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Population biology of shrimp *Macrobrachium jelskii* (Miers, 1778) (Decapoda, Palaemonoidea) at the Grande River at northwest of the state of Minas Gerais, Brazil

Biologia populacional do camarão *Macrobrachium jelskii* (Miers, 1778) (Decapoda, Palaemonoidea) no Rio Grande no noroeste do estado de Minas Gerais, Brasil

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Abstract: Aim: The population biology of the freshwater shrimp *Macrobrachium jelskii* was investigated here emphasizing the length-frequency distribution, sex ratio, reproductive period and juvenile recruitment. In addition, the abundance of individuals was correlated with the abiotic factors. **Methods:** Samples were collected on a monthly basis from July 2005 to June 2007 along the river margin in shallow water of Grande River, at Planura region, State of Minas Gerais, Brazil (20° 09' S and 48° 40' W), using a trawl net (1.0 mm mesh size, and 2.0 m × 0.5 m wide). The fishing gear was handled by two people along the marginal vegetation of the Grande River in a course of 100 m, covered for one hour. In the laboratory, the specimens were identified, measured and sexed. **Results:** A total of 2,789 specimens was analyzed, which corresponded to 1,126 males (549 juveniles and 577 adults) and 1,663 females (1,093 juveniles, 423 adults non-ovigerous and 147 ovigerous). The sex ratio differed significantly in favor of the females of *M. jelskii* (1:1.48; $\chi^2 = 103.95$; $p < 0.0001$). The mean size of carapace length (CL) of females (6.32 ± 1.84 mm CL) was statistically higher than of males (5.50 ± 1.07 mm CL) ($p < 0.001$). The length-frequency distribution of the specimens revealed an unimodal pattern and non-normal distribution for males and females ($W = 0.945$; $p < 0.01$). No significant relationship between the abundance of *M. jelskii* and the environmental variables was observed ($p = 0.799$). **Conclusion:** The presence of ovigerous females and juveniles in the population suggests a continuous reproduction pattern and recruitment for *M. jelskii* at Planura region.

Keywords: Caridea, distribution, juvenile recruitment, reproductive period, sex ratio.

Resumo: Objetivo: A biologia populacional do camarão de água doce *Macrobrachium jelskii* foi investigada, com ênfase na distribuição de frequência em classes de tamanho, razão sexual, período reprodutivo e recrutamento juvenil. Além disso, a abundância dos indivíduos foi correlacionada com os fatores abióticos. **Métodos:** Amostras foram coletadas mensalmente de julho de 2005 a junho de 2007, às margens do Rio Grande, região de Planura, estado de Minas Gerais, Brasil (20° 09' S e 48° 40' W), usando uma rede de arrasto (1.0 mm tamanho da malha e 2.0 × 0.5 m de largura). O equipamento foi arrastado por duas pessoas às margens da vegetação do rio por 100 metros de distância, percorridos por uma hora. Em laboratório, os espécimes foram identificados, mensurados e sexados. **Resultados:** Um total de 2,789 espécimes foi analisado, no qual correspondem a 1,126 machos (549 jovens e 577 adultos) e 1,663 fêmeas (1,093 jovens, 423 adultos não ovígeras e 147 ovígeras). A razão sexual diferiu significativamente a favor de fêmeas de *M. jelskii* (1:1.48; $\chi^2 = 103.95$; $p < 0.0001$). A média de tamanho do comprimento da carapaça (CL) das fêmeas (6.32 ± 1.84 mm CL) foi estatisticamente maior do que dos machos (5.50 ± 1.07 mm CL) ($p < 0.001$). A distribuição de freqüência em classes de

tamanho dos espécimes revela um padrão de distribuição unimodal e não normal para machos e fêmeas (W = 0.945; $p < 0.01$). Não foi observada relação entre a abundância de *M. jelskii* e as variáveis ambientais (p = 0.799). **Conclusão:** A presença de fêmeas ovígeras e jovens na população sugere um padrão de reprodução e recrutamento contínuos para *M. jelskii* na região de Planura.

Palavras-chave: Caridea, distribuição, recrutamento juvenil, período reprodutivo, razão sexual.

