Male Population Structure of the Amazon River Prawn (*Macrobrachium amazonicum*) in a natural environment

Janaína A. Santos; Célia M. S. Sampaio and Aldeney A. Soares Filho

(JAS, CMSS, AASF) Laboratório de Carcinicultura, Centro de Ciências da Saúde, Universidade Estadual do Ceará, Avenida Paranjana, 1700, 60740-903, Fortaleza, Ceará, Brazil.
(CMSS) E-mail: cmsamp@uece.br

Abstract

The prawn species *Macrobrachium amazonicum* (Heller, 1862) is popular in Brazilian aquaculture because of its rapid growth and easy maintenance. Studies show that population dynamics are quite variable and that sexually mature males of different sizes may be classified according to morphotype. The identification of such morphotypes is essential for an efficient management and handling of prawns. The objective of the present study was to describe the male population structure of *M. amazonicum* in a natural environment (the Jaguaribe River, Itaiaçaba, Ceará, Brazil). Prawns were collected monthly over the period August-December, 2002. Live animals were sent to the Biological Sciences Laboratory of the State University of Ceará and placed in well-aerated glass fiber tanks fitted with biological filters. The prawns were fed once a day with commercial aquaculture feed. The carapace length (L_C), the abdomen+telson length (L_{A+T}), and the total length (L_T) were registered for each of the 201 males in the study, as was the color, spination and length of second right cheliped (L_{CH}). An analysis of the color and spination and of the proportion between the segments of the right cheliped revealed three distinct male morphotypes *M. amazonicum:* Translucent Claw (TC), Cinnamon Claw (CC) and Green Claw (GC). The morphotypes differed with regard to the external cheliped morphology and the following morphometric relationships: L_T, L_C, L_{A+T}, L_{CH}, L_{CH} x L_T and L_{CH} x L_C.

Key words: *Macrobrachium amazonicum,* morphometric relationships, morphotypes, relative growth.

Introduction

According to New (2000), the annual world production of freshwater prawns rose from 21,000 to 118,500 tons between 1990 and 2000, corresponding to a growth of nearly 500%. These dates refer only to *Macrobrachium rosenbergii* (De Man, 1879), the most cultivated prawn species in the world today, but the industry promises other great developments in the near future. Two other species of *Macrobrachium* (Bate, 1868) are gaining popularity among farmers in Asian countries: *M. malcolmsonii,* (H. Milne Edwards, 1844) in India, and *M. nipponense* (De Haan, 1849), in China (Valenti, 1998).

Those three species of *Macrobrachium* are the most commercially exploited around in the world and distributed throughout the tropical and subtropical regions of the Indo-West Pacific as well as in a number of countries in South and Southeast Asia (Pinheiro and Hebling, 1998; Kutty *et al.,* 2000).

The most important *Macrobrachium* species in Brazil, *M. acanthurus* (Wiegmann, 1836), *M. amazonicum* (Heller, 1862) and *M. carcinus* (Linnaeus, 1758) became the object of research in the early 1970s. However, research efforts subsided after the importation of *M. rosenbergii* postlarvae from Hawaii in 1977 and the subsequent boom in the farming of this species worldwide (Valenti, 1993).

In the early 2000s, however, researchers at the Aquaculture Center of the São Paulo State University (UNESP) decided to resume studies on Brazilian prawn species with a view to developing new farming technologies and providing Brazilian farmers with more alternatives.

The native Brazilian species *M. amazonicum* has been viewed as a strong potential candidate for farming due to its rapid growth and easy maintenance in captivity. Although not as large as *M. acanthurus* and *M. carcinus,* it does not display the aggressive behavior characteristic of those species and is more resistant to disease (Lobão and Rojas, 1991).

M. amazonicum is found in many South American rivers that flow into the Atlantic Ocean, from Venezuela to Paraguay (Rodríguez, 1980; Romero, 1980; Gamba, 1984). In Brazil, it occurs in rivers of the North, Northeast and Southeast, with a clear preference for the warmer regions (Kensley and Walker, 1982; Bialetzki *et al.,* 1997).

Odinetz-Collart (1993) and Odinetz-Collart and Moreira (1993) observed differences in the growth rates of natural populations of *M. amazonicum,* including a great variation in the size of the males. In *M. rosenbergii* this variation produces a complex male population structure, with three well-defined types of sexually mature males: small males (SM), males with orange claws (OC) and males with blue claws (BC). Although mature, the types differ in morphology, physiology and behavior (Ra'anan and Sagi, 1985; Sagi and Ra'anan, 1988; Sagi *et al.,* 1990; Karplus *et al.,* 2000).

However, in a study on relative growth, Kuris *et al.* (1987) found not three but four morphotypes in the male population of *M. rosenbergii.* In their analysis, OC is divided into two subtypes: WOC (weak orange claw) and SOC (strong orange claw).

Moraes-Riodades and Valenti (2004) confirmed the existence of male morphotypes of *M. amazonicum* reared on farms in São Paulo using postlarvae from Pará. They identified four distinct types: Translucent Claw (TC), Cinnamon Claw (CC), Green Claw 1 (GC1) and Green Claw 2 (GC2). The types also differed in the external morphology of the chelipeds and in a range of morphometric measurements.

