



The influence of macrophytes in the population structure of *Palaemon pandaliformis* (Stimpson, 1871) in Salsa River, Bahia state, northeast Brazil

LUCAS REZENDE PENIDO PASCHOAL^{1,2,3*}, FERNANDA JORDAO GUIMARAES¹ & ERMINDA DA CONCEICAO GUERREIRO COUTO¹

¹ Laboratório de Ecologia Bêntica, Departamento de Ciências Biológicas, Universidade Estadual de Santa Cruz, Campus Soane Nazaré de Andrade, Rod. Ilhéus-Itabuna, Km 16, 45662-900, Ilhéus, Bahia, Brazil.

² Universidade Estadual Paulista – UNESP/Jaboticabal, Departamento de Biologia Aplicada, Invertebrate Morphology Laboratory (IML) and Aquaculture Center (CAUNESP). Via de Acesso Prof. Paulo Donato Castellane, S/N, CEP 14884-900, Jaboticabal, São Paulo, Brazil.

³ Faculdades de Inovação e Tecnologia de Minas Gerais, FIT-MG, Praça Monsenhor Messias Braganca, 185, 37900-060, Passos, Minas Gerais, Brazil

* Corresponding author: lucasrezende20@gmail.com

Abstract: The aim of this study is to evaluate the role of three species of macrophytes in the population dynamics of the amphidromous shrimp *Palaemon pandaliformis*. Results revealed that macrophytes perform important functions and are directly responsible for modulating spatial distribution of this species.

Key words: Caridea, habitat preferences, phytophilous shrimps, spatial distribution.

A influência de macrófitas na estrutura populacional de *Palaemon pandaliformis* (Stimpson, 1871) no Rio Salsa, estado da Bahia, nordeste do Brasil. Resumo: Neste estudo, avaliamos o papel de três espécies de macrófitas na dinâmica populacional do camarão anfídromo *Palaemon pandaliformis*. Nossos resultados revelaram que essas macrófitas desempenharam importantes funções e são responsáveis por modular diretamente a distribuição espacial dessa espécie.

Palavras-chave: Caridea, camarões fitófilos, distribuição espacial, preferência de habitats.

Introduction

Aquatic macrophytes carry significant ecological importance because they are used as areas of protection, reproduction, and nursery by several organisms, especially invertebrates. Furthermore, their underwater stems and roots retain considerable amounts of particulate matter and debris that comprise the diet of various species. Organisms associated with macrophytes are known as phytophilous (see Thomaz & Bini 2003, Thomaz & Cunha 2010, for revision).

A large number of phytophilous invertebrates live in or above emerging and/or floating macrophytes, forming a highly diversified community that can be obligatory or optional (Thomaz & Bini 2003). According to Dibble & Thomaz (2006) and Thomaz & Cunha (2010), the architecture of each species of macrophytes creates different levels of heterogeneity resulting in different habitats for aquatic organisms. Several groups of invertebrates are associated with macrophytes, ranging from protists to large crustaceans, including

shrimps of the infraorder Caridea (see Williner & Collins 2022, Montoya 2003).

The infraorder Caridea Dana, 1852 is a group composed of about 40 families represented by more than 3400 species (De Grave & Franssen 2011). Paschoal *et al.* (2013a) analysed the association of four species of caridean shrimps with three species of macrophytes and described some general ecological aspects of these phytophilous organisms. Recently, Paschoal *et al.* (2019) verified the importance of macrophytes in the reproductive biology of the Amazon River prawn *Macrobrachium amazonicum* (Heller, 1862). However, there is still no data in scientific literature or specific information on how a given species of macrophyte can influence or modulate the population structure of a caridean shrimp.

Considered a phytophilous shrimp, the “potitinga” shrimp *Palaemon pandaliformis* (Stimpson, 1871) is a small amphidromous species (total length range: 6.3 - 36.4 mm), i.e. its larvae

depend on estuarine environments (Fig. 1A). This non-commercial species shows a wide distribution along the Western Atlantic, occurring from Cuba to southern Brazil (Rio Grande do Sul state). It can be found in estuarine or freshwater environments with sand or mud substrates, under stones, plant debris or associated with macrophytes. Females of *P. pandaliformis* are larger than males, also, they exhibited longer lifespans. When carrying eggs, these females commonly associate with macrophytes - mainly, *Pontederia crassipes* (C. Mart.) Solms, probably using these areas as shelter and nursery. Despite its small size, this species plays an important role in the diet of many birds and fresh/saltwater fish species (Teixeira 1997, Melo 2003, Paschoal *et al.*, 2013a, 2016).