1. Introduction

Approximately 210 species of genus *Macrobrachium* Bate, 1868 are known all over the world (Short, 2004) 45 of which occur along the American Continent and 18 on the Brazilian coastline (Valenti, 1985; Melo, 2003; Mantelatto and Barbosa, 2005). These shrimps are widely distributed in the tropical and subtropical regions and in freshwater and estuarine ecosystems (Pereira et al., 2002), and they have great economic importance for human consumption and aquaculture (Valenti, 1985).

Studies conducted in Brazil with *Macrobrachium acanthurus* (Wiegmann, 1836), *Macrobrachium amazonicum* (Heller, 1862) and *Macrobrachium carcinus* (Linnaeus, 1758), aimed the development of new technologies of cultivation of the species (Valenti, 2002). However, additional investigations about the occurrence, life cycle, growth, reproduction and habitat preference can improve the knowledge of these new technologies, allowing an adequate cultivation of this and other species.

Among the freshwater shrimps, *Macrobrachium jelskii* (Miers, 1778) occurs in shallow water characterized by limited marginal vegetation and in association with roots of aquatic plants (Melo, 2003). According to Paiva and Barreto (1960) and Montoya (2003), this particular environment can provide food resources and protection for ovigerous females and for the larval development of *M. jelskii*.

Researches focused on population biology of decapod crustaceans have increased over the last years, since they enable the comprehension of the ecological stability of species, becoming an important tool in studies of different taxonomic groups, contributing therefore for the knowledge of some aspects commonly investigated, such as seasonal variations in population structure, size distribution of individuals, progression of modes in the distributions, sex ratio, recruitment, reproductive period, among others (Hutchinson, 1981).

This study provides information about the population biology of the freshwater shrimp *M. jelskii* in Grande River, at Planura region, State of Minas Gerais, Brazil, with emphasis on the length-frequency distribution, sex ratio, reproductive period and juvenile recruitment. In addition, the abundance of individuals was correlated with the abiotic factors. This information is required in order to understand the biology and ecology of this species, contributing to its preservation, management and conservation.

2. Material and Methods

Monthly samples of *M. jelskii* were collected from July 2005 to June 2007 along the river margin in shallow water of Grande River, at Planura region, State of Minas Gerais , southeastern of Brazil (20° 09' S and 48° 40' W). Due to the previous knowledge of the activity behavior already described for *Macrobrachium* species (Short, 2004), the collections were carried out at night, with a hand-net mesh size 1.0 mm knot-to-knot, 50 cm high and 2 m width. The fishing gear was handled by two people along the marginal vegetation of the Grande River in a course of 100 m, covered for one hour per month. The obtained material was separated on the field and the freshwater shrimps were bagged and maintained in boxes with crushed ice. After this, the material was transferred to labeled jars filled with 70% ethanol until analysis. For each monthly collection, the water temperature was recorded and some other abiotic parameters, such as pH and turbidity were obtained from "Companhia de Água de Minas Gerais (COPASA)" [Minas Gerais Water Supply Company]. Pluviosity data was obtained from "Instituto Nacional de Meteorologia – INMET". The reservoir level was obtained with the administration of the hydroelectric of Porto Colômbia and Marimbondo.

A sub sample (100 g) of *Macrobrachium jelskii* was taken monthly. The freshwater shrimps were sexed, under stereomicroscope, by the presence of

sexual secondary characters on the 2th pair of male pleopod (see Mantelatto and Barbosa, 2005).

The largest carapace length (CLmm), appendix masculinae for males and second pleura length for females were measured at with a vernier caliper or stereomicroscope.

These measures were used, according to K-means analysis, non hierarchical classification procedure, to separate males and females into two groups, juveniles or adults (about K-means, see Sampedro et al., 1999; Corgos and Freire, 2006). In addition, the individuals were grouped into five demographic categories: adult male, juvenile male, adult non-ovigerous female, ovigerous female and juvenile female.

The overall sex ratio of the population, as well as the monthly sex ratio and size classes variation, was compared using the Chi-square test (χ^2) ($\alpha = 0.05$). The comparison of the mean length between males and females from different demographic classes was performed by Mann-Whitney test ($\alpha < 0.05$) (Zar, 2010). Breeding period was accessed by the comparison of proportions between adult non-ovigerous and ovigerous females (Chi square $\alpha = 0.05$) (Zar, 2010).

