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ORIGINAL ARTICLE

# Population structure and fecundity of *Macrobrachium jelskii* (Miers, 1877) (Decapoda, Palaemonidae) on the Batateiras River, sub-basin of the Salgado River, in southern Ceará, Brazil

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## ABSTRACT

The freshwater prawn *Macrobrachium jelskii* (Miers, 1877) is a species with wide geographical distribution. However, the biological and ecological aspects of this species are poorly studied. Thus, the present study was carried out in Batateiras River, at the municipality of Juazeiro do Norte, located in the south of Ceará, in the semiarid region of northeastern Brazil. Samples were carried out monthly between January and December 2013, along the river margins. A total of 628 *M. jelskii* specimens were collected, 347 males and 281 females. The overall sex ratio was 1:0.81 (M:F). In relation to the carapace length, males reached sexual maturity at 5.1 mm while females reached morphological sexual maturity at 7.1 mm. Females were morphometrically larger than males, with means of 7.04 mm (± 1.61) and 5.97 mm (± 0.78), respectively. The ovigerous females were more frequent in the rainy season. Female fecundity showed a positive correlation with growth. Thus, our results report previously unknown information about *M. jelskii* for a semiarid region of northeastern Brazil.

## KEYWORDS

Freshwater prawn, semiarid region, sex ratio, sexual dimorphism

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## Introduction

The genus *Macrobrachium* Spence Bate, 1868 is the most representative of the Palaemonidae, with approximately 250 species distributed worldwide (De Grave and Fransen, 2011), and 19 registered for Brazil (Melo, 2003; Dos Santos *et al.*, 2013; Mantelatto *et al.*, 2016). *Macrobrachium jelskii* (Miers, 1877) is endemic to South America, with wide geographic distribution in Brazil (Melo, 2003; Magalhães *et al.*, 2005; Pileggi *et al.*, 2013; Vera-Silva *et al.*, 2016), and with a biological cycle restricted to freshwater (Melo, 2003).

Among its congeners, *M. jelskii* is characterized by a small morphometric dimension with small chelipeds (Holthuis, 1952), and, being easily found in macrophyte beds (Melo, 2003; Montoya, 2003), occurs mainly in the northern and northeast regions of Brazil (Pileggi *et al.*, 2013), inhabiting dark waters with little marginal vegetation and muddy substrate (Melo, 2003; Montoya, 2003).

Despite its geographical distribution *M. jelskii* is still poorly studied. However, aspects of its population and reproductive biology (Barros-Alves *et al.*, 2012; Lima *et al.*, 2013; Mossolin *et al.*, 2013; Soares *et al.*, 2015; Rocha and Barbosa, 2017), length/weight relationship (Taddei *et al.*, 2017a), fecundity (Nery *et al.*, 2015), larval development (Magalhães, 2000; Rocha *et al.*, 2016), microhabitat preferences (Silva *et al.*, 2019a), ecological responses (Lucena *et al.*, 2020), and evolutionary aspects of species sexual dimorphism (Nascimento *et al.*, 2020), have recently been done. However, little is still known about *M. jelskii* in the northeastern semiarid, with only three recent publications (Nery *et al.*, 2015; Lucena *et al.*, 2020; Nascimento *et al.*, 2020).

Thus, the present study reports new information about the population structure and fecundity of *M. jelskii* from the northeastern semiarid region, also indicating how the species is adjusted to the local conditions, and reports important information that may support future research and the species conservation in the Brazilian semiarid.

## Material and Methods

The specimens were collected in macrophyte beds in the riparian zone of Batateiras River (7°9'26.55"S 39°16'53.35"W), in the municipality of Juazeiro do Norte, Ceará, in the semiarid region of northeastern Brazil (Fig. 1). The sampling was carried out monthly from January to December 2013. Sieves with a diameter of 50 cm and mesh opening of 2 mm were used. The sampling procedure was carried out during the daylight, by two researchers for 30 minutes. The collected specimens were stored in crushed ice in an insulated box and transported to the Laboratório de Crustáceos do Semiárido (LACRUSE) of the Universidade Regional do Cariri (URCA). Water temperature was obtained using a digital thermo-hygrometer and the rainfall data was obtained from the Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME, 2019).

