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Population and reproductive features of the freshwater shrimp *Macrobrachium jelskii* (Miers, 1877) from São Paulo State, Brazil

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ABSTRACT. The aim of this study was to describe the population structure and reproduction of *Macrobrachium jelskii* from a stream in the central region of São Paulo State. A total of 1,215 specimens was collected monthly during one year (February 2008 to January 2009), being 535 males, 578 females and 102 juveniles. The overall sex-ratio was not significantly different from the expected 1:1, but has significantly differed in some months. A total of 136 ovigerous females were collected and the reproductive period was continuous with peak of occurrence on the hottest months. An increase in juveniles following the highest frequency of ovigerous females was observed and characterized the recruitment period. The fecundity was low and varied from 1 to 56 eggs per female. The biological profile observed here matched, in general aspects, with the pattern developed by tropical and subtropical inland populations, with some particularities related with environmental characteristics.

Keywords: Crustacea, Decapoda, fecundity, Palaemonidae, reproduction.

Aspectos populacionais e reprodutivos do camarão de água doce *Macrobrachium jelskii* (Miers, 1877) do Estado de São Paulo, Brasil

RESUMO. O objetivo deste estudo foi descrever a estrutura populacional e a reprodução de *Macrobrachium jelskii* de um ribeirão na região central do Estado de São Paulo. Um total de 1215 espécimes foi coletado mensalmente durante o período de um ano (fevereiro de 2008 a janeiro de 2009), sendo 535 machos, 578 fêmeas e 102 juvenis. A razão sexual total não foi significantemente diferente da esperada 1:1, mas diferiu significativamente em alguns dos meses coletados. Um total de 136 fêmeas ovígeras foi coletado e o período reprodutivo foi considerado contínuo com pico de ocorrência nos meses mais quentes. Um aumento no número de juvenis foi identificado após a mais alta frequência de fêmeas ovígeras e caracterizou o período de recrutamento. A fecundidade foi baixa e variou de 1 a 56 ovos por fêmea. O perfil biológico observado aqui correspondeu, em aspectos gerais, com o padrão desenvolvido por populações continentais tropicais e subtropicais, com algumas particularidades relacionadas com as características do ambiente.

Palavras-chave: Crustacea, Decapoda, fecundidade, Palaemonidae, reprodução.

Introduction

The genus *Macrobrachium* Spence Bate, 1868 includes approximately 243 species spread worldwide in tropical and subtropical coastal and inland waters (DE GRAVE; FRANSEN, 2011; PILEGGI; MANTELATTO, 2012; WOWOR et al., 2009). Species of inland waters do not need brackish waters to life cycle development, and this is one of their most important features. Among the American species with this pattern of development, we can cite *Macrobrachium brasiliense* (Heller, 1862), *M. iheringi* (Ortmann, 1897), *M. potiuna* (Müller, 1880) and *M. jelskii* (Miers, 1877) (ANTUNES; OSHIRO, 2004; BUENO; RODRIGUES, 1995; MAGALHÃES, 2000; MANTELATTO; BARBOSA, 2005). The latter one presents an extensive distribution, occurring in inland waters of Trinidad, through Venezuela, Guiana, Suriname, French Guiana, Bolivia and Brazil (state of Acre, Alagoas, Amapá, Amazonas, Bahia, Ceará, Espírito Santo, Maranhão, Mato Grosso, Minas Gerais, Pará, Paraíba, Pernambuco, Rio Grande do Norte, Rio de Janeiro, Santa Catarina, São Paulo and Sergipe) (MELO, 2003; PILEGGI et al., 2013). This species has nocturnal feeding habits and lives in vegetation and roots in the margin of aquatic environments (MONTOYA, 2003; PAIVA; BARRETO, 1960).

Information about the life cycle of this species is not completely known but some of its biological features have been accumulated in recent years. There are reports on its reproductive biology in Venezuela by Gamba (1997), and in Brazil there are studies on oxygen use (BASTOS; PAIVA, 1959), general biology (PAIVA; BARRETO, 1960), larval development in laboratory conditions (MAGALHÃES, 2000), population and reproductive biology (BARROS-ALVES et al., 2012;), its exotic presence in São Paulo State (MAGALHÃES et al., 2005) and on the basal position of the species in the evolution of the genus in America (PILEGGI; MANTELATTO, 2010). These two latter conditions bring an interesting scenario to study this species in that region, and we herein conducted an analysis on a population of *M. jelskii* from São Paulo State, Brazil, assessing the size classes' frequency distribution, sex-ratio, reproductive period, juvenile recruitment and fecundity.

