica*, 1999, 29(3), 395-409. http://dx.doi.org/10.1590/1809-43921999293409.

ARAÚJO, M.C. and VALENTI, W.C. Efeito da intensidade luminosa no desenvolvimento larval do camarão-da-amazônia, *Macrobrachium amazonicum. Boletim do Instituto de Pesca*, 2011, 37(2), 155-164.

ARAÚJO, M.C. and VALENTI, W.C. Feeding habit of the Amazon river prawn *Macrobrachium amazonicum* larvae. *Aquaculture (Amsterdam, Netherlands)*, 2007, 265(1), 187-193. http://dx.doi.org/10.1016/j.aquaculture.2007.01.016.

AUGUSTO, A., GREENE, L.J., MCNAMARA, J.C. and LAURE, H.J. The ontogeny of isosmotic intracellular regulation in the diadromous, freshwater palaemonid shrimps, *Macrobrachium amazonicum* and *M. olfersi* (Decapoda). *Journal of Crustacean Biology*, 2007, 27(4), 626-634. http://dx.doi.org/10.1651/S-2796.1.

BARKI, A., GOREN, M. and KARPLUS, I. Morphotype related dominance hierarchies in males of *Macrobrachium rosenbergii* (Crustacea, Palaemonidae). *Behaviour*, 1991, 117(3-4), 145-160. http://dx.doi.org/10.1163/156853991X00508.

BARROS-ALVES, S.D.P., ALMEIDA, A.C., FRANSOZO, V., ALVES, D.F.R., SILVA, J.C.D. and COBO, V.J. Population biology of shrimp *Macrobrachium jelskii* (Miers, 1778) (Decapoda, Palaemonoidea) at the Grande River at northwest of the state of Minas Gerais, Brazil. *Acta Limnologica Brasiliensia*, 2012, 24(3), 266-275. http://dx.doi.org/10.1590/S2179-975X2012005000044.

BASTOS, S.N. *Caracterização molecular e biologia reprodutiva de* Macrobrachium amazonicum *(Crustacea, Decapoda, Palaemonidae)* [Dissertação de Mestrado]. Bragança: Universidade Federal do Pará, 2002.

BAUER, R. and ABDALLA, J.H. Male mating tactics in the shrimp Palaemonetes pugio (Decapoda, Caridea): precopulatory mate guarding vs. pure searching. *Ethology*, 2001, 107(3), 185-199. http://dx.doi.org/10.1046/j.1439-0310.2001.00636.x.

BAUER, R.T. Analysis of embryo production in a caridean shrimp guild inhabiting tropical seagrass meadows. In: A. WENNER and A. KURIS, eds. *Crustacean egg production*. Leiden: Balkema Press, 1991, pp. 181-192. Crustacean issues, vol. 7.

BAUER, R.T. and THIEL, M. First description of a pure search mating system and protandry in the shrimp *Rhynchocinetes uritai* (Decapoda: Caridea). *Journal of Crustacean Biology*, 2011, 31(2), 286-295. http://dx.doi.org/10.1651/10-3378.1.

BAUER, R.T. and VEGA, L.W.R. Pattern of reproduction and recruitment in two sicyoniid prawn species (Decapoda: Penaeoidea) from a tropical seagrass habitat. *Journal of Experimental Marine Biology and Ecology*, 1992, 161(2), 223-240. http://dx.doi.org/10.1016/0022-0981(92)90099-V.

BAUER, R.T. Continuous reproduction and episodic recruitment in nine prawn species inhabiting a tropical seagrass meadow. *Journal of Experimental Marine Biology and Ecology*, 1989, 127(2), 175-187. http://dx.doi.org/10.1016/0022-0981(89)90183-4.

BAUER, R.T. *Remarkable shrimps: adaptations and natural history of the carideans*. Norman: University of Oklahoma Press, 2004, 282 p. Animal Natural History series, vol. 7.

BENTES, B., MARTINELLI, J.M., SOUZA, L.S., CAVALCANTE, D.V., ALMEIDA, M.C. and ISAAC, V.J. Spatial distribution of the Amazon river prawn *Macrobrachium amazonicum* (Heller, 1862) (Decapoda, Caridea, Palaemonidae) in two perennial creeks of an estuary on the northern coast of Brazil (Guajará Bay, Belém, Pará). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 2011, 71(4), 925-935. http://dx.doi.org/10.1590/S1519-69842011000500013.