At the laboratory, specimens were identified to the species level using dichotomous keys and specialized literature (Collins, 2000; Melo, 2003; Vera-Silva *et al.*, 2017). The sex was determined by the presence of the male appendix on the second pair of pleopods (Mantelatto and Barbosa, 2005). The carapace length (CL) was measured using a digital caliper with an accuracy of 0.01 mm from the inner margin of the eye orbit to the posterior margin of the carapace.

The normal distribution and homoscedasticity were tested using the Shapiro-Wilk and Levene's tests, respectively (Sokal and Rohlf, 1995). Thus, the inferential statistical tests were performed according to the nature of the data.

The population structure was obtained from the absolute frequency of males and females by sampling effort. Chi-square test ($\chi^2$) was used for statistical inference of sex ratio during the study period and at each sample effort. A Spearman correlation test between *M. jelskii* abundance and abiotic data obtained in each sample was performed.

To estimate the size at sexual maturity of *M. jelskii*, male and female specimens were grouped into juveniles and adults, using the "classify_mature" function of the "sizeMate" package (Torrejon-Magallanes, 2019) in software R (R Development Core Team, 2019). Then, the size at sexual maturity ($L_{50}$) was estimated separately for males and females, using the function "morph_mature" from the package "sizeMate" (Torrejon-Magallanes, 2019) in software R.

Sturges' rule ($K = 1 + 3.322 * logN$) was used to obtain the size classes for CL (Sturges, 1926).