Material and methods

Specimens of *M. jelskii* were sampled monthly, from February 2008 to January 2009, during the morning period. The sampling site (21°42'17"S/048°01'33"W), with a 50 m section of Anhumas stream (waterway of Clube Náutico Araraquara dam) and 1 m deep is located on the municipal district of Américo Brasiliense, on Mogi-Guaçu river basin in the central region of São Paulo State.

The water temperature was measured prior to sampling. Within a time effort of 20 minutes, two people collected manually the specimens by sweeping a 2 mm mesh sieve through the partially submerged vegetation. Ovigerous females were isolated to avoid loss of eggs and all sampled animals were frozen and transported to the laboratory.

Shrimps were classified into males, females (ovigerous and non-ovigerous) and juveniles based on Mossolin and Bueno (2002), by checking the sex according to the presence (male) or absence (female) of the male appendix on the second pair of pleopods. Individuals without complete development of the internal appendix on the base of the second pair of pleopods were classified as juveniles.

Specimens were measured at the carapace length (CL) (from post-orbital margin to posterior dorsal margin of the carapace) with a caliper (accurate to 0.05 mm) and preserved in ETOH 80%. Voucher individuals were deposited in the Crustacean Collection of Department of Biology (CCDB) of Faculty of Philosophy, Sciences and Letters of Ribeirão Preto of the University of São Paulo (FFCLRP/USP) (CCDB catalogue number 3520). Eggs of ovigerous females were classified according to the embryonic developmental stage (based on MOSSOLIN; BUENO, 2002), and the fecundity was obtained from ovigerous females with eggs at initial stage of development (vitellus occupying at least 3/4 of the egg and non-visible eyes), by counting the total amount of eggs per female.

A chi-square test (χ^2) was used to evaluate the sex ratio for the whole period and for each month sampled (WENNER, 1972). The correlation between water temperature and shrimp abundance was tested by Spearman correlation for non-parametric data (ZAR, 1996).

Results and discussion

A total of 1,215 individuals of *M. jelskii* was collected and analyzed: 535 males (44.0%), 578 females (47.6 %) and 102 juveniles (8.4%). The CL of males ranged from 3.45 to 9.15 mm, of females, from 3.00 to 11.25 mm, and of juveniles, from 1.85 to 3.50 mm.

For population structure analysis, individuals were distributed into 12 classes ranging in 0.80 mm (between 1.85 and 11.44 mm) (Figure 1). Only juveniles were observed in the first class (1.85-2.64 mm), being observed until the third class (3.45-4.24 mm). Females measuring from 3.45 to 5.04 mm (n = 147) outnumbered males (n = 91), while these latter ones prevailed from 5.05 mm to 8.24 mm. From size class 8.25-9.04 mm, the proportion of females increased and outnumbered males reaching 100% in the last two classes (9.85-10.64 and 10.65-11.44 mm). Males were restricted to seven classes, while females were present in eleven, including the major ones (Figure 1).

Females larger than males were observed in this study and a similar profile was found by Taddei (unpublished data), in another population studied in a different area in the same latitude, and by Barros-Alves et al. (2012), to a population of state of Minas Gerais (20°09'S 48°40'W). This size pattern may suggest that females grow faster than males, probably for developing body dimensions related with reproduction as the cephalothorax and the ovary, as well as the abdomen which would increase the area available to incubate the eggs (HARTNOLL, 1985; MOSSOLIN; BUENO, 2002; MÜLLER; CARPES, 1991; VALENTI et al., 1989).

