Reproductive biology of the freshwater prawn *Macrobrachium iheringi* (Ortmann, 1897) (Decapoda: Caridea: Palaemonidae) in the Botucatu region, São Paulo, Brazil

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Abstract

The reproductive biology of the freshwater prawn *Macrobrachium iheringi* was investigated with particular emphasis on its spawning period and juvenile recruitment. Prawns were sampled monthly over two years in the "Ribeirão da Hortelã" stream in the region of Botucatu, state of São Paulo, Brazil. Sampling was standardized using capture per unit effort. A total of 1482 individuals were collected over the course of the study. The highest abundance of adult and ovigerous prawns occurred during the warmest months in both years. Multivariate analysis of the seasonal occurrence of (undifferentiated) juvenile prawns showed that they were associated with water temperature and rainfall through the function: $J = 21.09 - 4.95\ T + 0.36\ P$ (J = Juvenile prawns; T = Water temperature; P = Pluviometric index). The beginning of the recruitment period occurred three months after the appearance of the first ovigerous females in the population. Therefore, one can infer that *M. iheringi* breeds seasonally in the study region.

Key words: prawns, *Macrobrachium*, reproduction, recruitment, temperature, precipitation.

Introduction

The genus *Macrobrachium* (Bate, 1868) is of special importance among freshwater shrimps for including species of major scientific and economic interest. Therefore, an understanding of the reproductive periodicity of this group is imperative for the development of management and culture programs, with obvious consequences for species conservation policies.

In general, research on the reproductive biology of *Macrobrachium* focused on species of economic interest, such as *M. carcinus* (Linnaeus, 1758) studied by Lobão *et al.* (1985), Valenti *et al.* (1986), and Grazziani *et al.* (1993), *M. acanthurus* Wiegmann, 1936 studied by Valenti *et al.* (1986, 1989), and Albertoni *et al.* (2002), *M. olfersii* Wiegmann, 1836 by Ammar *et al.* (2001), and Mossolin and Bueno (2002), *M. amazonicum* Heller, 1862 by Scaico (1992), Odinetz-Collart and Magalhães (1994), Bragagnoli and Grotta (1995), and Bialetzki *et al.* (1997), and *M. rosenbergii* De Man, 1979 by Rao (1991), and Ra'anan *et al.* (1991).

The freshwater prawn *Macrobrachium iheringi* Ortman, 1897 is endemic to continental streams and rivers of Brazil, being found in the States of Espírito Santo, Rio de Janeiro, São Paulo, Mato Grosso and Goiás (Melo, 2003). Its type locality is the Tietê river, in the state of São Paulo (Gomes-Corrêa, 1977).

Most previous studies on *M. iheringi* focused on its geographic distribution (Gomes-Corrêa, 1977, Coelho and Ramos-Porto, 1985, and Melo, 2003), ecophysiology (Favaretto, 1993),

agonistic behavior (Volpato and Hoshino, 1984), growth and reproductive period (Lobão *et al.* 1986) and post-embryonic development by Bueno (1981). However, little is known about the temporal pattern of the reproduction of *M. iheringi.*

According to Sastry (1983), there are two main reproductive modes in decapods: the continuous strategy, when spawning occurs at roughly constant levels year round; and the seasonal strategy, when spawning is concentrated in a certain period of the year. In the latter case, there is a close link between reproduction, environmental conditions and food supply, which are fundamental for the survival of larvae and juveniles.

The goal of this paper is to investigate some aspects of the reproductive biology of the freshwater prawn *M. iheringi* such as the pattern of juvenile recruitment, the seasonal variation in fecundity and its ovigerous ratio. Moreover, the relationship between reproductive traits and selected environmental variables were assessed using multivariate methods.

Materials and Methods

The "Ribeirão da Hortelã" is a first order stream, belonging to the basin of the upper Paranapanema river. It is located 880 m above sea level in the municipality of Botucatu, central region of the State of São Paulo (22°57'S and 48°26'W). The bottom of this stream is constituted by sand and mud, and it has around 80% shade cover. Current speed is approximately 0.3 m/s, with a discharge of $0.02m^3/s$. Stream width averaged 1m, with a depth of 0.1 m. Neighbouring vegetation is the typical riparian forest, with some sections being cleared for cattle grazing (Caramashi, 1986).