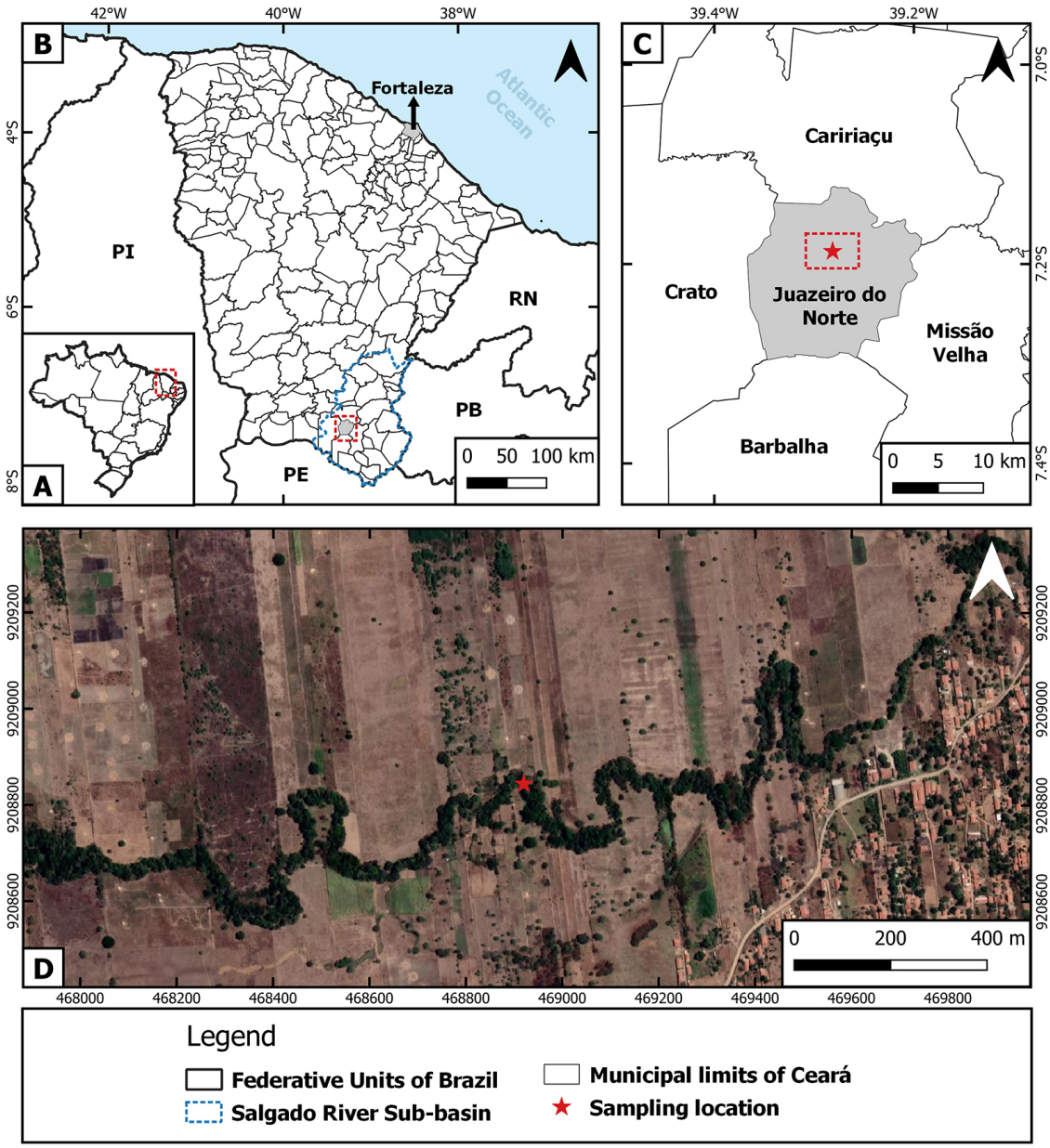


**Figure 1.** (**A**) Brazil delimitation; (**B**) Ceará delimitation; (**C**) sampling location of *Macrobrachium jelskii* (Miers, 1877) in municipality of Juazeiro do Norte; River (**D**) sampling location of *Macrobrachium jelskii* (Miers, 1877) in the Batateiras River.

Then, the groups of juvenile males (JM), adult males (AM), juvenile females (JF), and adult females (AF), were allocated into the groups and analyzed in each class by Chi-square test. Mann-Whitney U-test was used to analyze the morphometric difference between sexes for CL values (Sokal and Rohlf, 1995).

The reproductive period was determined by the absolute frequency of ovigerous females (OF) during the months sampled. The egg mass of each female was totally removed to determine the mean number of eggs per female for the population studied. The relationship between number of eggs and carapace length was determined by the coefficient of determination ($R^2$) from linear regression where number of eggs is the depend variable and CL the independent variable.

All analyses were performed using R software (R Development Core Team, 2019). The significance level was 5 % (Zar, 2010). All specimens used in this study are deposited in the carcinological collection of Laboratório de Crustáceos do Semiárido (LACRUSE) of Universidade Regional do Cariri (URCA).

## Results

The mean monthly rainfall during the year was 90 mm (± 88.37 mm). The greatest precipitation values were observed in the first six months of 2013, and the highest precipitation was in March (293 mm) (Fig. 2). The temperature ranged from 26 °C to 34 °C, with a mean of 29.98 °C (± 2.77 °C).

A total of 628 *Macrobrachium jelskii* were collected, 347 males and 281 females, of which 26 were ovigerous (Fig. 2). Sex ratio was 1:0.81 (M:F), differing from the expected 1:1 ($\chi^2 = 6.9363$; $P < 0.05$). There were no significant differences in the sex ratio for *M. jelskii* in eight of the twelve samplings, and the exact 1:1 sex ratio was observed in December 2013 (Tab. 1). The highest male abundance was observed between January and June (Fig. 2). Furthermore, males showed a positive correlation between abundance and the rainfall values ($t = 3.2181$, $df = 10$, $R^2 = 0.71$; $P < 0.05$). However, the same was not observed for females ($P > 0.05$).