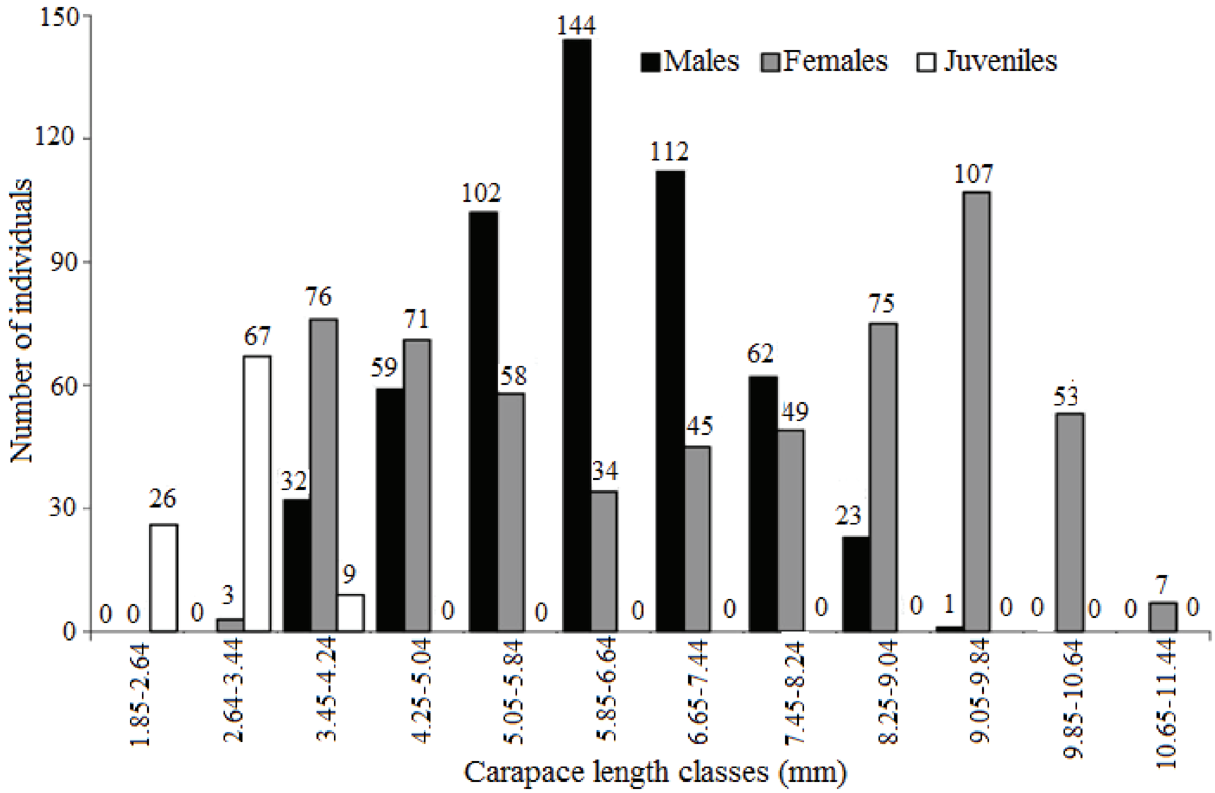

Figure 1. *Macrobrachium jelskii*. Size frequency distribution of total males, females and juveniles during the study period (from February 2008 to January 2009), in Anhumas stream, Américo Brasiliense (São Paulo State) (numbers above the bars indicate the total number of individuals per class).

The lack of a pattern for body size measurements observed in recent studies makes extremely difficult a detailed comparison within different populations. Holthuis (1952) had not indicated the extremes utilized to determine the total length; Paiva and Barreto (1960) obtained the total length from the post-orbital margin to the telson end, but have not checked the sex of adults, which is necessary for comparison; Gamba (1997) measured the total length from the top of the rostrum to the telson end, and the carapace length was measured from the post-orbital margin to dorsal posterior margin and obtained ovigerous females varying between 34.5 and 45.3 mm (total length). Size class distributions were determined by some of these authors (BARROS-ALVES et al. 2012; GAMBA, 1997; PAIVA; BARRETO, 1960), but differences among the methods of measurements available make a challenge to use their data. For this reason we strong recommend the use of standard measurements (i.e., CL = from post-orbital margin to posterior dorsal margin of the carapace, and TL = from the top of the rostrum to the telson end) in future studies on *Macrobrachium* species that enable comparisons between studied populations.

The sex-ratio has significantly differed from 1:1 in favor of males on February and April 2008, and in favor of females on August, October, and December 2008 and January 2009 (Figure 2). However, the overall sex ratio was not statistically significant (0.93 M: 1 F; χ^2: 1.66, $p > 0.05$).