BOUDOUR-BOUCHEKER, N., BOULO, V., LORIN-NEBEL, C., ELGUERO, C., GROUSSET, E., ANGER, K., CHARMANTIER-DAURES, M. and CHARMANTIER, G. Adaptation to freshwater in the palaemonid shrimp Macrobrachium amazonicum: comparative ontogeny of osmoregulatory organs. *Cell and Tissue Research*, 2013, 353(1), 87-98. http://dx.doi.org/10.1007/s00441-013-1622-x. PMid:23616029.

CHARMANTIER, G. and ANGER, K. Ontogeny of osmoregulatory patterns in the South American prawn *Macrobrachium amazonicum*: loss of hypo-regulation in a land-locked population indicates phylogenetic separation from estuarine ancestors. *Journal of Experimental Marine Biology and Ecology*, 2011, 396(2), 89-98. http://dx.doi.org/10.1016/j.jembe.2010.10.013.

COELHO, P.A. and SANTOS, M.C.F. Época da reprodução do camarão rosa, *Penaeus subtilis*, Pérez-Farfante, 1967 (Crustacea, Decapoda, Penaeidae) na região de Tamandaré, PE. *Boletim Técnico-Científico do CEPENE*, 1993, 1(1), 57-72.

COLLART, O.O. and RABELO, H. Variation in egg size of the freshwater prawn *Macrobrachium amazonicum* (Decapoda, Palaemonidae). *Journal of Crustacean Biology*, 1996, 16(4), 684-688. http://dx.doi.org/10.2307/1549189.

CORREA, C. and THIEL, M. Mating systems in caridean prawn (Decapoda: Caridea) and their evolutionary consequences for sexual dimorphism and reproductive biology. *Revista Chilena de Historia Natural*, 2003, 76(2), 187-203. http://dx.doi.org/10.4067/S0716-078X2003000200006.

DÍAZ, H. and CONDE, J.E. Population dynamics and life history of the mangrove crab *Aratus pisonii* (Brachyura, Grapsidae) in a marine environment. *Bulletin of Marine Science*, 1989, 45(1), 148-163.

FLEXA, C.E., SILVA, K.C.A. and CINTRA, I.H.A. Morfometria do camarão-canela, *Macrobrachium amazonicum* (HELLER, 1862), no município de Cametá - Pará. *Boletim* Técnico-*Científico do CEPNOR*, 2005, 5(1), 41-54. http://dx.doi.org/10.17080/1676-5664/btcc.v5n1p41-54.

FONTELES-FILHO, A. *Recursos pesqueiros: biologia e dinâmica populacional*. Fortaleza: Imprensa Oficial do Ceará, 1989, 296 p.

FOOD AND AGRICULTURE ORGANIZATION – FAO. *Fishery and aquaculture statistics – Global capture production 1950-2012 – FishStatJ*. Rome: FAO Fisheries and Aquaculture Department, 2014.

FRANSOZO, A., RODRIGUES, F.D., FREIRE, F.A.M. and COSTA, R.C. Reproductive biology of the freswater prawn *Macrobrachium iheringi* (Ortmann, 1897) (Decapoda, Caridea, Palaemonidae) in the Botucatu region, São Paulo, Brazil. *Nauplius*, 2004, 12(2), 119-126.

FREIRE, C.A., CAVASSIN, F., RODRIGUES, E.N., TORRES, A.H. and MCNAMARA, J.C. Adaptive patterns of osmotic and ionic regulation, and the invasion of fresh water by the palaemonid shrimps. *Comparative Biochemistry and Physiology*, 2003, 136(3), 771-778. http://dx.doi.org/10.1016/j.cbpb.2003.08.007. PMid:14613804.