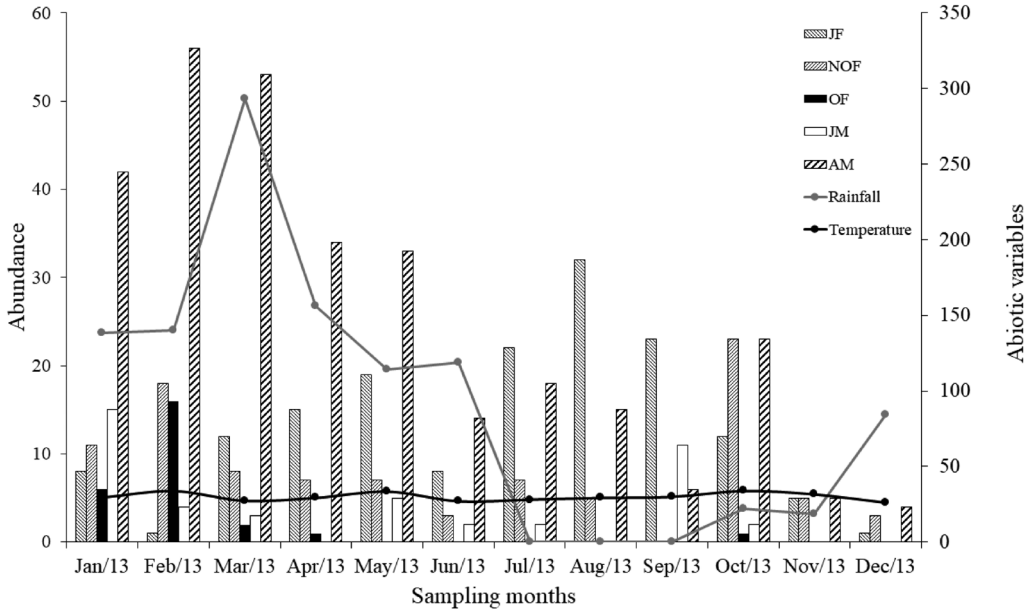


**Figure 2.** *Macrobrachium jelskii* (Miers, 1877). Values of temperature, rainfall and absolute frequency of juvenile males (JM), adult males (AM), juvenile females (JF), non-ovigerous females (NOF) and ovigerous females (OF) throughout the study period.

**Table 1.** *Macrobrachium jelskii* (Miers, 1877). Sampling and total number of males (M), females (F) and sex ratio (M:F), with Chi-square values ($\chi^2$) and probability ($P$).

| Month | M | F | M:F | $\chi^2$ | $P$ |
|---|---|---|---|---|---|
| Jan/13 | 57 | 25 | 1:0.44 | 12.48 | <0.01 |
| Feb/13 | 60 | 35 | 1:0.58 | 6.57 | <0.01 |
| Mar/13 | 56 | 22 | 1:0.39 | 14.82 | <0.01 |
| Apr/13 | 34 | 23 | 1:0.68 | 2.12 | 0.145 |
| May/13 | 38 | 26 | 1:0.68 | 2.25 | 0.133 |
| Jun/13 | 16 | 11 | 1:0.69 | 0.92 | 0.335 |
| Jul/13 | 20 | 29 | 1:1.45 | 1.63 | 0.198 |
| Aug/13 | 15 | 37 | 1:2.47 | 9.30 | <0.01 |
| Sep/13 | 17 | 23 | 1:1.35 | 0.9 | 0.342 |
| Oct/13 | 25 | 36 | 1:1.44 | 1.98 | 0.159 |
| Nov/13 | 5 | 10 | 1:2 | 1.66 | 0.196 |
| Dec/13 | 4 | 4 | 1:1 | 0 | 1 |
| Total | 347 | 281 | 1:0.81 | 6.93 | <0.01 |

The CL ranged from 3.10 mm to 8.34 mm (5.97 ± 0.78) for males and from 3.11 mm to 11.81 (7.04 ± 1.61) for females. This result shows sexual dimorphism in this population, with females presenting larger absolute and relative sizes ($U$ = 68704; $P$ < 0.05). In addition, morphological maturity for males was estimated at 5.1 mm (Confidence intervals = 5.0 – 5.2; $R^2$ = 0.74) (Fig. 3A), while for females the size of first morphological maturity was 7.1 mm (Confidence intervals = 7.1 – 7.2; $R^2$ = 0.98) (Fig. 3B).

Eleven size classes with an amplitude of 0.8 mm were obtained. JM were allocated only in the first three size classes, while JF were observed in the first five size classes. In addition, AM were allocated only in five size classes, being absent in the four largest classes. AF were dominant in the last six size classes, showing that they reach greater absolute sizes in relation to males (Tab. 2).

Ovigerous females of *M. jelskii* were found from January to April and August 2013, with a peak in February (Fig. 2). The CL ranged from 7.41 mm to 10.13 mm (8.52 ± 0.66 mm), mean fecundity was 18 eggs per female, ranging from 8 to 26 eggs, with a positive relationship between the total number of eggs and female growth ($R^2$ = 0.23; $df$ = 1; $F$ = 821.6; $P$ <0.05) (Fig. 4).