Normal distributions (modes) were identified and fitted to the monthly frequency distributions through the automatic least-squares method "*Automatic Peak Detection and Fitting*, *Method I – Residuals*", as performed by Pimenta et al. (2005) and Keunecke et al. (2007). The normality of the population size distribution was analyzed by the Shapiro-Wilks test ($\alpha < 0.05$). The recruitment was identified by modes in the first size classes, which indicate the entrance of new recruits into the population (Mattos and Oshiro, 2009). The association of the environmental factors (temperature, pH, pluviosity and turbidity) with the species abundance was evaluated by multiple linear regressions. Data were log-transformed prior to the analysis to improve their normality (Zar, 2010).

3. Results

A total of 2,789 specimens was analyzed in the current study, which corresponded to 1,126 males (549 juveniles and 577 adults) and 1,663 females (1,093 juveniles, 147 ovigerous and 423 adults non-ovigerous).

Size range, mean and standard deviation of the carapace length of individuals measured are reported in Table 1. The mean size of females (6.3 ± 1.8 mm CL) was statistically higher than the mean size of males (5.5 ± 1.1 mm CL) ($U = 733450.5$; $p < 0.001$).

Shrimps were distributed in nine size classes with intervals of 1.0 mm CL, as shown in Table 2. In general, the length-frequency distribution of the specimens revealed an unimodal pattern and a non-normal distribution for males and females ($W = 0.945$; $p < 0.01$). Juveniles males and females presented the largest absolute frequency in the same size class, which corresponded to 4-5 and 5-6 mm CL. Adult males and females showed the largest absolute frequency in the size classes with intervals of 6-7 and 7-8 mm CL, respectively (Table 2).

With regard to the total sex ratio, it was possible to observe significant deviation towards females of *M. jelskii* (Table 2). After analyzing them by size classes, it was observed significant differences at the size classes with intervals of 4-5 and 7-11 mm CL, all in favor of females (Table 2). In the last four size classes there are exclusively adult individuals whereas only juvenile individuals were registered exclusively in the first two size classes (Table 2).

According to the monthly sex ratio, significant differences were observed in several months, mostly in favor of females, as shown in Table 3. No significant monthly deviations at sex ratio were detected in September 2005, February 2006, April 2006, January 2007, April 2007 and May 2007 (Table 3; $p > 0.05$).

According to the monthly variation of the length-frequency distribution of the individuals analyzed, juvenile and adult males and females were registered in almost all months of the year, however, an exception was observed in September 2006 and April 2007, when only juvenile males and females were observed, respectively (Figure 1a, b). From the total of 24 months analyzed, ovigerous females occurred in 15 months, and the highest relative frequency of them was registered in April-May 2006, but there were no significant differences

Table 1. *Macrobrachium jelskii* . Number of individuals (N), minimum (Min), maximum (Max), mean and standard deviation (Mean ± SD) carapace length of sampled specimens during the period from July 2005 to June 2007.

Demographic categories	Carapace length (mm)			
	N	Min	Max	Mean ± SD
Juvenile male	549	3.2	5.6	4.61 ± 0.63
Adult male	577	5.3	9.9	6.34 ± 0.63
Juvenile female	1093	3.2	7.0	5.18 ± 0.86
Adult female	423	6.4	11.2	8.26 ± 1.07
Ovigerous female	147	6.5	11.2	9.21 ± 0.99

Table 2. *Macrobrachium jelskii*. Number of individuals of males (M) and females (F), sex ratio (M:F), chi square test values (χ^2) and probability of significance (*p*) by size classe (mm) of juveniles, adults and total of sampled specimens during the period from July 2005 to June 2007.

