Ecology

Growth and longevity of the freshwater prawn *Macrobrachium brasiliense* (Decapoda: Palaemonidae)

Crecimiento y longevidad del camarón de agua dulce Macrobrachium brasiliense *(Decapoda: Palaemonidae)*

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Abstract

Growth and longevity parameters of males and females of *Macrobrachium brasiliense* were analyzed. Sampling was carried out monthly from July 2012 to June 2013 in Triângulo Mineiro region, Minas Gerais, Brazil. A total of 199 adult prawns (97 males and 102 females) were analyzed and measured according to the carapace length (CL, mm). Males (9.64 ± 4.17 mm, CL) were larger than females (7.7 ± 3.39 mm, CL). CL growth curves by the von Bertalanffy model are described by the equations CL = 21.0 [1 - $e^{-0.00446\ (t)}$] for males and CL = 20.0 [1 - $e^{-0.00454\ (t)}$] for females. Comparison of the growth curves by performing the F-type test, showed that there was no difference between the growth coefficients (K) of males and females (GL_{22}; $F_{3.16}$ = 2.476; *p* = 0.088). Longevity was estimated as 2.83 years for males and 2.78 years for females. In general, the observed longevity is similar to that of other *Macrobrachium* species.

Keywords: Caridea; Life strategies; Minas Gerais; von Bertalanffy

Resumen

En el presente estudio se analizaron los parámetros de crecimiento y longevidad de machos y hembras de *Macrobrachium brasiliense*. Las muestras se obtuvieron mensualmente desde julio/2012 hasta junio/2013 en la región de Triângulo Mineiro, Minas Gerais, Brasil. Un total de 199 camarones adultos (97 machos, 102 hembras) fueron

analizados y medidos según la longitud del caparazón (CL, mm). Los machos (9.64 ± 4.17 mm, CL) fueron más grandes que las hembras (7.7 ± 3.39 mm, CL). Las curvas de crecimiento para CL por el modelo de von Bertalanffy se describen mediante las ecuaciones: CL = 21.0 [1 - $e^{-0.00446 (t)}$] para los machos y CL = 20.0 [1 - $e^{-0.00454 (t)}$] para las hembras. Al comparar las curvas de crecimiento con la prueba tipo F, no hubo diferencias entre los coeficientes de crecimiento (K) de machos y hembras (GL_{22}; $F_{3.16}$ = 2.476; p = 0.088). La longevidad se estimó en 2.83 años para los machos y 2.78 años para las hembras. En general, la longevidad observada es similar a la de las especies de *Macrobrachium*.

Palabras clave: Caridea; Estrategias de vida; Minas Gerais; von Bertalanffy

Introduction

Decapod crustaceans are widely studied in many aspects, both ecologically and populationally; however, information about some species in this group beyond the aspects mentioned above is very scarce (i.e., ontogenetic development, growth, and longevity) (Pinheiro & Boss, 2016). For example, it is estimated that less than 2% of existing decapod species have known growth and longevity parameters, although it is known that the majority of the studied species have a wide variation in longevity, living from 1 to 20 years (Vogt, 2019).

The growth process of this group is complex due to the occurrence of ecdysis, in which almost the entire exoskeleton is eliminated and replaced by a new one that will have a larger size. Therefore, the growth and longevity patterns of crustaceans are estimated based mainly on the total body or carapace length and the use of the von Bertalanffy growth model (Hartnoll, 1978; Vogt, 2012). Studies suggest that the growth and longevity of decapod crustaceans can be influenced by many variables, including latitude, habitat, and sex (Vogt, 2012). In addition, they may be related to other life history variables, such as mortality and size at sexual maturity, which can vary depending on the growth pattern of species (Kim, 2005).

Macrobrachium brasiliense (Heller, 1862) has a wide distribution in South America; it is found in Colombia, Ecuador, Guianas, Peru, Venezuela, and Brazil (Amazonas, São Francisco, Paraná, and coastal basins) (Pileggi & Mantelatto, 2012). Its occurrence is related to regions of low elevation and tropical climate (García-Dávila & Magalhães, 2003). In Brazil, *M. brasiliense* occurs in the states of Amapá, Amazonas, Roraima, Tocantins, Pará, Bahia, Maranhão, Goiás, Mato Grosso, Mato Grosso do Sul, Paraná, São Paulo, and Minas Gerais, in lotic and lentic environments, with clear or dark waters (Coelho & Ramos-Porto, 1984; García-Dávila & Magalhães, 2003; Rossi et al., 2020; Santos et al., 2018).