According to Smith and Sandifer (1981) and Daniels *et al.* (1995), the existence of three male morphotypes in *M. rosenbergii* is detrimental to productivity and profitability in prawn farming. To mitigate this problem, farmers regularly remove the larger males (types BC and OC) from the pond so as to allow the smaller ones (SM) to grow and thereby increase the final biomass and profit.

Studies on the male population structure of *M. amazonicum* under different environmental conditions have contributed significantly to our understanding of the social biology of the species and to the optimization of culture management. The objective of the present study was to describe the male population structure of *M. amazonicum* in a natural environment.

Material and Methods

Study location

The study was carried out in the Jaguaribe River (Itaiçaba, Ceará State, Brazil), north of the Canal do Trabalhador, at 04°40'28"S and 37°49'21"W, at an altitude of 200 m (Fig. 1). Samplings were performed in the period August-December, 2002.

The Jaguaribe River is 633 kilometers long and is divided into three basins: Upper, Middle and Lower Jaguaribe. The middle and lower parts are separated by a dam. The mouth of the river is lo-

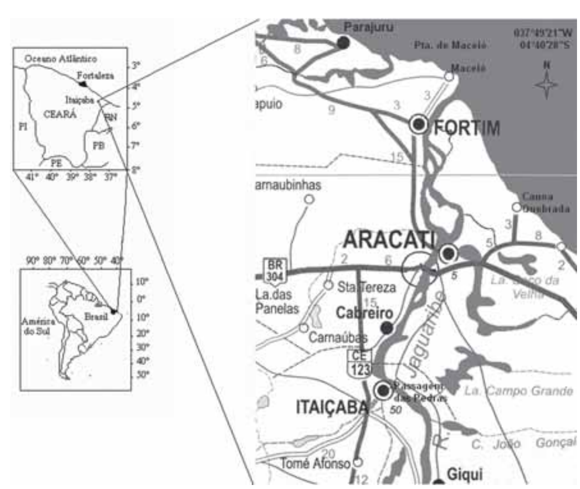

Figure 1. Study location. Contextualization of the Jaguaribe River. Maps of Itaiçaba, Ceará and Brazil.

cated 137 km from the dam, by the town of Fortim. While the upper and middle basins are characterized by crystalline soil, the soil of the lower basin is predominantly sedimentary (Iplance, 1995).

Sampling material

The prawns were captured using a 5-m casting net with a mesh size of 1.5 cm. The net was cast from a raft over sandy bottoms. Samplings always took place early in the morning and lasted for 1 hour. The collected prawns were sent to the Biological Sciences Laboratory at the State University of Ceará (LABIO/UECE).

In the laboratory, live prawns were placed in well-aerated 500-L tanks fitted with biological filters. The animals were given commercial aquaculture feed once daily, late in the morning. The prawns were examined and identified according to the classification keys proposed by Holthuis (1952, 1980). Sex differentiation was based on the morphology of the endopod of the second pair of pleopods, as proposed by Pinheiro and Hebling (1998).

Environmental and physicochemical parameters

The temperature, pH value, salinity and dissolved oxygen levels in the river water were measured monthly with a regular thermometer (Incoterm), a pocket pH-meter (Orion, Quikchek), and a portable refractometer (Alfakit, 211 model), respectively, while the local rainfall indices were retrieved from the state meteorology service (FUNCEME). The river water was collected in Van Dorn flasks and sent to the laboratory for determination of dissolved oxygen by the Winkler method.

Male population structure

A random, monthly sample of about 50 males was submitted to the following measurements: carapace length (L_C – defined as the distance between the tip of rostrum to the midpoint of the posterior border of the carapace), abdomen+telson length (L_{A+T} – defined as the distance between the midpoint of the anterosuperior border of the first abdominal segment and the end of the telson), and total length (L_T – defined as $L_C + L_{A+T}$).

Subsequently, the second right cheliped was detached and placed on white paper for the taking of the following measures with a 0.05-mm precision caliper: ischium length (L_I), merus length (L_M), carpus length (L_{CA}), propodus length (L_P) and dactylus length (L_D) (Moraes-Riodades and Valenti, 2004). The cheliped length (L_{CH}) was found by summing up the lengths of each segment. Color and spination were also registered for each second cheliped of male specimens with the aid of a stereomicroscope. Claws were photographed with a Canon EOS Digital Rebel. These characteristics were utilized to separate male morphotypes.

Individuals were excluded from the study if the rostrum or telson was broken, if undergoing ecdysis or if the right cheliped was missing or regenerating. In this study it was considered only adults prawns, that is, all those individuals that had a developed sexual appendage on the second pair of pleopods, while in juvenile that structure is not completely formed (Pinheiro and Hebling, 1998).

The mean L_T, L_C, L_{A+T} and L_{CH} values and the L_{CH} x L_T and L_{CH} x L_C relationships were compared for morphotype recognition. Mean values were subjected to analysis of variance (Kruskal-Wallis test) using the BioEstat 3.0 software (Ayres *et al.,* 2003). Differences were considered to be significant when $p \leq 0.05$.

Equations representing the relationships between body parts, between the cheliped segments and the carapace and between the segments themselves were calculated for each morphotype and adjusted with data converted into decimal logarithmic scale using the software Origin, version 7.0. The allometric equation $y = ax^b$ (Hartnoll, 1982) was used in the logarithmic form, i.e.: $\log y = \log a + b \log x$, where x is the size of the reference dimension from which the size of the y dimension will be estimated; a is a constant related to the intercept on the ordinate axis, and b is the allometric growth constant. In accordance with the procedures of Kuris *et al.* (1987) and Moraes-Riodades and Valenti (2002), allometry was said to be negative when $b < 0.9$, isometry was defined as $0.9 < b < 1.1$, and allometry was positive when b > 1.1. The statistical comparison test of the angular coefficients of the equations was calculated in agreement with Ivo and Fonteles-Filho (1997), followed by the Newman-Keuls test (Zar, 1974).