The overall sex ratio was almost equal, with a small advantage to females, also found by Barros-Alves et al. (2012) (1:1.48). This finding was very distinct from the data reported by Gamba (1997) (of the 3,438 individuals collected 36.8% were males and 63.2% females) in Venezuela over a one year period, and by Taddei (unpublished data) (of the 1,694 individuals collected, 36.0% were males and 63.8% females) in São Paulo State during a two years period. These authors obtained their samples from lentic habitats, which can justify differences in relation to the present study, developed in a lotic environment (river rapids). In lentic environment, females and juveniles spend more time in the submerged vegetation to get shelter and food, and males tend to be found on the bottom (MAGALHÃES, 1999; MANTELATTO; BARBOSA, 2005). In the methodologies used by the aforementioned studies, only the vegetation was sampled. In the stream analyzed in our study, the bottom is sandy, with no vegetation or shelters what means that males also remained in the marginal vegetation and were caught together with females and juveniles during daytime.

Among the 578 collected females in 10 of the 12 sampled months (absent only on August and September 2008), 136 were ovigerous (23.53%). Major frequencies in relation to total females were observed in November (47.82%), December 2008 (64.06%) and January 2009 (72.72%) (Figure 2).

The presence of ovigerous females in 10 of the 12 sampled months (between October and July) is indicative of a continuous reproductive period, with an extended (6 months - between November and April) peak of high reproductive activity (Figure 2). Gamba (1997) also found ovigerous females in Venezuela during a similar period (between May and October), with a peak of occurrence in July. However, Paiva and Barreto (1960) obtained ovigerous females (in northeastern Brazil) in a previous period (between April and October), similar to Barros-Alves et al. (2012), which found the highest abundance of juveniles in September for two consecutive years.

These differences may be related to water temperature, once in southeastern Brazil there is a considerable thermal variation that can be reflected in the reproductive period of freshwater species. This hypothesis can be supported by the study of Taddei (unpublished data) who observed in a population from São Paulo State, a continuous reproductive period, similar to the present study, with the highest intensity from November to February.

A close relationship on the occurrence of juveniles and ovigerous females in 9 samples characterized the recruitment period. Juveniles were observed two months after hatching (Figure 3). When the percentage of ovigerous females decreased to less than 10% of the total sampled (from May to October), the number of juveniles caught was low or nearly disappeared in subsequent months (between August and January).

In order to analyze the recruitment period observed, we grouped information about larval development duration, size of juveniles, and reproductive period previously studied in *M. jelskii*. All individuals measuring up to 3.5 mm (CL) were considered juveniles and this value is similar to that defined by Gamba (1997) for unsexed individuals (4.0 mm). Under laboratory conditions, Magalhães (2000) reported that the first juvenile stage was obtained in approximately eight days (considering that the larval period comprises the three first developmental stages), with total length starting on average of 7.24 mm.