The first studies on *M. brasiliense* had a faunistic and taxonomic focus, in addition to addressing some ecological aspects, such as the investigations by Coelho and Ramos-Porto (1984), García-Dávila et al. (2000), Vásquez et al. (2000), and García-Dávila and Magalhães (2003). Over the years, a few studies have been published on ecological aspects of this species, addressing topics such as population structure (Mantelatto & Barbosa, 2005; Oliveira et al., 2019; Pereira & Chacur, 2009), relative growth (Nogueira et al., 2019, 2020), reproductive biology (Oliveira et al., 2019), and habitat and diet preference and characterization (Melo & Nakagaki, 2013; Nogueira et al., 2018) throughout different regions of Brazil.

Growth and longevity are biological aspects still little studied within the genus *Macrobrachium*. There is information on these aspects only for 11 of the 246 species (Mantelatto et al., 2016): *M. amazonicum* (Heller, 1892) (Bentes et al., 2016; Freire et al., 2012), *M. americanum* Spence Bate, 1868 (Ibarra & Wehrtmann, 2020), *M. digueti* (Bouvier, 1895) (Ibarra & Wehrtmann, 2020), *M. equidens* (Dana, 1852) (Nwosu, 2008), *M. hancocki* Holthuis, 1950 (Ibarra & Wehrtmann, 2020), *M. macrobrachion* (Herklots, 1851) (Deekae & Abowei, 2010; Nwosu et al., 2007), *M. occidentale* Holthuis, 1950 (Ibarra & Wehrtmann, 2020), *M. panamense* Rathbun, 1912 (Ibarra & Wehrtmann, 2020), *M. rosenbergii* (de Man, 1879) (Harikrishnan & Madhusoodana, 1997), *M. tenellum* (Smith, 1871) (Ibarra & Wehrtmann, 2020), and *M. vollenhoveni* (Herklots, 1857) (Nwosu & Wolfi, 2006).

Thus, the general knowledge about aspects of population dynamics, such as growth and longevity of the genus *Macrobrachium* contributed with positive results for the understanding of the current situation of each population. The present study provides the first information about the growth and longevity of males and females of *M. brasiliense*, thus expanding the understanding of the biology of this freshwater prawn and providing data for future comparative analysis with its congeners.

Material and methods

Sampling was conducted monthly, from July 2012 to June 2013, in the Água Limpa stream (19°05'55.6" S 48°25'38.2" W; Fig. 1), approximately 30 km from

Uberlândia city, Minas Gerais, Brazil. Twelve collections were carried out over the sampling period; the specific dates are provided in Table 1. The sampling site was composed of typical vegetation of the Cerrado biome, and the collections took place in a single stretch of the stream that was approximately 20 m long and 2-3 m wide. *Macrobrachium brasiliense* specimens were sampled by 2 collectors using a sieve of 1.0 mm (mesh). The sieves were dragged along the submerged substrate at depths from 15 to 150 cm over a period of 90 minutes in order to catch the specimens. The sampled individuals were kept in ice storage containers during transport to the laboratory, where they were transferred to labeled pots containing 70% alcohol for posterior identification, sexing, and measurement. The water temperature was measured with a thermometer. Throughout the entire sampling period, the water temperature ranged from 18 to 28 °C (22.9 ± 3.1 °C).

The specimens collected were identified according to Melo (2003) and García-Dávila and Magalhães (2003). It is important to mention that only the species *M. brasiliense* is recorded in the current study area. Using a stereomicroscope, sex was identified by the presence (male) or absence (female) of the appendix masculina in the second pair of pleopods (Bauer, 2004). Then, the prawns were measured with a caliper (0.1 mm precision) considering the carapace length (CL), i.e., the distance between the posterior margin of the ocular orbit and the midpoint of the posterior margin of the carapace. Specimens that did not have an appendix masculina and were smaller than the smallest male identified were considered undifferentiated juveniles and were not used in the analyses.

Growth estimates were made for males and females. Initially, frequency distributions by size classes were built using Sturges' method (Sturges, 1926), in order to estimate the modal peaks using Peak-fit software (PeakFit v.4.06 SPSS Inc. for Windows, AISN Software Inc.), which adjusts the observed frequencies to normal distribution curves. The modal peaks were interpreted as age groups, which together over the time provide information for building the growth curves. In case of modal overlapping peaks, they were eliminated as they do not correspond to true age groups. For each adjusted normal curve, a numerical summary containing amplitude (number), mean and standard deviation was obtained. The critical F-value with a probability of 0.05 was calculated for each of the adjustments. Subsequently, the modal peak values were plotted on a scatter plot of age (days) vs. carapace length (mm), thus it was possible to determine cohorts (modal progressions).