Considering this context, the aim of this study is to describe the role of three species of aquatic macrophytes and evaluate their influence on the population structure of amphidromous shrimp *P. pandaliformis* in Northeastern Brazil.

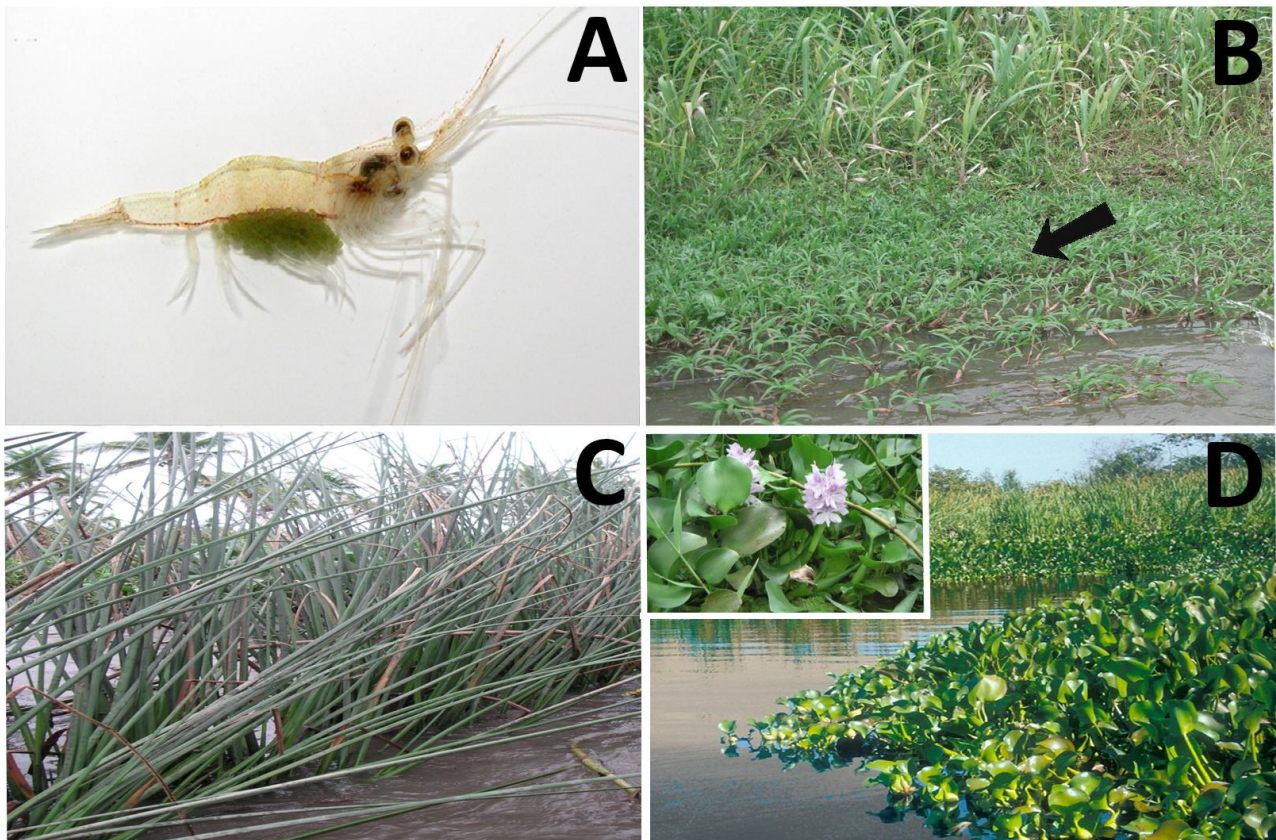


Figure 1. A) An ovigerous female of the “potitinga” shrimp *Palaemon pandaliformis* (Stimpson, 1871). Photo taken from WoRMS Photogallery: <https://www.marinespecies.org/photogallery.php?album=717&pic=151038#photogallery>. B) A bank of the erect emergent species of *Brachiaria* sp. (Trin.) Griseb., 1853. Note, the stolons (black arrow), long, strong and interlaced horizontal stems that enable buoyancy of the macrophyte bank. C) A bank of the erect emergent species of *Juncus* sp. (L.). D) A bank of the free-floating macrophyte species of *Pontederia crassipes* (C. Mart.) Solms. Inlet. The typical pale lilac flower of the water hyacinth showing the upper petal marked with blue and yellow splotch.