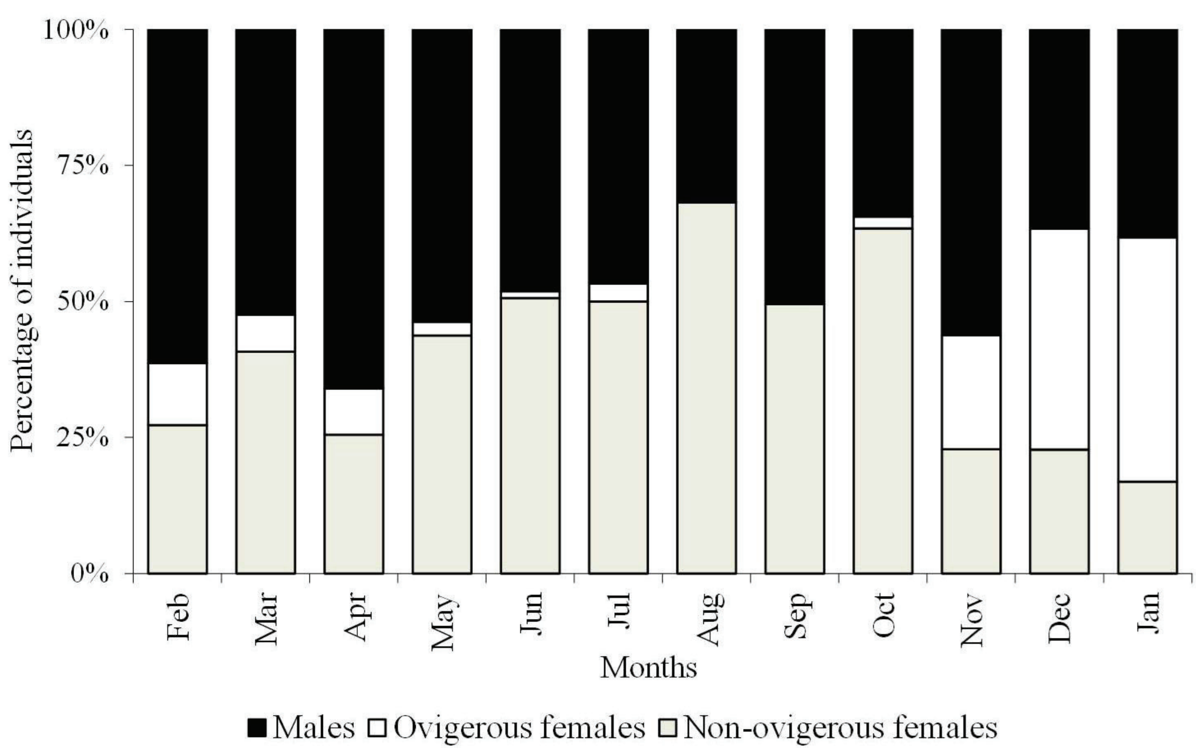

Figure 2. *Macrobrachium jelskii*. Percentage of males, ovigerous females and non-ovigerous females, collected from February 2008 to January 2009, in Anhumas stream, Américo Brasiliense (São Paulo State).

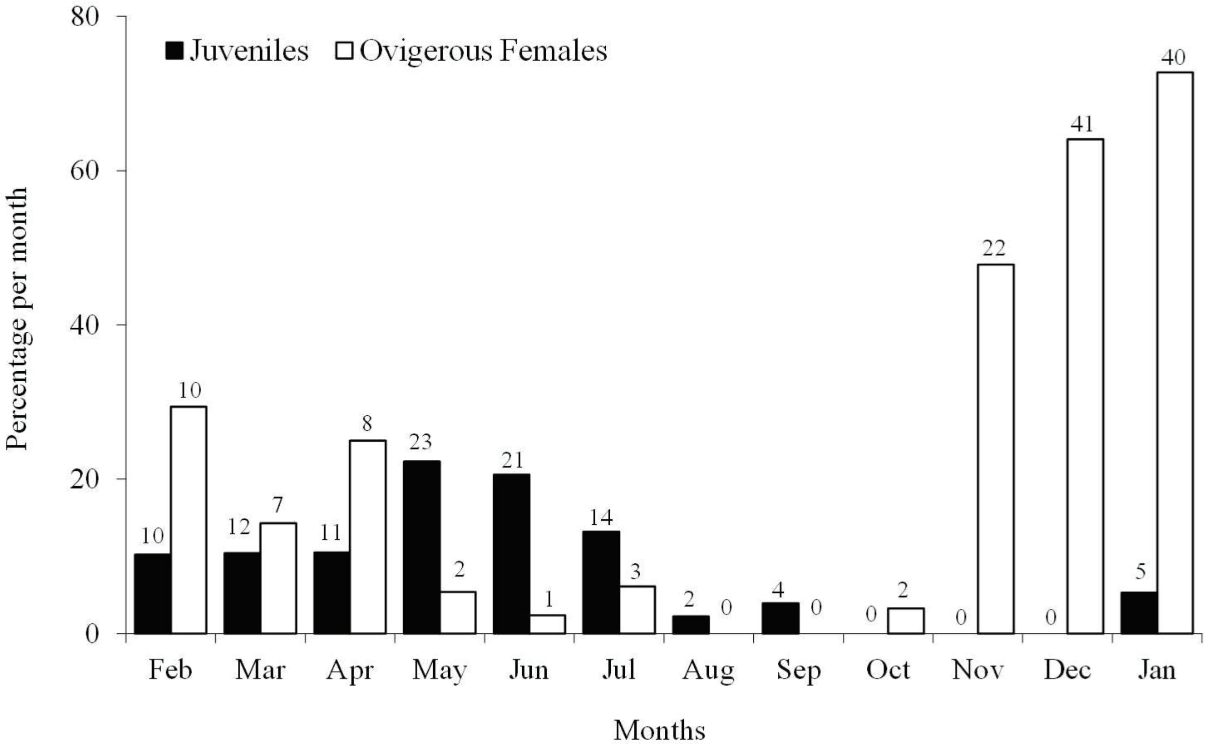

Figure 3. *Macrobrachium jelskii*. Percentage of juveniles in relation to total individuals collected by month and ovigerous females in relation to total females collected by month, from February 2008 to January 2009, in Anhumas stream, Américo Brasiliense (São Paulo State) (numbers above the bars indicate the absolute number of individuals).