The growth parameters of males and females were estimated according to the von Bertalanffy (1938) model, represented by the equation $CL_t = CL_\infty [1 - e^{-K(t-t_0)}]$, where CL_t: carapace length at time t; CL_∞: asymptotic length; K: constant growth; e: base of natural logarithms; t: age of the individuals; and t_0: initial age. The maximum carapace length recorded for captured individual was used as a parameter value for CL_∞, and the values of constant growth (K) and theoretical age (t_0) were tested in various iterations of trial and error (Fonseca & D'Incao, 2003). The growth curves were constructed through modal progresses, called cohorts in this study. The points were connected, defining different cohorts representing the population within that sampling period (Fonseca & D'Incao, 2003). For each cohort, we used the Solver routine of the Excel program, where the parameters in the von Bertalanffy model (CL_∞, K, t_0) were estimated based on the least-squared residuals between the lengths observed in the field and calculated by the von Bertalanffy model.

Once the growth curves were selected, age corrections in days were carried out based on time intervals between samples and the obtained t_0 value. The modal peaks and the corrected ages were used to calculate an average growth curve, also through the growth model of von Bertalanffy (1938). Mean curves for males and females were compared using a hypothesis test F-type (0.05), according to Cerrato (1990). Longevity (t_{max}) was obtained by the reverse of the von Bertalanffy equation: $t_{max} = t_0 - (1/K) \ln [1 - (CL_t/CL_\infty)]$, considering the t_0 parameter equal to zero and the expected length (CL_t) as 99% of the asymptotic length ($CL_t/CL_\infty = 0.99$, Fonseca & D'Incao, 2003; Miazaki et al., 2019).

Table 1

Information on the dates and quantity of samples of *Macrobrachium brasiliense*.

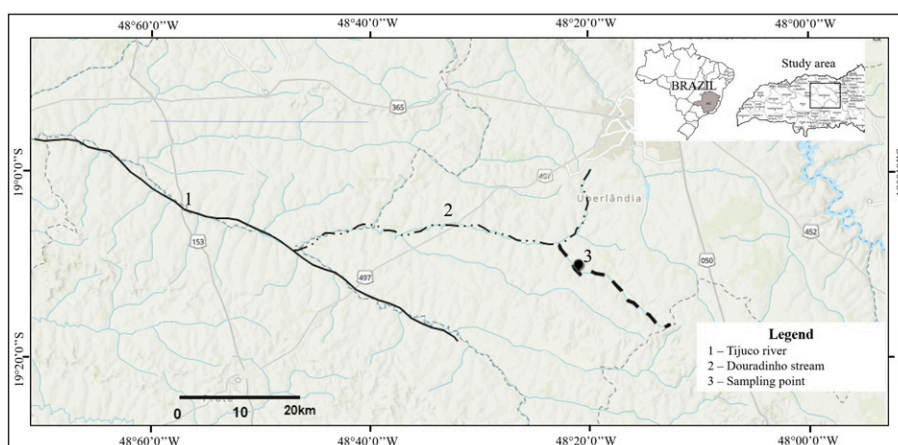| Sampling number	Months
1	07/19/2012
2	08/02/2012
3	09/20/2012
4	10/18/2012
5	11/30/2012
6	12/21/2012
7	01/31/2013
8	02/28/2013
9	03/15/2013
10	04/16/2013
11	05/31/2013
12	06/28/2013

Figure 1. Sampling area of *Macrobrachium brasiliense* in Água Limpa stream, in the southeastern region of Brazil. Map adapted from Cruz et al. (2021).

Results

A total of 199 individuals (97 males and 102 females) were analyzed. The average CL was 9.6 ± 4.2 mm for males and 7.7 ± 3.4 mm for females. The variation of CL in males was 4.8 to 20.5 mm, while in females it was 4.8 to 20.1 mm. Eight size classes were estimated, with lower and upper limits of the first and octave size classes of 4.3 and 20.6 mm, respectively, and 2.03 mm of amplitude (Fig. 2).

Four and 5 cohorts were analyzed for males and females, respectively. Their growth parameters are described in Table 2. The asymptotic size of males was set as 21.0

mm and females as 20.0 mm, values corresponding to the largest specimens obtained in the present study. From this result it was possible to describe the average growth curves for males $CL = 21.0 \ [1 - e^{-0.00446 \ (t)}]$ and females $CL = 20.0 \ [1 - e^{-0.00454 \ (t)}]$, calculated by the equation of the von Bertalanffy model (Fig. 3).