Prawn samples were collected monthly over a total of two years: from July 1991 to June 1992 (first period) and from July 1993 to June 1994 (second period). The sampling protocol was the capture per unit effort carried out by two collectors early in the morning for 90 minutes over an extension of 200 m. Collectors used a sieve (2 mm mesh diameter) near the stream margin (where there was some aquatic vegetation) in order to obtain both juveniles and adult prawns. Water temperature °C was taken early in the morning in each day of sampling. Average monthly precipitation data for the region of Botucatu were obtained in the website of the Integrated system for the management of hydric resources of the state of São Paulo (http://www.sigrh.sp.gov.br/cgi-bin/bdmh.exe/plu).

All prawns were identified, counted and sexed. Each prawn had its total length measured (TL = linear distance from the tip of the rostrum to the distal margin of the telson) with a vernier caliper (0.1 mm).

Prawns were grouped into the following demographic categories: males, females, ovigerous females and undifferentiated prawns (=juveniles). Prawn sexual differentiation was assessed by the observation of secondary sexual characteristics such as the masculine appendix in the second pleopods of the males and its absence in females and in small prawns (juveniles). This characteristic was observed in individuals larger than 20 mm. Prawns smaller than 200 TL were considered as undifferentiated juveniles.

The reproductive period was determined by the presence of ovigerous females during the sampling period. Similarly, recruitment was assessed by the presence of undifferentiated individuals in the sampled population.

The abundances of juvenile individuals and ovigerous females were compared between the two collection periods using the Student's t test and the Mann-Whitney test ($p < 0.05$). Water temperature and the pluviometric indices between the two sampling periods were compared using Student's t test ($p < 0.05$). Multiple linear regression analysis (Zar, 1999) was performed to evaluate the association between environmental factors (precipitation and water temperature) with the presence of juveniles in the sampled population.

Results

Water temperature and rainfall varied similarly between the two periods, as indicated in figure 1. Highest temperature values were observed from October to March (first period) and from October to April (second period), coinciding with the spring and summer seasons. Lowest temperature values were observed during July (late Fall) and from July to September (Winter) in both years. Highest values of the pluviometric index were observed in February and March (first period) and January and February (second period). The lowest values of the pluviometric index were recorded during the months of June, July and August (first period) and June and July (second period). There was no difference between the mean values of water temperature of the two study periods (*t* test; t = 0.76; d.f. = 22; p = 0.45) and also between the mean values of the pluviometric index (*t* test; t = 0.33; d.f. = 22; p = 0.78).

A total of 1482 specimens were captured, 563 (38%) in the first period and 919 (62%) in the second. The number of specimens obtained in each size class and demographic category are shown in table I. With respect the juvenile prawns, a higher abundance was observed in the second period (*t* test; t = 3.56; d.f. = 22; p = 0.0017). However, no significant difference in the abundance of ovigerous females was observed between both study periods (Mann-Whitney test, U = 130; d.f. = 22; p = 0.257).

An increase in capture rate was recorded during the warmer months (spring and summer), particularly for adult prawns, with a corresponding decrease toward the winter as temperatures dropped (Fig. 2). Ovigerous females were also most common in months with high temperatures (spring and summer). The beginning of the recruitment period was restricted to approximately 3 months after the appearance of the first ovigerous females, i.e. summer and fall (Fig. 3).

A statistically significant relationship was found between juvenile prawn abundance and environmental factors (ANOVA, F = 4.18, d.f. = 23, p = 0.03), which can be described by the following linear equation:

J = 21.09 - 4.95 T + 0.36 P, where:

J = Juvenile prawns (p = 0.008); T = Water temperature (p = 0.01); P = Pluviometric index (p = 0.02).

The total length of the prawns varied from 19.5 to 72 mm in males, from 19.6 to 63.5 mm in females, from 47.4 to 61.5 in ovigerous females and from 8.6 to 19.2 in juvenile prawns.

Males attained larger sizes than females, exceeding their maximum size by 13% (Table II).