Herein, the smallest juvenile measured 8.95 mm total length, indicating that we could assume that sampled individuals had more than eight days of life and would have born in the last two months. In relation to the recruitment period, it is supposed that in the study region the larval development started in the end of spring and the peak (size class 2.65-3.44 mm) may have occurred during late autumn and winter months. This pattern is similar to that found by Gamba (1997), with juveniles collected between February and September, however different from Paiva and Barreto (1960) who found juveniles between January and March, which attributed this result to the rainy season in the study site (northeastern Brazil) between January and June.

Based on the presence of ovigerous females (10 of 12 sampled months) and juveniles (9 of 12 months) (Figure 3), the reproductive period was classified as continuous, despite the marked reproductive peak in hottest and rainiest months (November to January). This peak followed the water temperature conditions that exceeded 25°C between October and April (maximum 28ºC in October 2008). The water temperature was lower than 25°C between May and September, with minimum of 19ºC on July 2008. Despite the pronounced pattern, the temperature had not been correlated with the total number of individuals and the number of ovigerous females ($p > 0.05$).

For Gamba (1997), rainfall is also an important factor to be considered in studies on freshwater species and the increased occurrence of ovigerous females was related to a period of heavy rainfall. In our study the percentage of ovigerous females has increased in the rainy months, similar to that author, but even so it needs more appropriated environmental analysis, such as the input of organic matter into the river with the rainfall. In contrast of this, for Paiva and Barreto (1960) the reproduction was not dependent on the rainy period.

Individual fecundity ranged from 1 (2 individuals, CL = 9.35 and 9.75 mm) to 56 (2 individuals, CL = 9.30 and 9.55 mm) eggs, with mean and standard deviation of 23.95 ± 14.8 eggs. The color of eggs in the initial stage of development was orange, while intermediate and final stages were whitish or transparent. The length of ovigerous females varied from 7.85 to 10.70 mm (CL), and the mean number of eggs increased with the increase of CL (Figure 4).

The number of eggs carried by *M. jelskii* is considered small due to its abbreviated larval development. The fecundity found in this study was similar to that obtained by Holthuis (1952) and Paiva and Barreto (1960).