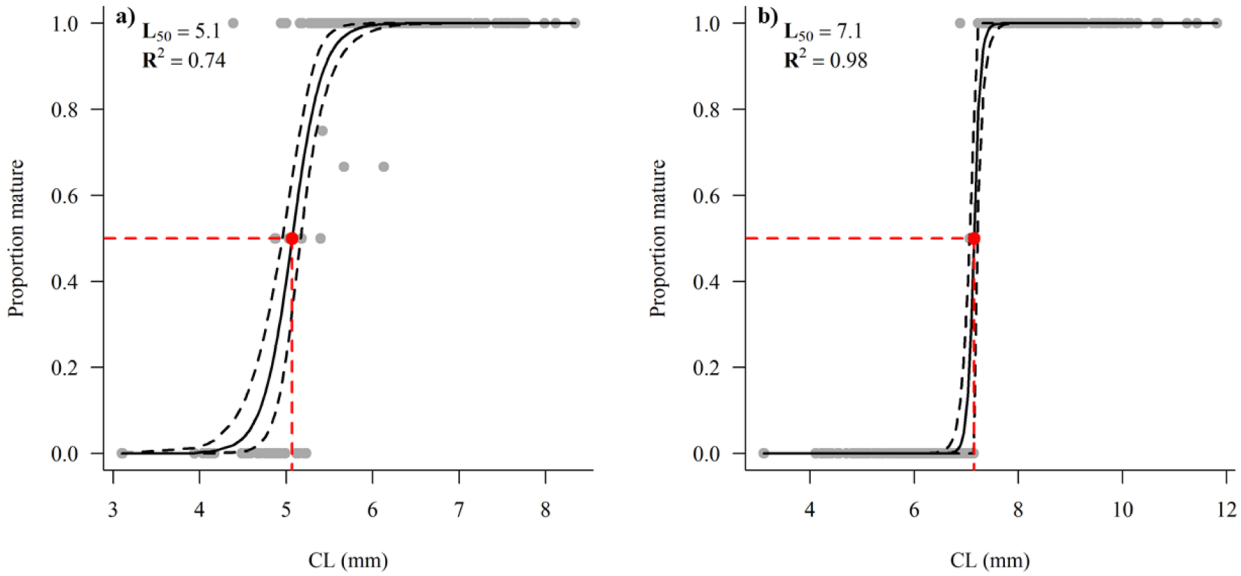


**Figure 3.** *Macrobrachium jelskii* (Miers, 1877). (**A**) Size at morphological sexual maturity for males; (**B**) size at morphological sexual maturity for females.

**Table 2.** *Macrobrachium jelskii* (Miers, 1877). Number of juvenile males (JM), adult males (AM), total males (M), juvenile females (JF), adult females (AF), total females (F) and sex ratio for each group (JM:JF, AM:AF, M:F), along the classes size, with Chi-square values ($\chi 2$) and probability ($P$).

| | Juveniles | | | | | Adults | | | | | Total | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Classes | JM | JF | JM:JF | $\chi^2$ | $P$ | AM | AF | AM:AF | $\chi^2$ | $P$ | M | F | M:F | $\chi^2$ | $P$ |
| 3.1–\|3.9 | 2 | 2 | 1:1 | 0 | 1 | 0 | 0 | - | - | - | 2 | 2 | 1:1 | 0 | 1 |
| 3.9–\|4.7 | 18 | 14 | 1:0.78 | 0.5 | 0.47 | 0 | 0 | - | - | - | 18 | 14 | 1:0.78 | 0.5 | 0.47 |
| 4.7–\|5.5 | 24 | 27 | 1:1.13 | 0.17 | 0.67 | 40 | 0 | 40:0 | 40 | <0.05 | 64 | 27 | 1:0.42 | 15.04 | <0.05 |
| 5.5–\|6.3 | 0 | 68 | 0:68 | 68 | <0.05 | 147 | 0 | 147:0 | 147 | <0.05 | 147 | 68 | 1:0.46 | 29.02 | <0.05 |
| 6.3–\|7.1 | 0 | 47 | 0:47 | 47 | <0.05 | 93 | 0 | 93:0 | 93 | <0.05 | 93 | 47 | 1:0.51 | 15.11 | <0.05 |
| 7.1–\|7.9 | 0 | 0 | - | - | - | 20 | 31 | 1:1.55 | 2.37 | 0.12 | 20 | 31 | 1:1.55 | 2.37 | 0.12 |
| 7.9–\|8.7 | 0 | 0 | - | - | - | 3 | 44 | 1:14.67 | 35.76 | <0.05 | 3 | 44 | 1:14.67 | 35.76 | <0.05 |
| 8.7–\|9.5 | 0 | 0 | - | - | - | 0 | 24 | 0:24 | 24 | <0.05 | 0 | 24 | 0:24 | 24 | <0.05 |
| 9.5–\|10.3 | 0 | 0 | - | - | - | 0 | 18 | 0:18 | 18 | <0.05 | 0 | 18 | 0:18 | 18 | <0.05 |
| 10.3–\|11.1 | 0 | 0 | - | - | - | 0 | 3 | 0:3 | 3 | 0.08 | 0 | 3 | 0:3 | 3 | 0.08 |
| 11.1–\|11.9 | 0 | 0 | - | - | - | 0 | 3 | 0:3 | 3 | 0.08 | 0 | 3 | 0:3 | 3 | 0.08 |