FREIRE, J.L., MARQUES, C.B. and SILVA, B.B. Estrutura populacional e biologia reprodutiva do camarão-da-amazônia *Macrobrachium amazonicum* (Heller, 1862) (Decapoda: Palaemonidae) em um estuário da Região Nordeste do Pará, Brasil. *Brazilian Journal of Aquatic Science and Technology*, 2012, 16(2), 65-76. http://dx.doi.org/10.14210/bjast.v16n2.p65-76.

FREIRE, K.M.F., TUBINO, R.A., MONTEIRO-NETO, C., ANDRADE-TUBINO, M.F., BELRUSS, C.G., TOMÁS, A.R.G., TUTUI, S.L.S., CASTRO, P.M.G., MARUYAMA, L.S., CATELLA, A.C., CREPALDI, D.V., DANIEL, C.R.A., MACHADO, M.L., MENDONÇA, J.T., MORO, P.S., MOTTA, F.S., RAMIRES, M., SILVA, M.H.C. and VIEIRA, J.P. Brazilian recreational fisheries: current status, challenges and future direction. *Fisheries Management and Ecology*, 2016, 23(3-4), 276-290. http://dx.doi.org/10.1111/fme.12171.

HAYD, L. and ANGER, K. Reproductive and morphometric traits of *Macrobrachium amazonicum* (Decapoda, Palaemonidae) from the Pantanal, Brazil, suggests initial speciation. *Revista de Biología Tropical*, 2013, 61(1), 39-57. http://dx.doi.org/10.15517/rbt.v61i1.10881. PMid:23894962.

KARPLUS, I., BARKI, A. and GOREN, M. The agonistic behaviour of the three male morphotypes of the freshwater prawn *Macrobrachium rosenbergii* (Crustacea, Palaemonidae*). Behaviour*, 1991, 116(3-4), 252-277. http://dx.doi.org/10.1163/156853991X00067.

LIMA, D.P., SILVA, L.M.A. and LIRA, A.C.S. Biologia populacional de *Macrobrachium jelskii* (Miers, 1778) (Crustacea, Decapoda, Palaemonidae) em uma planície inundável na Amazônia Oriental, Brasil. *Biota Amazônia*, 2013, 3(2), 11-22. http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v3n2p11-22.

LIMA, J.F. and SILVA, L.M.A. Population structure relative and relative growth of freshwater prawn *Macrobrachium amazonicum* (HELLER, 1862) (Crustacea, Palaemonidae) in two regions of the State of Amapá, Amazon River mouth, Brazil. *Biota Amazonica*, 2015, 5(2), 52-57. http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v5n2p52-57.

LOBÃO, V.L. and ROJAS, N.E.T. *Camarões de* água *doce: da coleta ao cultivo, à comercialização*. São Paulo: Ícone, 1991. 112p.

MACHADO, I.D.S., NUNES, C.A.R., SANTOS, H.B.L., LIMA, J.A., MEIRA, T.M., SENA, E.D. and SILVA, W.N. Desempenho do camarão *Macrobrachium amazonicum* (Heller, 1862) (Crustacea: Decapoda: Palaemonidae), em diferentes densidades. *Revista Brasileira de Engenharia de Pesca*, 2018, 11(1), 29-37. http://dx.doi.org/10.18817/repesca.v11i1.1486.

MACIEL, C.R. and VALENTI, W.C. Biology, fisheries, and aquaculture of the amazon river prawn *Macrobrachium amazonicum*: a review. *Nauplius*, 2009, 17(2), 61-79.

MANTELATTO, F.L., PILEGGI, L.G., MAGALHÃES, C., CARVALHO, F.L., ROCHA, S.S., MOSSOLIN, E.C., ROSSI, N. and BUENO, S.L.S. Avaliação dos camarões palemonídeos (Decapoda: Palaemonidae). In: M.A.A. PINHEIRO and H. BOOS, orgs. *Livro vermelho dos crustáceos do Brasil: avaliação 2010-2014*. Porto Alegre: Sociedade Brasileira de Carcinologia, 2016, cap. 20, pp. 252-267.

MANTELATTO, F.L.M. and BARBOSA, L.R. Population structure and relative growth of freshwater prawn *Macrobrachium brasiliense* (Decapoda, Palaemonidae) from São Paulo State, Brazil. *Acta Limnologica Brasiliensia*, 2005, 17(3), 245-255.