Materials and Methods

The Salsa River (15° 42'S; 38°59'W) is located in the south of the state of Bahia, northeast of Brazil. It is considered one of the main tributaries of the Pardo River, with a basin that covers an area of 30,360 km². This region is subject to *in natura* domestic sewage discharge, exploitation of artisanal and commercial fishing of fish and crustaceans, nature tourism and water sports (Paschoal *et al.* 2013b, 2016).

Samples were collected during the day on a monthly basis from September 2009 to August 2010, at nine sampling sites along a stretch of the Salsa River in Canavieiras municipality (for more details, see the Figure 1 of Paschoal *et al.* 2016). Shrimps were captured by means of active sampling, where samples were taken by one collector with a hand net (0.5 mm mesh) that was swept through marginal vegetation and macrophyte banks for 20 minutes, with three of which consisted of the erect emergent species of *Brachiaria* sp. (Trin.) Griseb., 1853 - Bra I, Bra II and Bra III, three other banks of the erect emergent *Juncus* sp. (L.) - Junc I, Junc II and Junc III and the last three *P. crassipes* - Poc I, Poc II and Poc III, a free-floating macrophyte (Figure 1C-D). With the exception of banks Bra I and Bra II, which are surrounded by pasture areas for livestock, no human activities were observed in the sampling area (Paschoal *et al.* 2013b, 2016). These sampling sites were selected due to the similar vegetative extension, abundance, and longevity of the macrophyte banks. All banks had approximately 5 x 10 m width x length, being 300 meters apart from each other. The sampling sites are located ~11 km from the estuary area.

After collection, the samples were preserved in 70% ethanol and transported to the Biological Oceanography Laboratory of the Universidade Estadual de Santa Cruz. Shrimps were identified according to Melo (2003). The sex of the individuals was determined by an examination of the shape of endopodite of the first pair of pleopods. In mature shrimps, the sex was confirmed by the presence or absence of the appendix masculina on the endopodite of the second pair of pleopods (Bauer 2004). Voucher specimens collected were deposited in the Museu de Zoologia da Universidade de São Paulo (MZUSP), under code MZUSP 28.313.

The carapace length (CL in mm - the distance between the posterior margin of the ocular orbit and the midpoint of the posterior margin of the carapace) of shrimps was measured using a stereomicroscope coupled to an imagery system.

Images were analysed using *ImageJ*[®] software version 1.45 (Rasband 2006). Immature individuals were considered for this study, all animals of which present CL ≤ 4.53 mm according to Paschoal *et al.* (2013b, 2016).

Population structure in each macrophyte bank was analysed by means of frequency distribution of individuals of both sexes in classes of carapace length (CL) with intervals of 1.0 mm. Sex proportions at sampling stations were compared to verify if the sexes differed from the expected proportion of 1:1, with application of the Chi-Square (χ^2) test. Data were submitted to Correspondence Analysis (CA) to sort and graphically summarize the relationship patterns between the individuals of *P. pandaliformis* (sex and maturity) and the nine macrophyte banks along the Salsa River. This analysis was performed using Statistica 8.0 software (StatSoft Inc 2007).

Results and discussion

A total of 4,151 individuals were captured and analysed (2,860 males and 1,291 females, of which 452 were ovigerous) between September 2009 and August 2010. Figure 2 shows distribution by size classes in the nine macrophyte banks. Around 13% of the captured individuals were juvenile, mainly concentrated at sampling stations Bra I and Bra II (Fig. 2). The highest total abundances were recorded in Bra I, Bra II and Junc I. Males and females presented a greater number of individuals (i.e. modal peak) in intermediate size classes, maintaining a high abundance (> 60%) between classes of 4-7 mm CL. The highest record of ovigerous females (N: 105) occurred in Poc II.