Results

During sampling, the water temperature of the Jaguaribe River varied between 27.0 and 28.5°C, the dissolved oxygen ranged from 6.1 to 9.0 mg/L and pH values were in the range 7.6-8.4 (Table I). The salinity and the rainfall indices were null and constant during the study period.

A total of 503 prawns were collected, of which 201 (40%) were males and 302 (60%) females. The proportion between males and females in the population was 1:1.5. Ovigerous females accounted for 105 individuals (34.8%) versus 197 (65.2%) non ovigerous females, with a total length of 45.2-82.0 mm and 48.8-91.5 mm, respectively. In this study it was not observed intact females, that is, females that never spawned.

Male total length ranged from 38.55 to 94.30 mm. The animals were then classified according to the color and spination of the right cheliped: Translucent Claw (TC; n=66), Cinnamon Claw (CC; n=113) and Green Claw (GC; n=22).

The proportion of male morphotypes in the population examined was TC=32.8%, CC=56.2% and GC=11.0%. The external cheliped morphology and spination pattern of the male prawn are shown in Figs. 2 and 3.

Morphotype identification

Prawns of the TC morphotype had a total length (L_T) of 38.55-77.30 mm. Cheliped length (L_{CH}) ranged from 23.05 to 63.85 mm. In general, chelipeds did not have spines, segments were translucent and featured occasional orange pigmentation at the joints. In some, the propodus and dactylus were light green (Fig. 3).

Prawns of the CC morphotype had a total length (L_T) of 45.70-93.55 mm. Cheliped length (L_{CH}) ranged from 24.20 to 106.25 mm. The is-

Table I. Physicochemical parameters of water collected from the Jaguaribe River (Ceará, Brazil), measured monthly between August and December, 2002.

Month	Temperature (°C)	Dissolved Oxygen (mg/L)	pH
	Physicochemical parameters		
08/2002	27.5	6.9	8.3
09/2002	28.5	9.0	8.4
10/2002	27.0	7.6	8.4
11/2002	27.5	6.1	7.6
12/2002	28.0	5.7	8.0

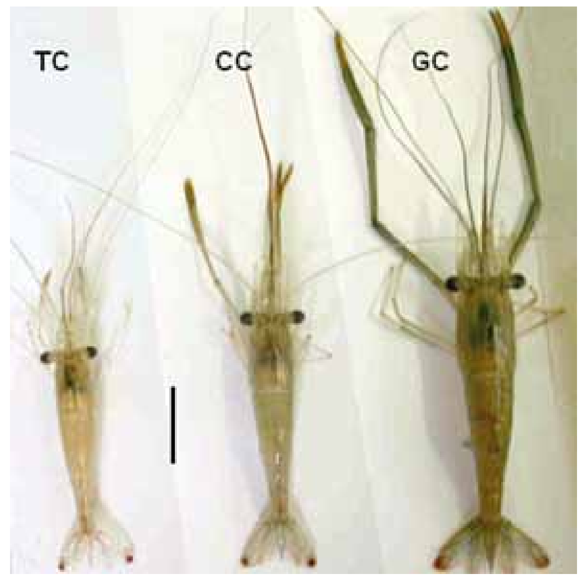

Figure 2. Three male morphotypes of the amazon river prawn (*Macrobrachium amazonicum*). TC = Translucent Claw, CC = Cinnamon Claw, CG = Green Claw. Scale bar, 20 mm.

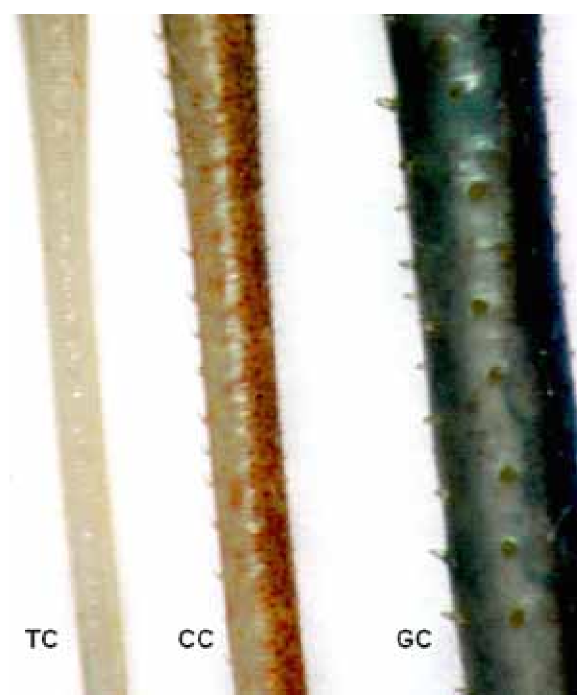

Figure 3. Spination pattern of the right carpus of the amazon river prawn (*Macrobrachium amazonicum*). TC = Translucent Claw, CC = Cinnamon Claw, CG = Green Claw.

chium and merus were translucent, the latter being occasionally light green. The carpus was light green, with orange pigmentation throughout. In some individuals a brownish coloring was predominant. The propodus and dactylus were green and beige with orange pigmentation. The prawns presented few spines on the merus and propodus, many spines on the carpus and no spines on any other segment (Fig. 3).