Size classe (mm)	Juvenile					Adult					Total				
	M	F	M:F	χ^2	(*p*)	M	F	M:F	χ^2	(*p*)	M	F	M:F	χ^2	(*p*)
3-4	88	74	1:1.18	1.21	ns	0	0	-	-	-	88	74	1:0.84	1.21	ns
4-5	221	325	1:0.68	19.81	<0.0001	0	0	-	-	-	221	325	1:1.47	19.81	<0.0001
5-6	251	423	1:0.59	50.51	<0.0001	128	0	128:0	128.00	<0.0001	379	423	1:1.12	2.41	ns
6-7	0	270	270:0	270.00	<0.0001	340	22	1:0.064	279.34	<0.0001	340	292	1:0.86	3.65	ns
7-8	0	1	0:1	-	ns	85	166	1:1.95	26.13	<0.0001	85	167	1:1.96	26.68	<0.0001
8-9	0	0	-	-	-	10	165	1:16.5	137.28	<0.0001	10	165	1:16.5	137.29	<0.0001
9-10	0	0	-	-	-	3	136	1:45.33	127.25	<0.0001	3	136	1:45.33	127.26	<0.0001
10-11	0	0	-	-	-	0	72	0:72	72.00	<0.0001	0	72	0:72	72.00	<0.0001
11-12	0	0	-	-	-	0	9	0:9	-	ns	0	9	0:9	-	ns
Total	560	1093	1:1.99		<0.0001	566	570	1:0.987	180.22	ns	1126	1663	1:1.48	103.39	<0.0001

ns: non-significant.

Table 3. *Macrobrachium jelskii*. Sex ratio (M:F), chi square test values (χ^2) and probability of significance (*p*) by months of sampled specimens during the period from July 2005 to June 2007.

Months	M:F	χ^2	(*p*)
July/05	1:2.40	20.18	<0.0001
Aug./05	1:2.00	5.67	0.0173
Sept./05	1:1.39	3.28	ns
Oct./05	1:2.05	21.36	<0.0001
Nov./05	1:1.33	5.92	0.015
Dec./05	1:1.44	7.60	0.0058
Jan./06	1:0.72	5.37	0.0206
Feb./06	1:1.37	2.04	ns
Mar./06	1:2.64	10.37	0.0013
Apr./06	1:0.64	0.89	ns
May/06	1:2.35	16.96	<0.0001
June/06	1:2.18	24.14	<0.0001
July/06	1:2.14	23.60	<0.0001
Aug./06	1:1.80	5.71	0.0168
Sept./06	1:1.45	8.13	0.0043
Oct./06	1:2.31	28.16	<0.0001
Nov./06	1:2.29	14.09	0.0002
Dec./06	1:0.44	5.44	0.0196
Jan./07	1:0.50	2.00	ns
Feb./07	1:0.50	4.67	0.0308
Mar./07	1:0.71	3.98	0.0461
Apr./07	1:0.67	-	ns
May/07	1:0.88	0.26	ns
June/07	1:1.76	7.19	0.0073

ns: non-significant.

($p > 0.05$) when compared to the abundance of non-ovigerous females (Figure 1b).

The recruitment of *M. jelskii* was detected during the entire sampling period according to the presence of modals in the first size classes. In September 2005 and September 2006 was observed the highest abundance of juveniles (Figures 2 and 3). The unimodal pattern observed for the species, bimodalities were also identified in some months, as shown in Figures 2 and 3.

With respect to environmental parameters, the water average temperature over the entire study period at Grande River was 25.5 °C, not reaching values lower than 21.0 °C. The average turbidity average was 8.2 ± 2.90. The pH remained constant during the study period, near 7.0. The average pluviosity over the entire study period was 141.30 mm, reaching 320 mm. However, no significant relationship between the abundance of *M. jelskii* and the environmental variables (Abundance × Temperature, Abundance × Turbidity, Abundance × Pluviosity and Abundance × pH) was observed (p = 0.799).

4. Discussion

The unimodal pattern observed in the current length-frequency distributions of *M. jelskii* is a common pattern among tropical crustaceans, as a result of continuous reproduction, recruitment, migration, and mortality (Díaz and Conde, 1989), while the bimodal pattern reflects seasonality in reproductive and recruitment events (Tsuchida and Watanabe, 1997). Similar results were obtained by Soares et al. (2009) for the same species in a study conducted at Três Marias Dam and São Francisco River. However those authors noticed a unique pattern in the length-frequency distributions for both sexes at Três Marias Dam, categorized as unimodal, and an unimodal pattern for males and a bimodal pattern for females at São Francisco River.