Comparing these growth curves using *F*-test there was no statistical difference between the growth coefficient (K) of males and females (GL_{22}; $F_{3.16} = 2.476$; $p = 0.088$). Using the reverse von Bertalanffy equation, the longevity of *M. brasiliense* was estimated at 2.83 years for males and 2.78 years for females.

Discussion

Important information on ecological aspects, growth, and longevity of *Macrobrachium brasiliense* were obtained. These population traits had not yet been investigated for this species. It is noticed that *M. brasiliense* has such aspects within the parameters already observed in other species of the same genus. In the present study, it was seen that males and females have similar growth rates and longevity values. Such information was discussed, and comparisons were made with congeners and other biological characteristics that influence these aspects (i.e., body size and habitats).

The growth coefficients (K) obtained for males and females of *Macrobrachium brasiliense* were very close and did not differ statistically. Individuals of both sexes have similar growth rates while they are juveniles. However, once these animals become adults, females grow more slowly than males, possibly due to the high energy investment in gonadal development compared to the

Table 2

Growth parameters of males and females of *Macrobrachium brasiliense*. Abbreviations: K, growth coefficient; t_0, theoretical age at time zero.

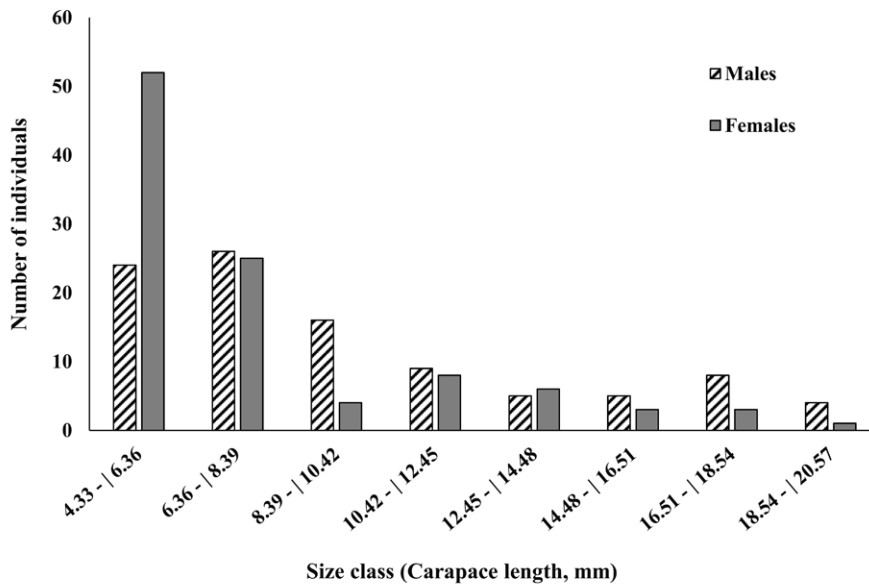| Groups	Cohorts	K (days^{-1})	t_0	Longevity (years)
Males	1	0.0043	-160.9909	2.9575
	2	0.0044	-61.9680	2.8878
	3	0.0049	-65.6324	2.5699
	4	0.0054	-80.8642	2.3444
	1	0.0043	-109.6510	2.9557
	2	0.0048	-82.5130	2.6537
Females	3	0.0052	-60.7503	2.4241
	4	0.0047	-64.9655	2.6623
	5	0.0046	-245.6057	2.7653

Figure 2. Size-frequency distribution of the carapace length of 97 males and 102 females of *Macrobrachium brasiliense* sampled from July 2012 to June 2013 in the Água Limpa stream about 30 km from Uberlândia city, Minas Gerais, Brazil.
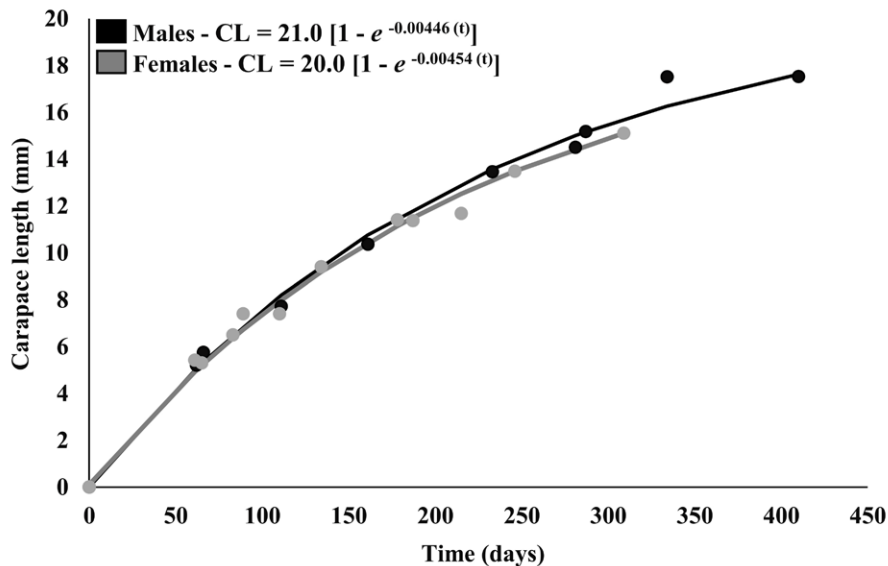