Prawns of the GC morphotype had a total length (L_T) of 72.85-94.30 mm. Cheliped length (L_{CH}) ranged from 57.10 to 120.15 mm. The ischium was greenish, the merus was green and the carpus, propodus and dactylus were moss green. The ischium presented some tubercles suggesting the development of spines; the merus, carpus and propodus featured short and robust spines.

Relative growth

The length parameters for the three morphotypes of *M. amazonicum,* expressed as mean ± standard deviation, are shown in Table II. The three morphotypes are statistically different with regard to total length (L_T), carapace length (L_C), abdomen+telson length (L_{A+T}), cheliped length (L_{CH}), cheliped length/total length ratio and cheliped length/carapace length ratio.

The morphometric relationships between log L_{CH} and log L_C are shown in Fig. 4. The determination coefficient of the equations (0.58-0.68) was significant for the three morphotypes, indicating good data adjustment. The TC morphotype showed negative allometry ($b < 0.9$) and the CC and GC morphotypes showed positive allometry ($b > 1.1$).

Table II. Total length (L_T), carapace length (L_C), abdomen+telson length (L_{A+T}), cheliped length (L_{CH}), cheliped length/total length ratio and cheliped length/carapace length ratio for the three morphotypes of *Macrobrachium amazonicum* (TC, CC and GC).

Parameters	TC (n = 66)	CC (n = 113)	GC (n = 22)
L_T	64.76 ± 8.84 a	73.62 ± 9.02 b	85.27 ± 4.81 c
L_C	30.66 ± 4.71 a	35.21 ± 4.93 b	41.75 ± 2.99 c
L_{A+T}	34.11 ± 4.41 a	38.41 ± 4.33 b	43.52 ± 2.06 c
L_{CH}	36.45 ± 7.45 a	58.45 ± 15.96 b	90.31 ± 16.23 c
L_{CH} x L_T	0.56 ± 0.08 a	0.79 ± 0.16 b	1.06 ± 0.17 c
L_{CH} x L_C	1.20 ± 0.18 a	1.65 ± 0.35 b	2.16 ± 0.33 c

Means in the same line followed by different letters are significantly different ($p \leq 0.05$).
Data are reported as mean ± S.D. The number of specimens (n) is presented in parentheses.
TC = Translucent Claw, CC = Cinnamon Claw, CG = Green Claw.

The morphometric relationships between log LP and log LC are shown in Fig. 5. The determination coefficients were in the range 0.58-0.67, indicating acceptable data adjustment. The TC morphotype showed isometry ($0.9 < b < 1.1$) and the CC and GC morphotypes showed positive allometry ($b > 1.1$). Table III shows the morphometric relationships and equations for the three morphotypes (TC, CC and GC) of *M. amazonicum.*

The morphotypes TC and CC differed statistically in the morphometric relationships between cheliped length and carapace length (L_{CH} x L_C) ($q_{0.05\,(175,2)} = -2.772$; $q_{cal.} = -3.996$) and between the propodus length and carapace length (L_P x L_C) ($q_{0.05\,(175,2)} = -2.772$; $q_{cal.} = -4.843$).

Discussion

According to Valenti (1996), the freshwater prawns are tropical species that live in waters with temperatures varying from 28 to 32°C, although in extreme situations they can tolerate minimum and maximum temperatures of 15 and 35°C, respectively.

Moreover, the water should be soft with a pH between 7.0 and 9.0 and a high rate of dissolved oxygen. The temperature, dissolved oxygen and pH levels observed for the water in the Jaguaribe River during the study period varied very little and were within the ranges reported by Valenti (1996) for freshwater prawns and by Sampaio and Valenti (1996) for *M. rosenbergii.* It may therefore be assumed that the influence of the physicochemical parameters of the Jaguaribe River upon the amount of prawns collected for this study, if any, were negligible.

The total length of the specimens of *M. amazonicum* collected for the present study (38.55-94.30 mm) was slightly below that reported by Vásquez León (1980) for specimens collected in the Orinoco River, Venezuela (44.0-109.0 mm).

In the male/female ratio encountered in our study, the females were predominant over the males, opposite to what was related by Silva *et al.* (2002) with samples from the same species collected in the State of Pará, where the males were predomi-