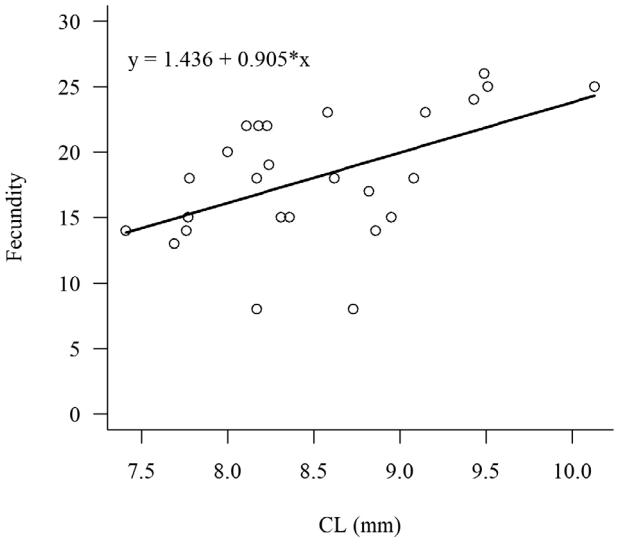


**Figure 4.** *Macrobrachium jelskii* (Miers, 1877). Relationship between the maximum number of eggs from each female (fecundity) and the carapace length (CL).

## Discussion

The Batateiras River is a typical Brazilian semiarid region river, with concentrated rainfall in the first months of the year and low annual rainfall. The sex ratio of *M. jelskii* from the Batateiras River deviated from 1:1 for males, although the sex ratio was similar in most months. In addition, males were positively correlated with the rainfall period, being more abundant in the rainy months. Regarding morphometry, males reach their first sexual maturity before females. The species exhibits sexual size dimorphism with larger females, with ovigerous females occupying larger size classes. The reproductive period was observed in the rainy season, with a main peak in February, and a positive correlation between the number of eggs carried by females and the size of their carapace (Fig. 4).

Variation in the expected sex ratio of 1:1 is common among crustaceans (Wenner, 1972). However, the male bias observed seems to be uncommon among *Macrobrachium* species, where the sex ratio is frequently female biased, as observed by Silva *et al.* (2019b) (1M:2.21F) and Taddei *et al.* (2017b) (1M:2.36F) in *M. amazonicum* (Heller, 1862), by Ji and Deekae (2016) (1M:2.35F) in *M. felicinum* (Holthuis, 1949), by Mossolin and Bueno (2002) (1M:4.3F) in *M. olfersi* (Wiegmann, 1836), and by Mantelatto and Barbosa (2005) (1M:2.6F) in *M. brasiliense* (Heller, 1862).

In *M. jelskii*, Barros-Alves *et al.* (2012) observed a sex ratio of 1M:1.48F in Minas Gerais, Brazil; Rocha and Barbosa (2017) and Silva *et al.* (2019a) in separate populations from Bahia, Brazil, observed a sex ratio of 1M:1.4F and 1M:1.04F, respectively; and Mossolin *et al.* (2013) also observed the female biased sex ratio (1M:1.08F) in São Paulo, Brazil, but without statistical significance. Soares *et al.* (2015) observed a biased proportion for females (1M:1.76F) upstream of the Três Marias Dam, Minas Gerais, Brazil, however, the sex ratio downstream was 1M:0.75F. These latter authors attributed these results to a preference for females to seek refuge in marginal vegetation, abundant downstream of the dam (Soares *et al.*, 2015).