Greatest abundances of individuals were recorded in banks with a predominance of *Brachiaria* sp. (Bra I: 597 and Bra II: 713), located at the margins of an extensive pasture without cattle rotation. This characteristic, added to high rainfall rates in the region, causes direct surface flow of faecal matter generating high levels of organic matter (Paschoal *et al.* 2016). Furthermore, in aquatic environments, species of the genus *Brachiaria* create stolons, long, strong and interlaced horizontal stems that enable buoyancy (Figure 1B). The largest input of organic matter and the complex spatial structure of the root system of the dominant macrophyte could justify the higher number of individuals found in comparison with the others, and the fact that their stolons are capable of retaining a considerable amount of faecal matter; Frankenberg & Smith Jr. (1967) and Hall-Spencer &

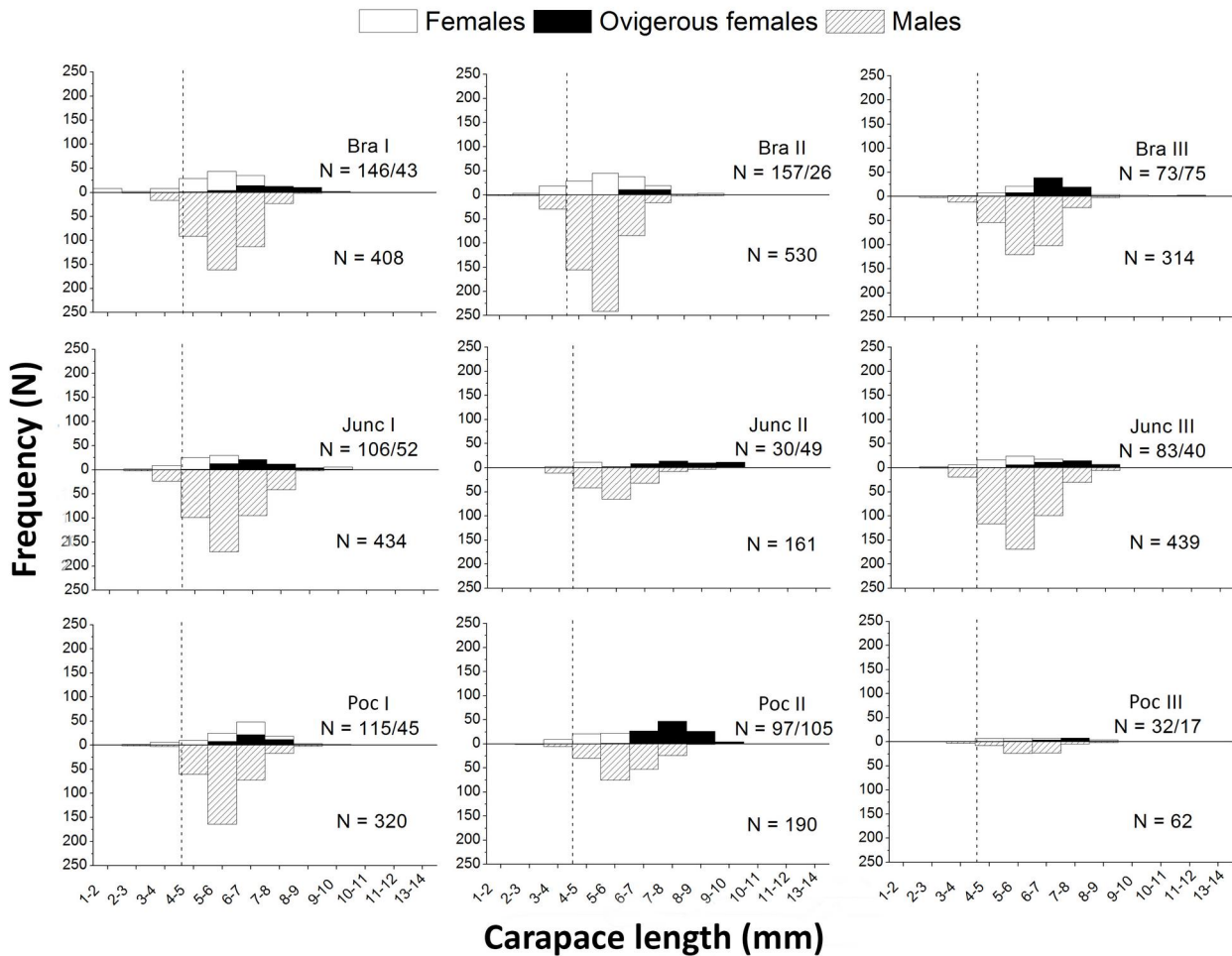


Figure 2. Absolute length–frequency distribution of males and females of *Palaemon pandaliformis* collected from September 2009 and August 2010 in nine macrophytes banks of Salsa River (Canavieiras, Bahia, Brazil). Dotted line at 4.53 mm was drawn for illustrative purposes, indicating recruitment of small individuals into the population, according to Paschoal *et al.* (2013b).

Bamber (2007) observed this assimilation and signalled their use as a food source for crustaceans.

The total mean sex proportion (M:F) during the year was 2.21:1. Males dominated most of the collection sites, varying from 3.57:1 in Junc I to 1.26:1 in Poc III. Only banks Poc II and Poc III did not significantly differ from the expected sex proportion (Fig. 3).

According to Fisher (1930), sexual selection favours the production of offspring with a sex proportion of 1:1. However, Wilson & Pianka (1963) noted that differences in rates of growth, mortality and lifespan between sexes may result in a sexual ratio that deviates from the normally expected ratio, which may manifest at birth and increase among adult individuals, as observed in this study. Paschoal