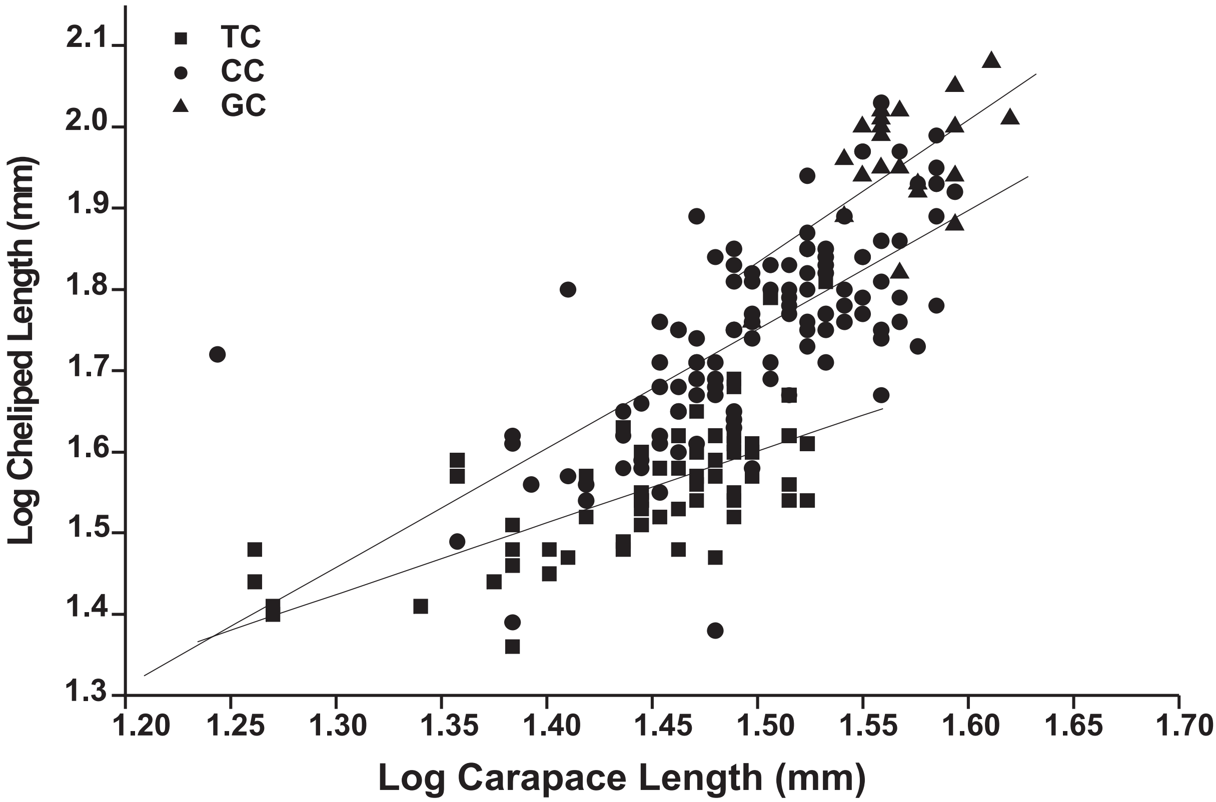

Figure 4. Relationships between log cheliped length (L_{CH}) and log carapace length (L_C) for the three male morphotypes of *Macrobrachium amazonicum*. TC, Translucent Claw; CC, Cinnamon Claw; CG, Green Claw.

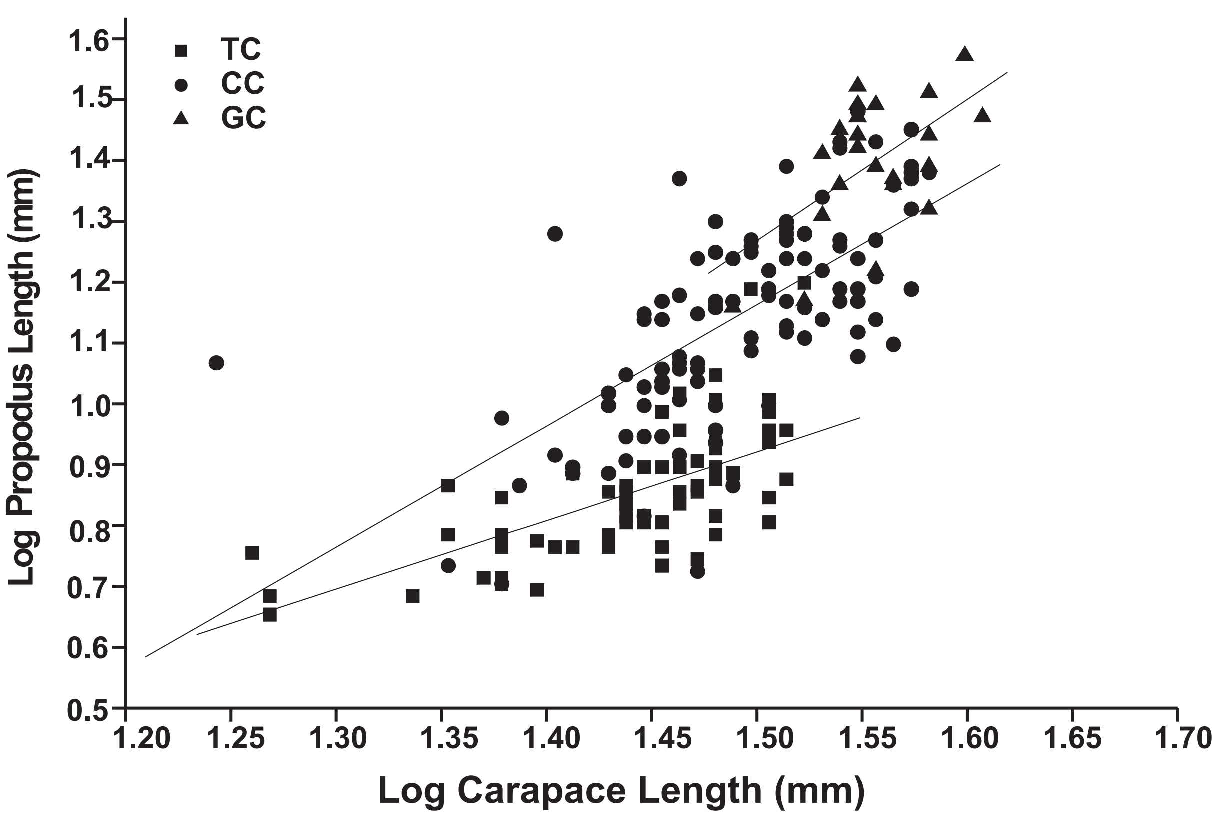

Figure 5. Relationships between log propodus length (L_P) and log carapace length (L_C) for the three male morphotypes of *Macrobrachium amazonicum*. TC, Translucent Claw; CC, Cinnamon Claw; CG, Green Claw.