The higher abundance of *M. jelskii* males in our results may be related to their reproductive biology, especially in the rainy months. If males exhibit the "pure search" behavior, as proposed by Nascimento *et al.* (2020), they are more active and consequently more exposed in these months, when females are more receptive to mating. In addition, females, especially when ovigerous, use macrophytes from marginal areas as a refuge (Montoya, 2003; Soares *et al.*, 2015), reducing their capture probability. Finally, a similar pattern for sex ratio in *M. jelskii* was observed by Lucena *et al.* (2020), in a reservoir in the semiarid region of southern Ceará. These results indicate that females search for refuge in macrophytes in semiarid ecosystems, however further research is needed to analyze whether this pattern can be repeated in other populations of *M. jelskii* in the Brazilian semiarid.

The results obtained for first morphological sexual maturity in males and females of *M. jelskii* are previously unreported. However, Pantaleão *et al.* (2012) reported a similar pattern for a continental population of *M. amazonicum*, where males also reached morphological sexual maturity in smaller sizes than observed for females. Sexual maturity is associated with the reproductive strategy of each sex (Shine, 1988). In *M. jelskii*, males probably exhibit "pure search" behavior with no need for a large body size and may reach sexual maturity at smaller sizes. The females of *M. jelskii*, on the other hand, probably prioritize a larger body size (Nascimento *et al.*, 2020), since an increase in fertility is directly related to growth of the body, as observed in our results and by other authors (Nery *et al.*, 2015; Soares *et al.*, 2015).

The sexual size dimorphism found in the present study, where females are morphometrically larger than males, is widely known for *M. jelskii* (Barros-Alves *et al.*, 2012; Rocha and Barbosa, 2017; Taddei *et al.*, 2017a; Silva *et al.*, 2019a; Nascimento *et al.*, 2020). This pattern can be explained by the evolution of reproductive strategies for *M. jeslkii*. Probably, the selection of female fecundity is associated with the strategy of "pure search" by males of these species (Nascimento *et al.*, 2020). Corroborating our results of sexual size dimorphism and morphological sexual maturity, we can highlight the absence of males in the largest size classes for the population studied, as well as the greater abundance of ovigerous females in the largest size classes. This is demonstrated by the female dominance in these classes, a pattern well recorded in *M. jelskii* (Barros-Alves *et al.*, 2012; Rocha and Barbosa, 2017; Taddei *et al.*, 2017a).

The reproductive period for the population of *M. jelskii* in the Batateiras River is probably continuous, due to the presence of ovigerous females in the dry period, with reproductive peaks in the period of greatest rainfall. Corroborating our results, continuous seasonal reproduction has been reported for *M. jelskii* in other studies, where the reproductive peak is associated with higher precipitation (Barro-Alves *et al.*, 2012; Mossolin *et al.*, 2013; Soares *et al.*, 2015; Mossolin *et al.*, 2013). Additionally, a positive correlation was observed between the number of eggs and the growth of females, indicating that their fecundity increases with body size. This pattern is very common for *M. jelskii* (Nery *et al.*, 2015; Mossolin *et al.*, 2013; Soares *et al.*, 2015), and can be explained by the evolution of reproductive strategies in this species, favoring the selection of female fecundity.

However, this pattern can be directly influenced by the environment, such as the ecological adjustment of the species to freshwater ecosystems, variation in environmental conditions, stress, lack of resources or predation (Silva *et al.*, 2019b). Therefore, the low average fecundity observed for the studied population seems to be a pattern for females of *M. jelskii* in the semiarid region of southern Ceará, corroborating what was previously observed by Nery *et al.* (2015).

The semiarid conditions of northeastern Brazil are frequently assumed to be extreme for the survival of many aquatic species. However, more detailed studies on such organisms may reveal ecological adjustments and patterns that refute such assumptions. In conclusion, the growth patterns, size, and sexual dimorphism of *M. jelskii* did not change in response to conditions in the semiarid region, however, as observed by (Nery *et al.*, 2015), low fertility was observed. The low frequency of ovigerous females during the study may be related to the lack of resources, however, additional studies are necessary. Finally, the present study shows unreported results on first morphological sexual maturity for this species, where males reach sexual maturity at a smaller size than females. Thus, this research brings previously unknown information about the population structure of *M. jelskii* for the Northeastern semiarid region, with new information on sexual maturity of this species.

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