The sex ratio observed in *M. jelskii* at the present study differed from the expected theoretical (1:1), showing predominance of females in the population. This female-biased sex ratio is common

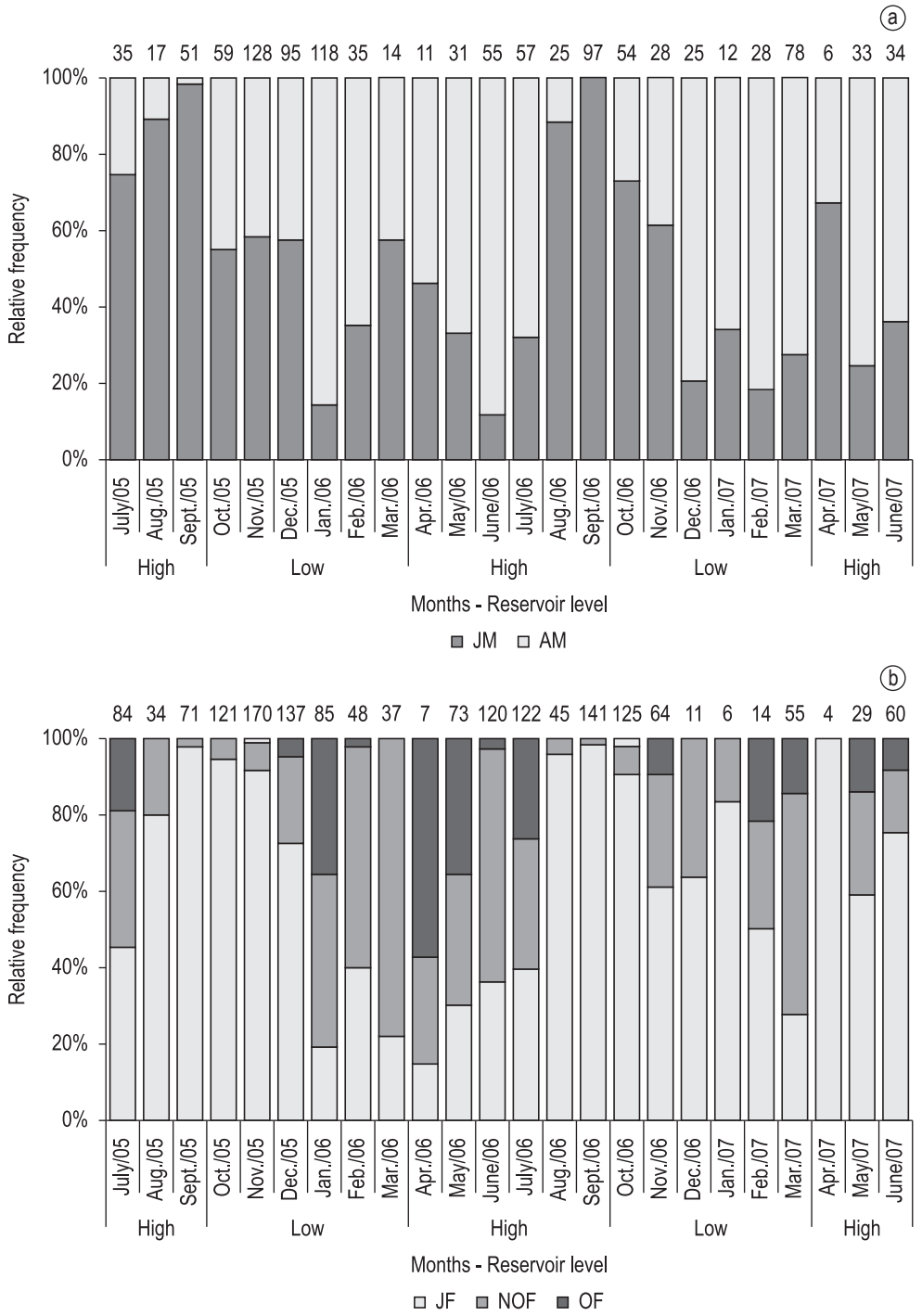

Figure 1. *Macrobrachium jelskii*. Relative frequency distribution by sampled months and data about months reservoir level. a) Males (AM – Adult Male; JM – Juvenile Male); b) Females (OF – Ovigerous Female; NOF – Non-ovigerous Adult Female, JF - Juvenile Female).

in caridean shrimps, mostly in many species of *Macrobrachium*, which can be confirmed in the studies by Román-Contreras and Campos-Lince (1993) for *M. acanthurus*, Montoya (2003) for *M. amazonicum* (Heller, 1862), Fransozo et al. (2004) for *Macrobrachium iheringi* (Ortamann, 1897), and Mantelatto and Barbosa (2005) for *Macrobrachium brasiliense* (Heller, 1862).