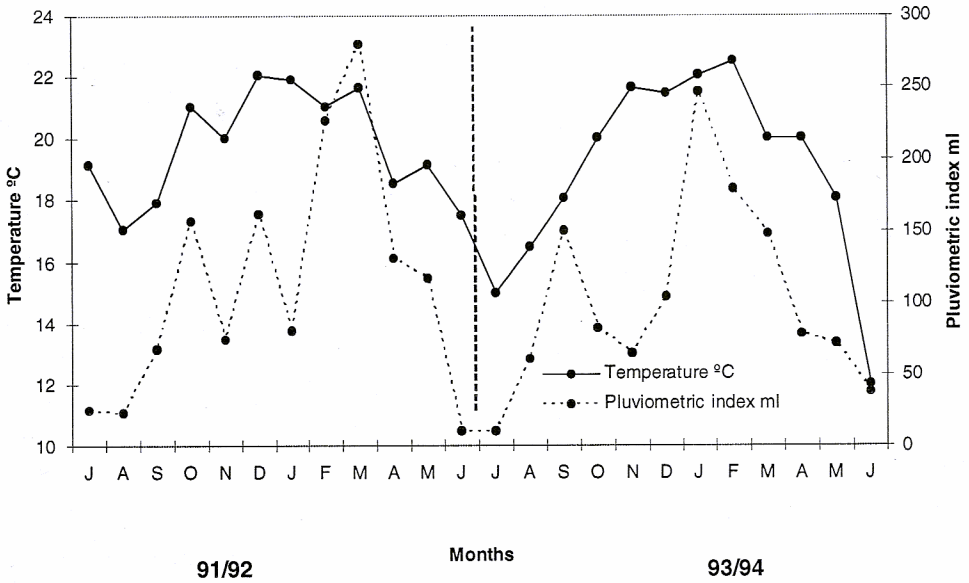

Figure 1: Variation of the water temperature and the pluviometric index in the studied site and periods from July, 1991 to June, 1992 and from July, 1993 to June, 1994.

Table I: *Macrobrachium iheringi* (Ortmann, 1897) – Number of collected prawns: males, females, ovigerous females and juveniles obtained in "Ribeirão da Hortelã" from July, 1991 to June, 1992 (first period) and from July, 1993 to June, 1994 (second period).

Period	Males	Females	Ovigerous females	Juveniles	Total
First	229	300	4	30	563
Second	265	385	15	254	919
Total	494	685	19	284	1482

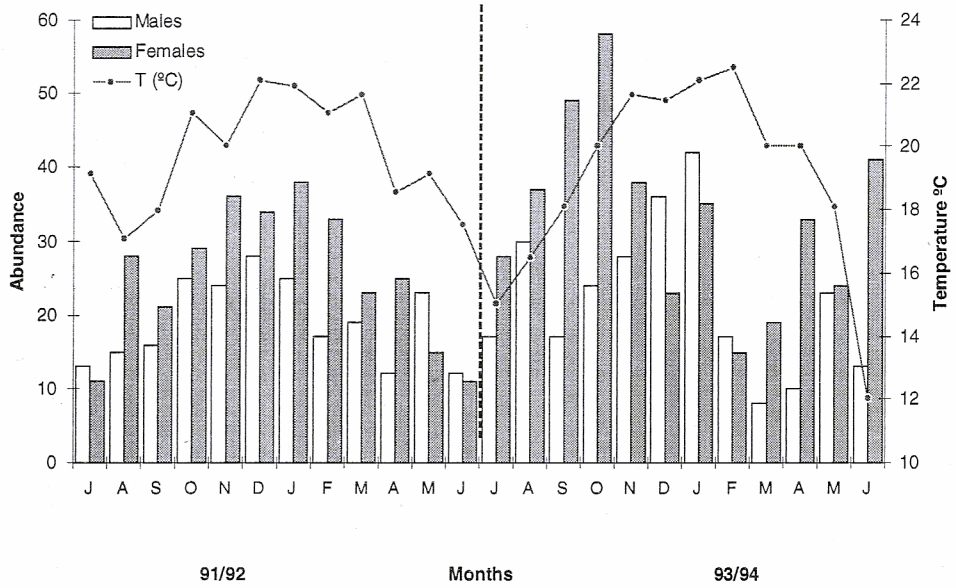

Figure 2: Abundance of the prawn *M. iheringi* according to each sex (bars) and the water temperature fluctuation (line), obtained in "Ribeirão da Hortelã" from July, 1991 to June, 1992 (first period) and from July, 1993 to June, 1994 (second period).