et al. (2013b, 2016) suggest that deviations in favour of males are caused by the shorter lifespan of males in relation to females, constantly being replaced within the population, while older and larger females remain. This fact would also explain the predominance of males in intermediate size classes and lesser average sizes.

In the study area, females were larger than males (Paschoal *et al.* 2013b, 2016). Berglund (1981) states that larger females are more vulnerable to starvation and predation, in addition to having a limited escape capacity due to egg incubation, which impairs quick bending of the abdomen. Paschoal *et al.* (2013a) suggest that adult females of Palaemonidae and Atyidae (especially ovigerous ones) seek refuge in specific habitats to become less

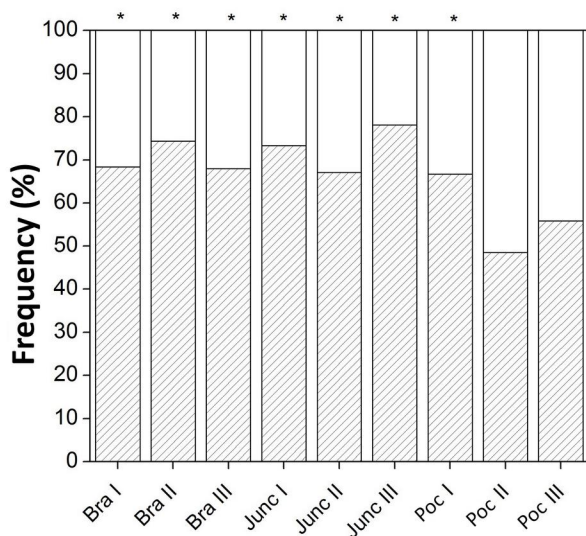


Figure 3. Sex proportion of males (dashed) and females (white) of *Palaemon pandaliformis* collected from September 2009 and August 2010 in nine macrophytes banks of Salsa River (Canavieiras, Bahia, Brazil). * statistically significant at $p \leq 0.05$.

susceptible to predators. In addition, Paschoal *et al.* (2019) verified that ovigerous females of *M. amazonicum* of small-size phenotype were commonly captured near to macrophytes of deeper environments. The authors related this occurrence to the fact that small-sized caridean ovigerous shrimps use macrophytes as shelter and nursery. Probably, areas with high densities of macrophytes, as observed in Poc II and Bra III, likely serve as a habitat and shelter against predators, thus favouring the occurrence of ovigerous females.

Figure 4 shows CA for sex and maturity of *P. pandaliformis* and three species of macrophytes in which they were captured. Analysis revealed that the first two axes (dimensions) explain 86.2% of the data variability (inertia). Ovigerous females and juvenile males of *P. pandaliformis* and banks Bra II and Poc II were the ecological parameters with the largest contribution in the Axes 1 and 2 (Table 1).