In contrast, in some studies deviations at sex ratio were in favor of males, as observed by Mantel and Dundgeon (2005) for *Macrobrachium hainanense* (Parisi, 1919) in Hong Kong streams, and by

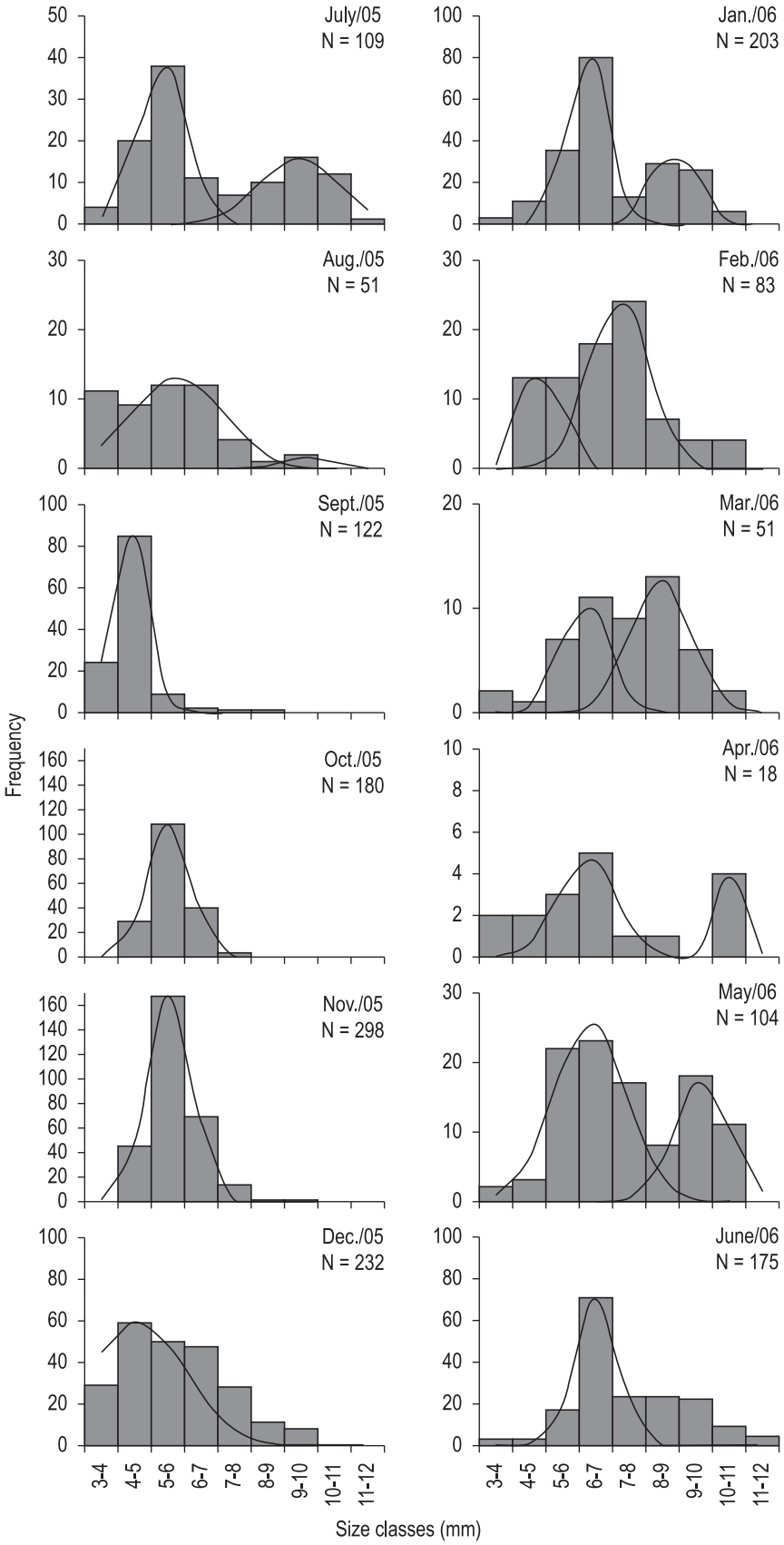