Table III. Morphometric relationships for the three male morphotypes of *Macrobrachium amazonicum* (TC, Translucent Claw; CC, Cinnamon Claw; CG, Green Claw).

Morphometric relationships	TC (n = 66)	CC (n = 113)	GC (n = 22)
Log L_{CH} x Log L_C (mm)	y = 0.4094 + 0.7723 x	y = -0.2248 + 1.2803 x	y = -0.5347 + 1.5347 x
	r = 0.68	r = 0.68	r = 0.58
	p < 0.0001	p < 0.0001	p = 0.0043
Log L_P x Log L_C (mm)	y = -0.5563 + 0.9472 x	y = -1.8139 + 1.9077 x	y = -1.7721 + 1.9510 x
	r = 0.67	r = 0.65	r = 0.58
	p < 0.0001	p < 0.0001	p = 0.0060

L_C – carapace length; L_{CH} – cheliped length; L_P – propodus length.

nant over the females. Perhaps this difference may be explained by the collection duration of our study that was of five months, opposite of the time determined by Silva *et al.* (2002), which was of 12 months. In our work, ovigerous females were captured throughout all five months of study. On the other hand, Silva *et al.* (2004) observed an occurrence of ovigerous females of this specie in the same river from June 1999 to June 2001, quite an extensive period of time. Thus, it may be safely concluded that *M. amazonicum* is capable of reproducing around the year. Likewise, in a study on the same species, Bragagnoli and Grotta (1995) observed females in all gonadal stages throughout the year in the Epitácio Pessoa reservoir (Boqueirão, Paraíba).

The classification of males of *M. amazonicum,* collected in the natural environment, into three morphotypes according to the color and spination of the second right cheliped was borne out by the morphometric analysis. The chelipeds of the three morphotypes (TC, CC and GC) differed in both morphology and size.

Only the morphotypes TC and CC presented a specific model of growth demonstrated by the differences observed in the allometric constant of growth. This fact was not observed for the morphotypes GC, possibly due to the small number of samples. It is worth emphasizing that the collection of *M. amazonicum* were not selective since the time schedule and length of time were standardized.

The three morphotypes (TC, CC and GC) observed in this study correspond closely to three of the morphotypes (TC, CC and GC1) identified by Moraes-Riodades and Valenti (2004) in a population of *M. amazonicum* collected from ponds at the Aquaculture Center of the São Paulo State University (CAUNESP). However, the GC2 morphotype identified by those authors was not observed in our study, possibly because animals of this type are bigger and more sedentary and tend to seek shelter by the pondside vegetation where they are more difficult to catch with a casting net. In fact, although used for decades by Ceará river and reservoir fishermen to capture prawns, casting nets may have to be replaced by other types of traps, such as the fyke net, in difficult-to-access areas.

Papa *et al.* (2004), by analyzing the morphology of the testis and the gonadosomatic and hepatosomatic indexes of the male morphotypes of *M. amazonicum,* identified by Moraes-Riodades and Valenti (2004), observed only three of the four morphotypes.

They suggested that the GC1 morphotype is merely a transition between CC and GC2, much like the transition between OC and BC in *M. rosenbergii,* as described by Sagi and Ra'anan (1988).

However, differences in cheliped color were observed between our specimens and those examined by Moraes-Riodades and Valenti (2004). Although the physicochemical parameters of the Jaguaribe River and the prawn farming ponds in São Paulo were broadly similar, the animals in the latter environment interacted with no other species and their feeding habits were much less diversified. Since, according to Moraes-Riodades and Valenti (2004), the color of crustaceans is partly determined by the characteristics of the environment, differences in environment may account for differences in cheliped color between the specimens collected for this study and those examined by Moraes-Riodades and Valenti (2004).

The mean cheliped lengths of TC, CC and GC observed in the present study were close to those registered by Moraes-Riodades and Valenti

(2004) for morphotypes TC, CC and GC1. However, since Moraes-Riodades and Valenti (2004) based their measurements on the postorbital length, a comparison of mean total lengths was not possible. The cheliped length x total length ratio calculated in our study matched that of Moraes-Riodades and Valenti (2004), and so did the cheliped length x postorbital length ratio for the morphotypes TC, CC and GC1.

Differences in the cheliped length x carapace length ratio of the TC, CC and GC morphotypes suggest that chelipeds possess morphotype-specific functions. According to Moraes-Riodades and Valenti (2002), the cheliped length x carapace length ratio differs between immature animals, females and males. Cheliped growth and carapace growth are isometric until maturity. From this point onwards, allometry becomes slightly positive in females and highly positive in males. Changes in cheliped size have been associated with changes in intraspecific interactions and in the animal's relation to the environment (Moraes-Riodades and Valenti, 2002).