MARQUES, H.L.A. and MORAES-VALENTI, P.M.C. Current status and prospects of farming the giant river prawn *Macrobrachium rosenbergii* (De Man, 1879) and the Amazon river prawn *Macrobrachium amazonicum* (Heller, 1862) in Brazil. *Aquaculture Research*, 2012, 43(7), 984-992. http://dx.doi.org/10.1111/j.1365-2109.2011.03032.x.

MEIRELES, A.L., VALENTI, W.C. and MANTELATTO, F.L. Reproductive variability of the Amazon River prawn, *Macrobrachium amazonicum* (Caridea, Palaemonidae): influence of life cycle on egg production. *Latin American Journal* *of Aquatic Research*, 2013, 41(4), 718-731. http://dx.doi.org/10.3856/vol41-issue4-fulltext-8.

MELO, G.A.S. Famílias Atyidae, Palaemonidae e Sergestidae. In: G.A.S. MELO, ed. *Manual de identificação dos crustacea decapoda de* água *doce do Brasil*. São Paulo: Loyola, 2003, pp. 289-415.

MORAES-RIODADES, P.M.C. and VALENTI, W.C. Morphotypes in male amazon river prawns, *Macrobrachium amazonicum. Aquaculture*, 2004, 236(1), 297-307. http://dx.doi.org/10.1016/j.aquaculture.2004.02.015.

MORAES-VALENTI, P.M.C. and VALENTI, W.C. Culture of the Amazon river prawn *Macrobrachium amazonicum*. In: M.B. NEW, W.C. VALENTI, J.H. TIDWELL, L.R.D. ABRAMO and M.N. KUTTY, eds. *Freshwater prawn biology and farming*. Oxford: Wiley-Blackwell, 2010, p. 485-501.

MOSSOLIN, E.C. and BUENO, S.L.S. Reproductive biology of *Macrobrachium olfersi* (Decapoda, Palaemonidae) in São Sebastião. *Journal of Crustacean Biology*, 2002, 22(2), 367-376. http://dx.doi.org/10.1163/20021975-99990244.

NEW, M.B. Freshwater prawn farming: global status, recent research and glace at the future. *Aquaculture Research*, 2005, 36(3), 210-230. http://dx.doi.org/10.1111/j.1365-2109.2005.01237.x.

NÓBREGA, P.S.V., BENTES, B. and MARTINELLI-LEMOS, J.M. Population structure and relative growth of the Amazon shrimp *Macrobrachium amazonicum* (Heller, 1862) (Decapoda: Palaemonidae) on two islands in the fluvial-estuarine plain of the Brazilian Amazon. *Nauplius*, 2014, 22(1), 13-20. http://dx.doi.org/10.1590/S0104-64972014000100002.

ODINETZ-COLLART, O. La pêche crevettière de *Macrobrachium amazonicum* (Palaemonidae) dans Le Bas-Tocantins après la fermeture du barrage de Tucuruí (Brésil). *Revue d'Hydrobiologie Tropicale*, 1987, 20(2), 131-144.

ODINETZ-COLLART, O. and MAGALHÃES, C. Ecological constraints and life history of palaemonid prawns in Amazonia. *Verhandlungen des Internationalen Verein Limnologie*, 1994, 25(4), 2460-2467.

ODINETZ-COLLART, O. and MOREIRA, L.C. Potencial pesqueiro de *Macrobrachium amazonicum* na Amazônia Central (Ilha do Careiro): variação da abundância e do comprimento. *Amazoniana*, 1993, 12(3-4), 399-413.

PANTALEÃO, J.A.F., HIROSE, G.L. and COSTA, R.C. Ocurrence of male morphotypes of *Macrobrachium amazonicum* (Caridea, Palaemonidae) in a population with an entirely freshwater life cycle. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 2014, 74(3, Suppl 1), 223-232. http://dx.doi.org/10.1590/1519-6984.03713. PMid:25627389.