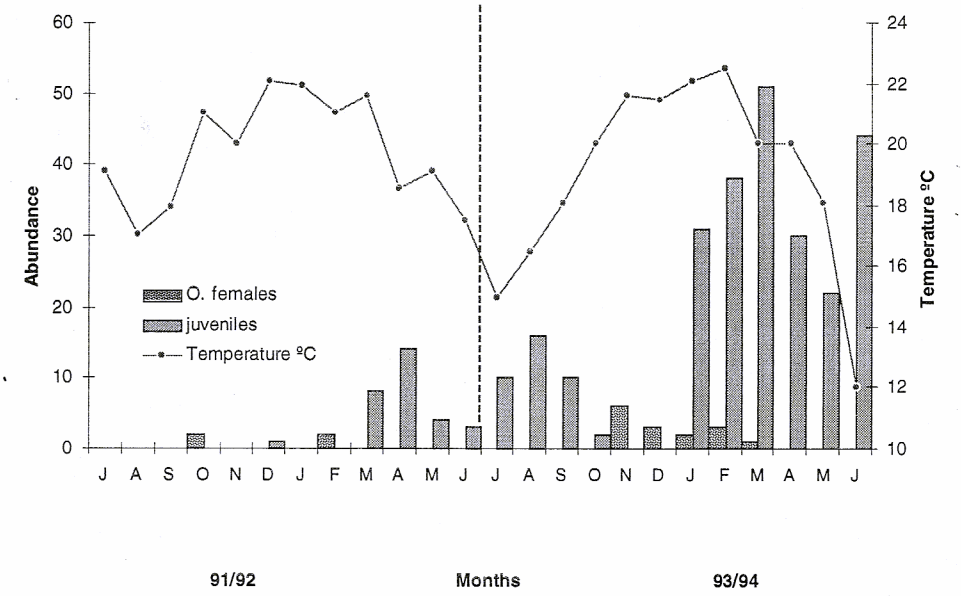

Figure 3: Abundance of ovigerous females and juveniles (bars) of the prawn *M. iheringi* and the water temperature fluctuation (line), obtained in "Ribeirão da Hortelã" from July, 1991 to June, 1992 (first period) and from July, 1993 to June, 1994 (second period).

Table II: Frequency distribution of the prawn *M. iheringi* in size classes (TL, mm), obtained in "Ribeirão da Hortelã" from July, 1991 to June, 1992 (first period) and from July, 1993 to June, 1994 (second period).

Size Classes (TL, mm)	Males		Non-Ovigerous Adult females		Ovigerous females		Juveniles		Total	
	N	%	N	%	N	%	N	%	N	%
8.6 --| 13.9	0	0	0	0	0	0	81	5.5	81	5.5
13.9 --| 19.2	0	0	0	0	0	0	203	13.7	203	13.7
19.2 --| 24.5	60	4	207	14	0	0	0	0	267	18
24.5 --| 29.8	112	7.6	139	9.4	0	0	0	0	251	16.9
29.8 --| 35.1	97	6.5	87	5.9	0	0	0	0	184	12.4
35.1 --| 40.4	80	5.4	97	6.5	0	0	0	0	177	11.9
40.4 --| 45.7	57	3.8	74	5	0	0	0	0	131	8.8
45.7 --| 50.0	37	2.5	52	3.5	1	0.1	0	0	90	6.1
50.0 --| 56.3	21	1.4	17	1.1	16	1.1	0	0	54	3.6
56.3 --| 61.6	15	1	11	0.7	2	0.1	0	0	28	1.9
61.6 --| 66.9	6	0.4	1	0.1	0	0	0	0	7	0.5
66.9 --| 72.2	9	0.6	0	0	0	0	0	0	9	0.6
Total	494	33.3	685	46.2	19	1.3	284	19.2	1482	100