The ratio of male morphotypes of *M. amazonicum* collected in Jaguaribe River differs from that observed for pond reared *M. rosenbergii* (5 SM: 4 OC: 1BC) (Brody *et al.,* 1980; Cohen *et al.,* 1981). In the present study, the CC morphotype, which corresponds to the OC morphotype of *M. rosenbergii,* was the most prevalent. The ratios are actually dynamic, depending on environmental factors. Males of *M. rosenbergii* move from one morphotype to another, following an irreversible order: SM→OC→BC (Kuris *et al.,* 1987). Karplus *et al.* (1986) found the ratio of male morphotypes of *M. rosenbergii* to be related to density: an increase in density favored SM over BC. Likewise, social mechanisms can induce changes in morphotype prevalence. In this respect, Karplus *et al.* (1986) stress competition for food, early sexual maturation, hyperactivity of subordinate individuals, ecdysis, aggressiveness and social hierarchy.

Karplus *et al.* (2000) found male morphotypes of *M. rosenbergii* to differ in morphology, physiology and behavior. Likewise, *M. amazonicum* morphotypes will require further investigation with regard to these aspects in order to improve our knowledge of the population structure and dynamics of this species.

Acknowledgements

We are grateful to CNPq (Grants #479843/01-5) and FUNCAP (Grants #151/01) for the scholarships and financial support provided.

References

Ayres, M.; Ayres Jr., M.; Ayres, D. L. and Santos, A. S. 2003. BioEstat 3.0: Aplicações estatísticas nas áreas das ciências biológicas e médicas. Belém: Sociedade Civil Mamirauá; Brasília CNPq, 290 p.

Bialetzki, A.; Nakatani, K.; Baumgartner, G. and Bond-Buckup, G. 1997. Occurrence of *Macrobrachium amazonicum* (Heller, 1862) (Decapoda, Palaemonidae) in Leopoldo's inlet (Resacado do Leopoldo), upper Paraná river, Porto Rico, Paraná, Brasil. Revista Brasileira de Zoologia, 14(2): 379-390.

Bragagnoli, G. and Grotta, M. 1995. Reprodução do camarão de água doce *Macrobrachium amazonicum* do açude Epitácio Pessoa, Boqueirão (PB), Brasil. Parte I: Ciclo sexual. Revista Nordestina de Biologia, 10(2): 141-154.

Brody, T.; Cohen, D.; Barnes, A. and Spector, A. 1980. Yield characters of *Macrobrachium rosenbergii* in monoculture. Aquaculture, 21: 375-385.

Cohen, D.; Ra'anan, Z. and Brody, T. 1981. Population profile development and morfotypic differentiation in the giant freshwater prawn *Macrobrachium rosenbergii* (De Man). Journal of the World Mariculture Society, 12(2): 231-243.

Daniels, W. H.; D'abramo, L. R.; Fondren, M. W. and Durant, M. D. 1995. Effects of stocking density and feed on pond production characteristics and reserve of harvested freshwater prawns *Macrobrachium rosenbergii* stocked as size-graded juveniles. Journal of the World Aquaculture Society, 26(1): 38-47.

Gamba, A. L. 1984. Different egg-associated and larval development characteristics of *Macrobrachium jelskii* and *Macrobrachium amazonicum* (Arthropoda: Crustacea) in a Venezuelan continental lagoon. International Journal Invertebrate and Reproduction Development, 7: 135-142.

Hartnoll, R. G. 1982. Growth. Pp. 111-196. *In* Bliss, D. E. Ed. The Biology of Crustacea. Embriology, Morphology and Genetics. Vol. 2, Academic Press, New York.

Holthuis, L. B. 1952. A general revision of the Palemonidae (Crustacea, Decapoda, Natantia) of the Americas. Allan Hancock Foundation Publications, Occasional Papers, 12: 1-396.

Holthuis, L. B. 1980. FAO species catalogue. Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries. FAO Fish. Synopses, 125(1): 1-261.

Iplance. 1995. Atlas do Ceará. Fortaleza, 64 p.

Ivo, C. T. C. and Fonteles-Filho, A. A. 1997. Estatística pesqueira: aplicação em Engenharia de Pesca. Fortaleza, Tom Gráfica e Editora, vi + 193 p.

Karplus, I.; Hulata, G.; Wohlfarth, G. W. and Halevy, A. 1986. The effect of density of *Macrobrachium rosenbergii* raised in earthen ponds on their population structure and weight distribution. Aquaculture, 52: 307-320.

Karplus, I.; Malecha, S. and Sagi, A. 2000. The biology and management of size variation. Pp. 254-289. *In* New, M.B. and Valenti, W. C. Eds. Freshwater Prawn Culture: the