In this study, juvenile individuals of both sexes and adult males were extensively associated with banks of *Brachiaria* sp.. The structural characteristics of this macrophyte may offer shelter for juvenile and smaller adult males. Moreover, as their roots retain a considerable amount of organic matter (Thomaz & Cunha 2010), this environment may represent a feeding area for this species.

Females were associated with banks of *P. crassipes*, as previously observed by Montoya (2003) and Paschoal *et al.* (2013a, 2019), who stated

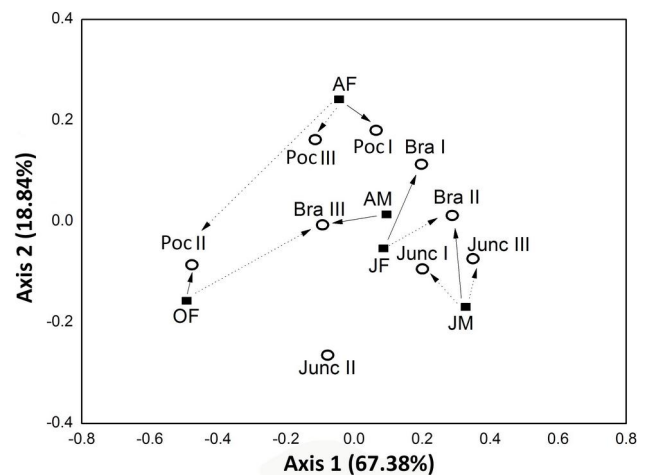


Figure 4. Total occurrence of *Palaemon pandaliformis* and macrophyte banks of Salsa River (Canavieiras, Bahia, Brazil) based on Correspondence Analysis. Solid arrows indicate greater association with each species to a given macrophyte bank, dotted arrows indicate secondary associations. JM: juvenile male, JF: juvenile female, AM: adult male, AF: adult female, OF: ovigerous females. For others abbreviations see the text above.

Table I. Mass, quality and relative inertia (proportion of the contribution) of ecological parameters in the Correspondence analysis used in Figure 4. Values in bold indicate the largest contribution in axes. For abbreviations, see Figure 4.

Parameters	Mass	Quality	Relative inertia
AF	0.138	0.905	0.127
OF	0.111	0.999	0.501
JF	0.064	0.021	0.085
AM	0.470	0.237	0.046
JM	0.217	0.973	0.241
Bra I	0.144	0.586	0.047
Bra II	0.174	0.862	0.143
Bra III	0.111	0.530	0.103
Poc I	0.115	0.892	0.085
Poc II	0.094	0.944	0.367
Poc III	0.027	0.916	0.038
Junc I	0.142	0.794	0.033
Junc II	0.058	0.994	0.090
Junc III	0.135	0.894	0.094

that this macrophyte plays an important role in the population dynamics of Palaemonidae and that their parts (especially roots and rhizomes) are used as sites of protection, reproduction and nursery by shrimps of the genus *Macrobrachium* Bate, 1868. Considering that the roots of floating species, such as the genus *Pontederia*, are rich in microalgae and

particulate matter (Thomaz & Cunha 2010), they can increase the quantity and quality of nutritional resource that will be used, which supports the pattern found in the present study where banks of this species presented the highest number of females. Ovigerous females were segregated from the other groups showing a pattern of habitat preference that depended both on complexity and density of the studied bank with greater abundance in bank Poc II, followed by Bra III. Consequently, juveniles and adult males share different niches than those used by females and ovigerous females, reducing intraspecific competition.

We can conclude that the composition and density of macrophyte banks influences spatial distribution of *P. pandaliformis* in the Salsa River, indicating the importance of studies that analyse interactions between shrimps and plants in natural environments. More robust studies involving these interactions in other freshwater systems are necessary to understand the role that environment characteristics can play in the biological and evolutionary processes of phytophilous caridean shrimps.

Ethical statement

The present investigation did not involve regulated animals and did not require approval by an Ethical Committee.

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References

Bauer, R. T. 2004. **Remarkable Shrimps. Adaptations and Natural History of the**

Carideans. University of Oklahoma Press, Oklahoma, 282 p.