Males - $CL = 21.0 [1 - e^{-0.00446 (t)}]$
Females - $CL = 20.0 [1 - e^{-0.00454 (t)}]$

Figure 3. Growth curves and von Bertalanffy's equation parameters estimated for males and females of *Macrobrachium brasiliense* sampled from July 2012 to June 2013 in the Água Limpa stream about 30 km from Uberlândia city, Minas Gerais, Brazil.

somatic growth of males, as observed for *Macrobrachium borellii* (Nobili, 1896), *M. potiuna* (Müller, 1880), and *M. brasiliense* (Bond & Buckup, 1983; Mantelatto & Barbosa, 2005; Nogueira et al., 2019). The differences in the values of the growth coefficient (*K*) for crustaceans might be related to the energy relocation strategies of each sex (Freire et al., 2012; Hartnoll, 1982).

Although males and females of *M. brasiliense* have an average CL value with an evident difference, the maximum size that each sex reaches, observed in the

present study, is not so unequal (20.5 and 20.1 mm CL for males and females, respectively). This small difference could explain the divergence in life span required to reach the maximum size of males (2.83 years) and females (2.78 years). Possibly the longevity of these individuals is similar because they inhabit small streams where all individuals are susceptible to the same environmental conditions, which can directly influence this correlated life span (Trevisan & Santos, 2011).

Age in decapods can be influenced by many factors, for example, biological traits, geographic distribution, habitat, and others. In addition, there is a negative correlation between growth rate and longevity, in which the latter can vary considerably (Vogt, 2012). In Caridea, longevity can vary from 1 to 11 years, as observed for *Pandalus borealis* Krøyer, 1838 (11 years; Nilssen & Aschan, 2009), *Plesionika izumiae* Omori, 1971 (1.5 years; Ahamed & Ohtomi, 2012), *Palaemon pandaliformis* (Stimpson, 1871) (1-1.5 years; Paschoal et al., 2016), and *Exhippolysmata oplophoroides* (Holthuis, 1948) (2 years; Pescinelli et al., 2018). Thus, this longevity amplitude is also recorded for congenerics such as *M. brasiliense* (2.78 and 2.83 years) in the present study, *M. hainanense* (Parisi, 1919) (4 years; Mantel & Dudgeon, 2005), *M. macrobrachion* (2.48 years; Deekae & Abowei, 2010; Enin, 1995), *M. vollenhoveni* (1.97 years; Alhassan & Armah, 2011; Etim & Sankare, 1998), and *M. amazonicum* (3.86 years; Lucena-Frédou et al., 2010).

Considering some of the freshwater prawns that occur in Brazil, Freire et al. (2012) observed a longevity of approximately 4 years for *M. amazonicum*, with an average length of 32.5 mm CL (populations from northwestern Brazil). Souza and Fontoura (1996) estimated longevity of approximately 1.25 years for *M. potiuna* with individuals that had between 8 and 10.5 mm CL (populations from southern Brazil). Therefore, there is a strong relationship between maximum size and longevity, since among these 2 species mentioned and *M. brasiliense* (present study), *M. amazonicum* has the largest size and longest longevity, while *M. potiuna* has a smaller size and shorter longevity. In turn, *M. brasiliense* has average values of size and longevity between these 2 species, below *M. amazonicum* and above *M. potiuna*. Furthermore, such variation in the longevity of *M. brasiliense* compared to other species of the same genus may be related to interspecific factors (i.e., life history, reproductive strategies, and environmental conditions) and to the different habitats of each species.

This study provides relevant information on the growth and longevity of *M. brasiliense*, which together with other data available in the literature, can help understand the vulnerability of this species. Furthermore, the results of the present work may contribute to future research of comparative studies carried out in different regions to increase the knowledge in terms of the biology of *M. brasiliense*.

Acknowledgements

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