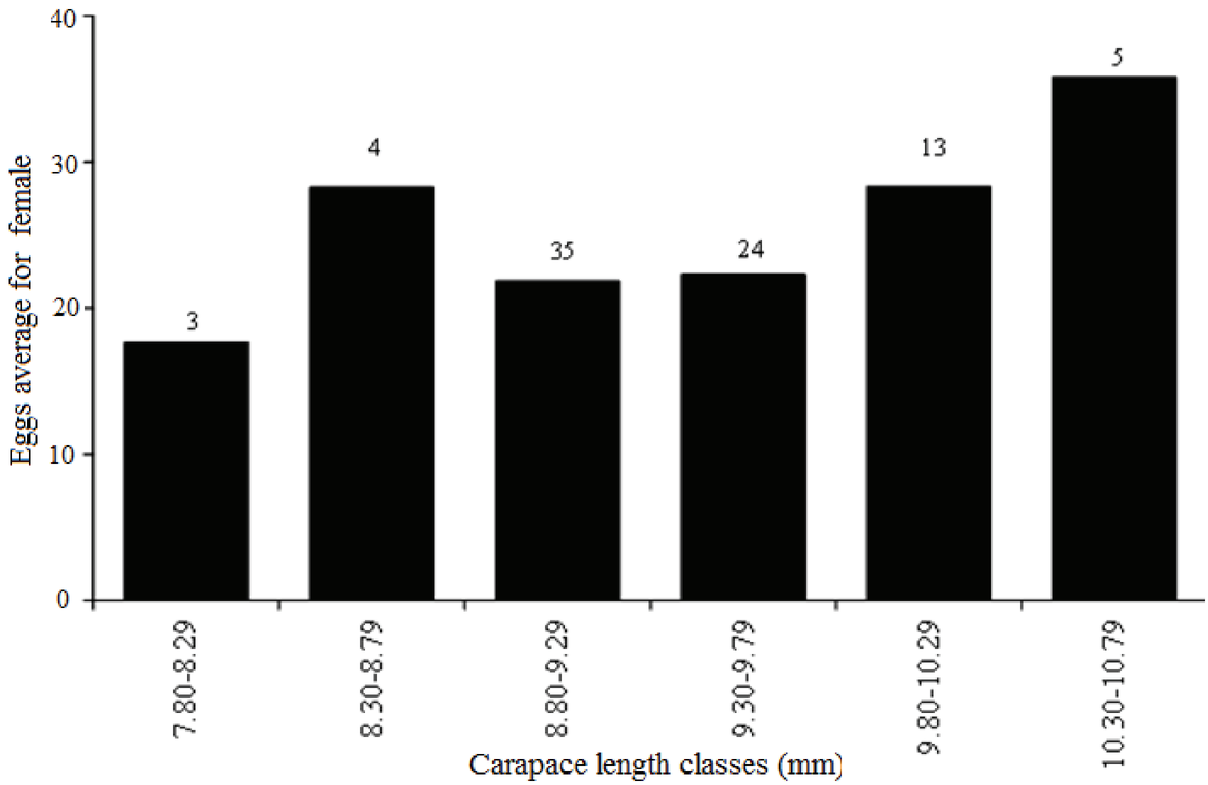

Figure 4. *Macrobrachium jelskii*. Mean fecundity of ovigerous females distributed by size classes with range of 0.50 mm, collected from February 2008 to January 2009, in Anhumas stream, Américo Brasiliense (São Paulo State). (numbers above the bars indicate the total number of individuals by class in mm).

The variation in the number of eggs observed in females of the same size class was also noted by Gamba (1997) and the low fecundity registered may be attributed to the loss of eggs during the incubation period, once many females presented few eggs (e.g., 19 females carried less than 10 eggs). According to Ammar et al. (2001), variations in fecundity can be caused either by differences in the size of individuals from different populations or due the performance on energy investment of females during the reproductive process (MAGALHÃES et al., 2012; TAMBURUS et al., 2012). For Clarke (1993), a relevant fact to be considered is the small size of females limiting their physiological and morphological capacity. This condition may affect the spawning, by producing fewer eggs in function of reduced ovarian size and the restricted area in the abdomen chamber for egg incubation.

Newly spawned eggs had orange coloration as also observed by Paiva and Barreto (1960) and differently from Gamba (1997) that found bright green eggs at initial stage. Despite this variation, all authors found whitish eggs in the final developmental stage, probably due to the consumption of vitellus by the embryo. Paiva and Barreto (1960) reported the presence of eggs in different color patterns (both red and white eggs) in the same individual, suggesting that these eggs were at different stages of development at the same time, but this was not observed in this study.

When checked the amount of studies on *Macrobrachium jelskii* in relation to other species of *Macrobrachium*, it is clear the lack of knowledge on its biology. Comparing the results obtained herein with the few available (GAMBA, 1997; MAGALHÃES, 2000; PAIVA; BARRETO, 1960; BARROS-ALVES et al., 2012), it was noticed that the latitude difference between the study sites can directly interfere with the size of specimens, the reproductive period and other reproductive aspects.

Conclusion

We can infer that the *M. jelskii* population in the central area of São Paulo State is well-established, mainly in terms of incorporation and dispersion rates of individuals. In the past years, freshwater ecosystems conditions have been changed in the Brazilian land due different reasons and consequently some species and populations are in risk of dismissing or close to the extinction (see MAGRIS et al., 2010). In this sense, studies on inland prawns aiming to assist in the comprehension of biological and population aspects, as made here on *M. jelskii*, are important and can be used as comparative parameters and indicative for tracking changes in environmental quality of their habitats (CUMBERLIDGE et al., 2009). This scenario is predictable in the study region (MANTELATTO; BARBOSA, 2005), where the water quality are subjected to be impaired by the sugar cane culture (planting, maintenance and harvesting), near the stream under study.

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