- Berglund, A. 1981. Sex dimorphism and skewed sex ratios in the prawn species *Palaemon adspersus* and *P. squilla*. **Oikos**, 36: 158-162.
- De Grave, S. & Fransen, C. H. J. M. 2011. Carideorum Catalogus: The recent species of the Dendrobranchiate, Stenopodidean, Procarididean and Caridean shrimps (Crustacea: Decapoda). **Zoologische Mededeelingen**, 85: 195-589.
- Dibble, E. D. & Thomaz, S. M. 2006. A simple method to estimate spatial complexity in aquatic plants. **Brazilian Archives in Biology and Technology**, 49: 421-428.
- Fisher, R. A. 1930. **The genetical theory of natural selection.** Clarendon Press, New York, 291 p.
- Frankenberg, D. & Smith Jr, K. L. 1967. Coprophagy in marine animals. **Limnology and Oceanography**, 12: 443-450.
- Hall-Spencer, J. & Bamber, R. 2007. Efectos del cultivo de salmón sobre crustáceos bénticos. **Ciencias Marinas**, 33(4): 353-366.
- Melo, G. A. S. 2003. Famílias Atyidae, Palaemonidae, Sergestidae. Pp. 289-415. In: Melo, G. A. S (Org.). **Manual de Identificação dos Crustacea Decapoda de água doce do Brasil.** Edições Loyola/Museu de Zoologia, São Paulo, Brazil, 430 p.
- Montoya, J. V. 2003. Freshwater shrimps of the Genus *Macrobrachium* Associated with roots of *Eichhornia crassipes* (Water Hyacinth) in the Orinoco Delta (Venezuela). **Caribbean Journal of Science**, 39(1): 155-159.
- Paschoal, L. R. P., Guimarães, F. J. & Couto, E. C. G. 2016. Growth and reproductive biology of the freshwater shrimp *Palaemon pandaliformis* (Stimpson, 1871) (Crustacea: Palaemonidae) in northeast of Brazil (Canavieiras, Bahia). **Zoologia**, 33 (6): e20160060.
- Paschoal, L. R. P., Guimarães, F. J. & Couto, E. C. G. 2013b. Relative growth and sexual maturity of the freshwater shrimp *Palaemon pandaliformis* (Crustacea: Palaemonidae) in northeast of Brazil (Canavieiras, Bahia). **Iheringia, Série Zoologia**, 103(1): 31-36.
- Paschoal, L. R. P., Oliveira, L. J., Andrioli, G. C., & Zara, F. J. 2019. Reproductive biology of *Macrobrachium amazonicum* (Heller, 1862) populations with distinct phenotypes in Neotropical reservoirs during the ‘El Niño’

- event. **Marine and Freshwater Research**, 70(10), 1465-1479.
- Paschoal, L. R. P., Souza, R. M., Guimarães, F. J. & Couto, E. C. G. 2013a. Phytophilous caridean shrimps in northeast of Brazil (Canavieiras, Bahia). **Nauplius**, 21(1):123-126.
- Rasband, W. S. 2006. **ImageJ: Image Processing and Analysis in Java**. National Institutes of Health, Research Services Branch Bethesda, accessible at <http://rsb.info.nih.gov/ij/docs/index.html>. (Accessed on: 09/01/2010).
- STATSOFT INC. 2007. **STATISTICA (data analysis software system)**. Software version 8.0, accessible at <http://www.statsoft.com>. (Accessed on: 09/01/2010).
- Teixeira, R.L. 1997. Distribution and feeding habits of the young common snook, *Centropomus undecimalis* (Pisces: Centropomidae), in the shallow waters of a tropical Brazilian estuary. **Boletim do Museu de Biologia Mello Leitão**, 6, 35-46.
- Thomaz, S. M. & Bini, L. M. 2003. **Ecologia e manejo de macrófitas aquáticas**. EdUEM, Maringá, 341 p.
- Thomaz, S. M. & Cunha, E. R. 2010. The role of macrophytes in habitat structuring in aquatic ecosystems: methods of measurement, causes and consequences on animal assemblages composition and biodiversity. **Acta Limnológica Brasiliensia**, 22(2), 218-236.
- Williner, V. & Collins, P. 2002. Variación espacio-temporal de la actividad del camarón dulceacuícola *Macrobrachium jelskii* (Miers, 1877). **Ecología Austral**, 123, 3-10.
- Wilson, M. F. & Pianka, E. R. 1963. Sexual selection, sex ratio and mating system. **American Nature**, 97: 405-407.

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