Figure 2. *Macrobrachium jelskii*. Monthly distribution of individuals by size classes, from July 2005 to June 2006.

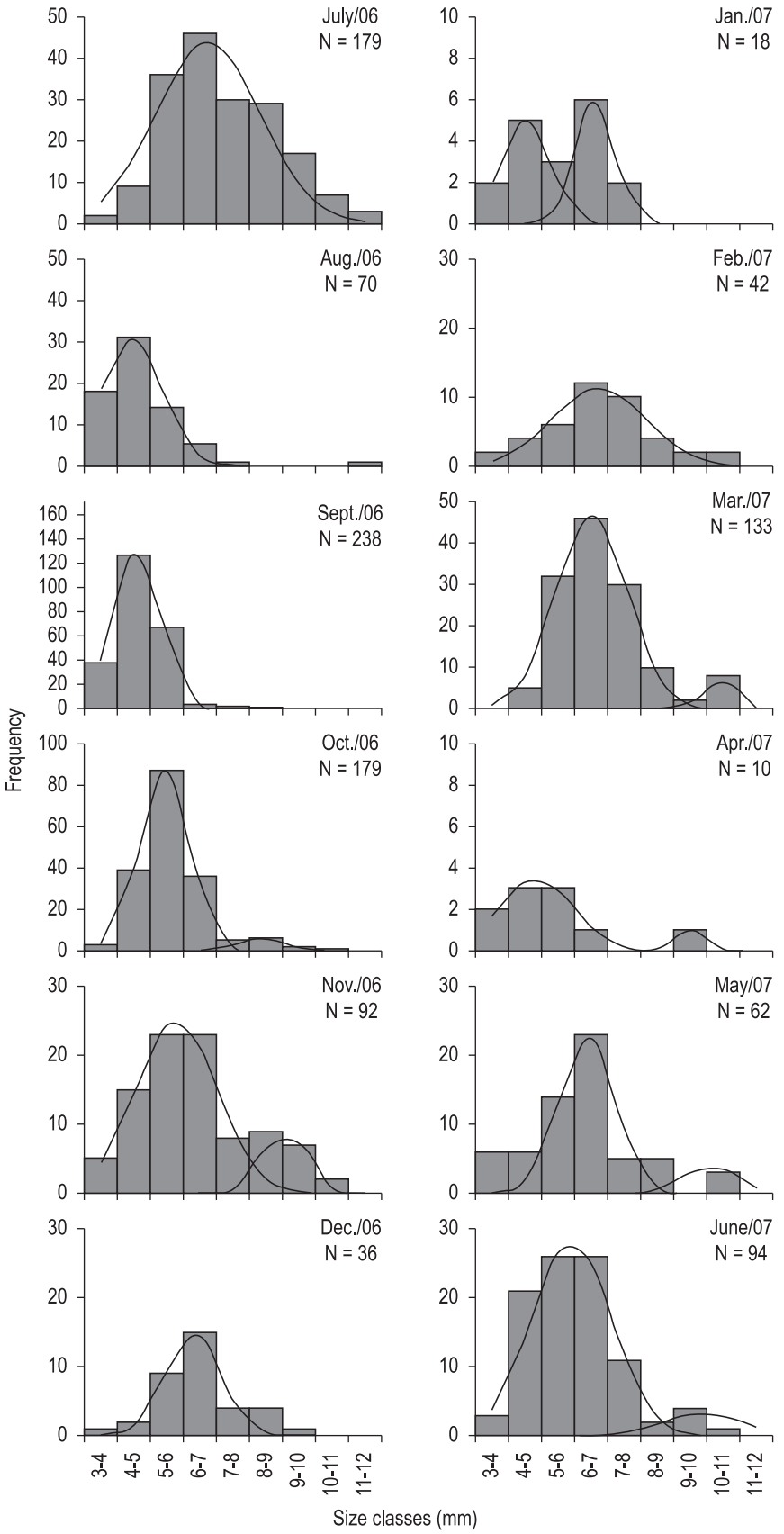

Figure 3. *Macrobrachium jelskii*. Monthly distribution of individuals by size classes, from July 2006 to June 2007.