PANTALEÃO, J.A.F., HIROSE, G.L. and COSTA, R.C. Relative growth, morphological maturity, and size of *Macrobrachium amazonicum* (Heler, 1862) (Crustacea, Decapoda, Palaemonidae) in a population with an entirely freshwater life cycle. *Invertebrate Reproduction & Development*, 2012, 56(3), 180-190. http://dx.doi.org/10.1080/07924259.2011.587276.

PILEGGI, L.A., MAGALHÃES, C., BOND-BUCKUP, G. and MANTELATTO, F.L. New records and extension of the known distribution of some freshwater prawns in Brazil. *Revista Mexicana de Biodiversidad*, 2013, 84(2), 563-574. http://dx.doi.org/10.7550/rmb.30504.

PINHEIRO, M.A.A. and HEBLING, N.J. Biologia de Macrobrachium amazonicum (De Man, 1879). In: W.C. VALENTI, ed. *Carcinicultura de* água *doce: tecnologia para produção de camarões*. São Paulo: FAPESP; Brasília: IBAMA, 1998, pp. 21-46.

PORTO, L.A.C. *Estudos morfológicos em populações do complexo Macrobrachium amazonicum (Heller, 1862) (Crustacea, Decapoda, Palaemonidae) em diferentes bacias hidrográficas brasileiras* [Tese de Doutorado]. Universidade de São Paulo, São Paulo, 2004.

ROCHA, S.S. and BARBOSA, R.J. Population biology of *Macrobrachium jelskii* (Miers, 1877) (Decapoda, Palaemonidae) from an artificial pond in Bahia, Brazil. *Nauplius*, 2017, 25, e2017023. http://dx.doi.org/10.1590/2358-2936e2017023.

ROCHA, S.S., SILVA, R.L.S., SANTOS, J.L. and OLIVEIRA, G. Length-weight relationship and condition factor of *Macrobrachium amazonicum* (Heller, 1862) (Decapoda, Palaemonidae) from a reservoir in Bahia, Brazil. *Nauplius*, 2015, 23(2), 146-158. http://dx.doi.org/10.1590/S0104-64972015002308.

ROMÁN-CONTRERAS, R. and CAMPOS-LINCE, L.S. Aspectos reproductivos y aproximación a un modelo de crecimiento para una población de *Macrobrachium acanthurus* (Wiegmann, 1836) en el río Palizada, Campeche, México. *Anales del Instituto Ciencias del Mar y Limnologia*, 1993, 20(1), 78-96.

SAMPAIO, C.M.S., SILVA, R.R., SANTOS, J.A. and SALES, S.P. Reproductive cycle of *Macrobrachium amazonicum* females (Crustacea, Palaemonidae). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 2007, 67(3), 551-559. http://dx.doi.org/10.1590/S1519-69842007000300022. PMid:18094840.

SANCHES, F. and FISCH, G. As possíveis alterações microclimáticas devido a formação do lago artificial da hidrelétrica de Tucuruí-PA. *Acta Amazonica*, 2005, 35(1), 41-50. http://dx.doi.org/10.1590/S0044-59672005000100007.

SANTOS, M.R., RODRIGUES, C.G. and VALENTI, W.C. Effect of habitat diversity on population development of the Amazon river prawn. *Journal of*

Shellfish Research, 2016, 35(4), 1075-1082. http://dx.doi.org/10.2983/035.035.0430.

SILVA, K.C.A., SOUZA, R.A.L. and CINTRA, I.H.A. Camarão-cascudo *Macrobrachium amazonicum* (Heller, 1862) (Crustacea, Decapoda, Palaemonidae) no município de Vigia-Pará-Brasil. *Boletim* Técnico-*Científico do CEPNOR*, 2002a, 2(1), 41-73.

SILVA, K.C.A., SOUZA, R.A.L. and CINTRA, I.H.A. Espécies de camarões capturadas em áreas estuarinas no município de Vigia, Pará, Brasil. *Boletim* Técnico-*Científico do CEPNOR*, 2002b, 2(1), 81-96.

SILVA, M.C.N., FRÉDOU, F.L. and ROSA FILHO, J. Estudo do crescimento do camarão *Macrobrachium amazonicum* (Heller, 1862) da ilha de Combú, Belém, estado do Pará, Amazônia. *Ciência e Desenvolvimento*, 2007, 2(4), 85-104.