farming of *Macrobrachium rosenbergii*. London, Blackwell Science.
Kensley, B. and Walker, I. 1982. Palaemonid shrimp from the Amazon Basin Brazil (Crustacea: Decapoda: Natantia). Smithsonian Contributions to Zoology, 362: 1-28.
Kuris, A. M.; Ra'anan, Z.; Sagi, A. and Cohen, D. 1987. Morphotypic differentiation of male Malaysian giant prawns, *Macrobrachium rosenbergii*. Journal of Crustacean Biology, 7: 219-237.
Kutty, M. N.; Herman, F. and Le Menn, H. 2000. Culture of other prawn speciesThe biology and management of size variation. Pp. 393-410. *In* New, M. B. and Valenti, W. C. Eds. Freshwater Prawn Culture: the farming of *Macrobrachium rosenbergii*. London, Blackwell Science.
Lobão, V. L. and Rojas, N. E. T. 1991. Camarões de água doce. Da coleta ao cultivo, à comercialização. São Paulo, Ícone, 112 p.
Moraes-Riodades, P. M. C. and Valenti, W. C. 2002. Crescimento relativo do camarão canela *Macrobrachium amazonicum* (Heller) (Crustacea, Decapoda, Palaemonidae) em viveiros. Revista Brasileira de Zoologia, 19(4): 1169-1176.
Moraes-Riodades, P. M. C. and Valenti, W. C. 2004. Morphotypes in male Amazon River Prawns, *Macrobrachium amazonicum*. Aquaculture, 236: 297-307.
New, M. B. 2000. History and global status of freshwater prawn farming. Pp. 1-11. *In* New, M. B. and Valenti, W. C. Eds. Freshwater Prawn Culture: the farming of *Macrobrachium rosenbergii*. London, Blackwell Science.
Odinetz-Collart, O. 1993. Ecologia e potencial pesqueiro do camarão-canela, *Macrobrachium amazonicum,* na Bacia Amazônica. Pp. 147-166 *In* Ferreira, E. J. G. Santos, G. M.; Leão, E. L. M. and Oliveira, L. A. Eds. Bases científicas para estratégias de preservação e desenvolvimento da Amazônia. Manaus, INPA.
Odinetz-Collart, O. and Moreira, L. C. 1993. Potencial pesqueiro do camarão *Macrobrachium amazonicum* na Amazônia Central (Ilha do Careiro). Amazoniana, 12(3/4): 399-413.
Papa, L. P.; Vicentini, I. B. F.; Ribeiro, K.; Vicenti, A. and Pezzato, L. E. 2004. Diferenciação morfotípica de machos do camarão de água doce *Macrobrachium amazonicum* a partir da análise do hepatopâncreas e do sistema reprodutor. Acta Scientiarum. Animal Sciences, 26(4): 463-467.
Pinheiro, M. A. A. and Hebling, N. J. 1998. Biologia de *Macrobrachium rosenbergii* (De Man, 1879). Pp. 21-46. *In* Valenti, W. C. Ed. Carcinicultura de água doce: Tecnologia para produção de camarões. Brasília, IBAMA.
Ra'anan, Z. and Sagi, A. 1985. Alternative mating strategies in males of the freswater prawn *Macrobrachium rosenbergii* (De Man). Biological Bulletin, 69: 592-601.
Rodríguez, G. 1980. Los crustaceos decapodos de Venezuela. Caracas, Instituto Venezolano de Investigaciones Cientificas. 443 p.
Romero, M. E. 1980. Preliminary observations on potential of culture of *Macrobrachium amazonicum* in Venezuela. Pp. 411-416. *In* New, M. B. Ed. Giant prawn farming. Amsterdan, Elsevier.
Sagi, A. and Ra'anan, Z. 1988. Morphotypic differentiation of males of the fresh-water prawn *Macrobrachium rosenbergii:* changes in the midgut glands and the reproductive system. Journal of Crustacean Biology, 8(1): 43-47.
Sagi, A.; Cohen, D. and Milner, Y. 1990. Effect of androgenic gland ablation on morphotypic differentiation and sexual characteristics of male freshwater prawns *Macrobrachium rosenbergii*. General and Comparative Endocrinology, 77: 15-22.
Sampaio, C. M. S. and Valenti, W. C. 1996. Growth curves for *Macrobrachium rosenbergii* in semi-intensive culture in Brazil. Journal of the World Aquaculture Society, 27(3): 353-358.
Silva, K. C. A.; Souza, R. A. L. and Cintra, I. H. A. 2002. Camarão-cascudo *Macrobrachium amazonicum* (Heller, 1862) (Crustacea, Decapoda, Palaemonidae) no município de Vigia – Pará – Brasil. Boletim Técnico Científico do Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Norte, 1(2): 41-73.
Silva, R. R.; Sampaio, C. M. S. and Santos, J. A. 2004, Fecundity and fertility of *Macrobrachium amazonicum* (Crustacean, Palemonidae). Brazilian Journal of Biology, 64(3A): 489-500.
Smith, T. I. J. and Sandifer, P. A. 1981. Effect of population structure and density at stocking of production and commercial feasibility of prawn *(Macrobrachium rosenbergii)* farming in temperate climates. Journal of World Mariculture Society, 12(1): 233-250.
Valenti, W. C. 1993. Frehswater prawn culture in Brazil. *World Aquaculture,* 21(1): 29-34.
Valenti, W. C. 1996. Criação de Camarões em Águas Interiores. Jaboticabal, Funep. Bol.Técnico do Caunesp, 2.
Valenti, W. C. 1998. Carcinicultura de água doce: Tecnologia para produção de camarões. Brasília, IBAMA, 383 p.
Vásquez León, E. 1980. Contribucion al conocimiento de la biología del camarón de río *Macrobrachium amazonicum* (Heller) (Decapada, Palaemonidae) en función de su potencial de cultivo. Memoria de la sociedad de ciencias naturales La Salle, 113: 140-155.
Zar, J. H. 1974. Bioestatistical analysis. Prentice-Hall, Englewood Cliffs, xiv + 620 p.

Received: May 2006
Accepted: July 2006