Soares et al. (2009) for *M. jelskii* in São Francisco River. Moreover, an identical proportion of males and females were also recorded by Mattos and Oshiro (2009) for *Macrobrachium potiuna* (Müller, 1880), in which the sex ratio did not differ from the expected 1:1. According to Wilson and Pianka (1963), deviations in the sex ratio could be a consequence of differences in size, mortality and birth rates between males and females. In addition, other factors may influence these differences, such as molt rates, dispersal, reproduction and migration differential (Botelho et al., 2001).

Among crustaceans it is common for males to reach larger sizes than females, probably in order to ensure mating and success at the intraspecific competition (Gherardi and Micheli, 1989). Nevertheless, in freshwater species the eggs contain great amounts of yolk due to their short development; consequently the females reach larger sizes increasing the cephalothorax region required for development of eggs (Beck and Cowell, 1976; Parker, 1992). This pattern has been confirmed for other caridean shrimps and also for some penaeid shrimps presenting commercial interest, such as *Litopenaeus schmitti* (Burkenroad, 1936), *Farfantepenaeus subtilis* (Pérez-Farfante, 1967), and *Xiphopenaeus kroyeri* (Heller, 1862). On the other hand, there are exceptions, as for *M. brasiliense* studied by Mantelatto and Barbosa (2005) in different region of Brazil, in which males were significantly larger than females. Those variations could be the result of genetic variations among populations and/or different environmental conditions that stimulate or inhibit the differential growth between sexes.

A continuous reproduction pattern was identified for *M. jelskii* at the present study based on the predominance of ovigerous females in almost all the sampling period, as well as continuous recruitment due to the presence of juveniles in all samples analyzed. The continuous reproduction pattern is not a common pattern among freshwater shrimps, being a seasonal reproduction pattern frequently noticed in some species, such as *M. potiuna* and *Potimirim glabra* (Kingsley, 1878) studied, respectively, by Mattos and Oshiro (2009) and Hoffmann and Negreiros-Fransozo (2010), in the Rio de Janeiro and São Paulo states, respectively. However, differences between reproductive periods are probably related to small variations in the climate of the studied region, constituting a limiting factor for the development of females.

With regard to the recruitment, Lima et al. (2006) identified a continuous recruitment for *P. glabra* and *Potimirim potimirim* (Müller, 1881) in a tropical area. The authors suggested that the fact that temperatures remain relatively constant in the tropics may enable such continuous reproduction throughout the year. However, continuous recruitment suggests that both larvae and juveniles of *M. jelskii* can be considered as an important item food for species at higher trophic levels of the food web.

In this study there was no correlation between the abundance of the species and water turbidity, pH, temperature and rainfall, which contradicts the results observed for other species such as *Macrobrachium tenellum* (Smith, 1871) by Román-Contreras (1979) in Tres Palos – Mexico; *M. amazonicum* by Odinetz-Collart and Moreira (1993) in Manaus – Amazônia Central; *M. olfersi* (Wiegmann, 1836) by Mossolin and Bueno (2002), in São Sebastião – São Paulo; and *M. iheringi* by Fransozo et al. (2004) in Botucatu – São Paulo, but other factors could contribute to the abundant variation of the species, such as local vegetation, food availability and water quality. However, these suggestions need to be confirmed in further studies.

In general, this study showed that the population biology of *M. jelskii* in the studied area can be characterized by a continuous reproductive period and therefore, continuous recruitment. However, investigations with emphasis on somatic growth, sexual maturity, and fertility would contribute to a better understand of the potential of *M. jelskii* in aquaculture, as well as for determining capture sizes, supporting the maintenance of natural stocks and sustainable use of this population at the study region.

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