Discussion

Intraspecific variation in the life cycle of prawns from different geographical regions have usually been attributed to differences in environmental conditions among those regions. According to Bhaud *et al.* (1995), warm and cold periods result in spatial and temporal variation in water temperature, which in turn control distributions, reproductive periods and shifts in the life cycle of aquatic organisms. In the present study, the highest abundance of *M. iheringi* occurred during periods of high temperature and pluviosity. Similarly, a study by Müller *et al.* (1996) on *Palaemon pandaliformis* (Stimpson, 1871) showed a low abundance of prawns in certain periods of the year, coinciding with the dry season. In these periods, aquatic plants in the margins are exposed, and given the lack the protection conferred by this microhabitat, prawns probably move elsewhere.

The low number of adult prawns obtained in the present study probably reflects the great amount of refuges found in the river margin, including several aquatic macrophyte species, diminishing their chance of capture. This fact was also recorded by Darnell (1956) and Galvão and Bueno (1999) when studying *Atya scabra* (Leach, 1815). In this species, juveniles and large adults occupy different habitats, with the former being more distributed at the edges of the riffle.

In this study, adult specimens of *M. iheringi* were 20% larger than the size previously recorded in the literature. According to Melo (2003), the largest length found in males and females (including ovigerous females) were 65 and 50 mm in TL, respectively. However, *M. iheringi* is still considered a small species within its genus.

Males reached the largest size among all demographic categories. The observed sexual size dimorphism can result from differential growth among the sexes, given that females need to invest more energy into gonad development. Such process has been suggested in several other palaemonid species (Mashiko, 1981; Ammar *et al.* 2001; Moraes-Riodades and Valenti, 2002).

The presence of ovigerous females only during spring and summer, as well as the predominance of juveniles during summer and fall in both years indicate that this species breeds seasonally. Continuous reproduction is quite common in carideans in tropical regions, whereas periodic reproduction is found in species inhabiting subtropical and temperate latitudes (Bauer, 1991; 1992; Graziani *et al.* 1993). However, Walter and Ferreira (1985) recorded a pattern of seasonal reproduction in the genus *Macrobrachium* collected in the Tarumã-Mirim river in central Amazon, namely in *M. nattereri* (Heller, 1862) and *M. inpa* (Kensley and Walker, 1982). In those species, ovigerous females were observed only during the rainy season (January-June), whereas a higher percentage of juveniles was observed in the dry season (July-December). This observation characterizes a reproductive period based on the seasonal periodicity of high and low tides of the Amazon river.

The recruitment of undifferentiated juveniles, particularly during summer and fall months, can be explained by the occurrence of ovigerous females in the preceding months (spring and summer). The beginning of the juvenile recruitment occurs in the population around three months after the highest capture rate of ovigerous females (figure 3).

In a population of *M. iheringi* from the Buava river, São Paulo State (Lobão *et al.*, 1986), the highest recruitment occurred in April and May and the reproductive period from December to January. On the other hand, the reproductive and recruitment periods in the population of *M. iheringi* studied here (Botucatu, São Paulo) extended longer, *i.e.* around six months each. However, in both studies a typical seasonal reproduction was observed. According to Müller *et al.* (1996), the observation of differences in the duration of the reproductive periods of a single species can be understood as the result of the influence of distinct environmental factors. In the present study, the influencing factor could be temperature variation.

During the sampling periods, the warmest months of the year also coincided with an increase in the pluviometric level. As asserted by Odinetz-Collart (1991), these variables can cause an intense reproductive process, being common in tropical shrimps during the flood period. Similar data were obtained by Lobão *et al.* (1986), Valenti *et al.* (1986) and Takino *et al.* (1989).

In São Paulo state, other studies have indicated that temperature is an important factor regulating spawning periodicity. Nakagaki and Negreiros-Fransozo (1998), Costa and Fransozo (2004) and Galvão and Bueno (1999) have demonstrated that spawning in penaeid and caridean shrimps is usually centered in the warmer months. These authors concluded that this variable might directly affect the development of ovaries.

The present study showed a close relation between *M. iheringi* population and environmental conditions in the study region. However, further studies incorporating eventual migrations for reproduction or by changes in climate condition should provide better understanding on the life cycle of this species.

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