SILVA, R., JACOBUCCI, G. and MOSSOLIN, E. Reproductive biology of *Macrobrachium amazonicum* (Heller, 1862) (Decapoda: Palaemonidae) in a reservoir situated in Minas Gerais State, southeastern Brazil. *Latin American Journal of Aquatic Research*, 2017, 45(4), 776-786. http://dx.doi.org/10.3856/vol45-issue4-fulltext-13.

SILVA, R.R., SAMPAIO, C.M.S. and SANTOS, J.A. Fecundity and fertility of *Macrobrachium amazonicum* (Crustacea, Palaemonidae). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 2004, 64(3A), 489-500. http://dx.doi.org/10.1590/S1519-69842004000300012. PMid:15622846.

SILVA, T.E., ALVES, D.F.R., BARROS-ALVES, S.D.P., ALMEIDA, A.C., TADDEI, F.G. and FRANSOZO, A. Morphometric differences between two exotic invasive freshwater caridean species (genus *Macrobrachium*). *Invertebrate Reproduction & Development*, 2018, 62(4), 221-228. http://dx.doi.org/10.1080/07924259.2018.1505668.

SIMPLE INTERACTIVE STATISTICAL ANALYSIS – SISA. *Calculate binomial probabilities* [online]. The Netherlands: SISA, 2018 [viewed 13 Dec. 2018]. Available from: https://www.quantitativeskills.com/sisa/distributions/binomial.htm

TADDEI, F.G., REIS, S.S., DAVID, F.S., SILVA, T.E., FRANSOZO, V. and FRANSOZO, A. Population structure, mortality, and recruitment of *Macrobrachium amazonicum* (Heller, 1862) (Caridea: Palaemonidae) in the eastern Amazon region. *Brazil Journal of Crustacean Biology*, 2017, 37(2), 131-141. http://dx.doi.org/10.1093/jcbiol/rux006.

VALENTI, W.C. and LOBÃO, V.L. Dinâmica de reprodução de *Macrobrachium acanthurus* (Wiegmann, 1836) e *Macrobrachium carcinus* (Linnaeus, 1758) do Rio Ribeira de Iguape (Crustacea, Decapoda, Palaemonidae). *Ciência e Cultura*, 1986, 38(7), 1256-1262.

VERGAMINI, F.G., PILEGGI, L.G. and MANTELATTO, F.L. Genetic variability of the Amazon river prawn *Macrobrachium amazonicum* (Decapoda, Caridea, Palaemonidae). *Contributions to Zoology (Amsterdam, Netherlands)*, 2011, 80(1), 67-83.

VILAS BOAS, C.L. *Modelo multicritérios de apoio à decisão aplicado ao uso múltiplo de reservatórios: estudo da barragem do ribeirão João Leite* [Dissertação de Mestrado]. Brasília: UnB, 2006.

VONO, V., SILVA, L.G.M., MAIA, B.P. and GODINHO, H.P. Biologia reprodutiva de três espécies simpátricas de peixes neotropicais: *Pimelodus maculatus* Lacépede (Siluriformes, Pimelodidae), *Leporinus amblyrhynchus* Garavello & Britski e *Schizodon nasutus* Kner (Characiformes, Anostomidae) do recém-formado Reservatório de Miranda, Alto Paraná. *Revista Brasileira de Zoologia*, 2002, 19(3), 819-826. http://dx.doi.org/10.1590/S0101-81752002000300020.

WENNER, A.M. Sex ratio as a function of size in marine Crustacea. *American Naturalist*, 1972, 106(949), 321-350. http://dx.doi.org/10.1086/282774.

ZAR, J.H. *Biostatistical analysis*. 3rd ed. New Jersey: Prentice Hall International, 1996, 662 p.

ZIMMERMANN, G., BOSC, P., VALADE, P., CORNETTE, R., AMÉZIANE, N. and DEBAT, V. Geometric morphometrics of carapace of *Macrobrachium australe* (Crustacea: Palaemonidae) from Reunion Island. *Acta Zoologica*, 2012, 93(4), 492-500. http://dx.doi.org/10.1111/j.1463-6395.2011.00524.x.

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