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POPULATIONAL DYNAMICS OF *Pseudodiaptomus marshi* (CRUSTACEA: COPEPODA) IN THE CAETÉ ESTUARY (BRAZIL)

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ABSTRACT

The aim of this study was to evaluate the spatial and temporal density and biomass distribution of the planktonic copepod *Pseudodiaptomus marshi* in the Caeté Estuary (Pará, Brazil) during the months of June and December of 1998 (dry season), February and May of 1999 (rainy season). The Caeté Estuary was characterized by high spatial and temporal variations in salinity (0.7±0.55 to 37.2±0.21). The Spearman correlation analysis showed a significant negative correlation (rs = -0.75, p<0.05) between salinity and density of *P. marshi*, suggesting the species preference for estuarine areas where oligohaline-mesohaline regimes were predominant. A linear length-weight relationship was obtained and expressed as: DW = 125.46 + 0.1467PL (r = 0.32; p<0.05). In the present study, density and biomass values oscillated between 0.0 to 21.4±18.26 ind.m^{-3} and 0.0 to 0.583±0.51 mg DW. m^{-3}, respectively. There, monthly differences in density (H=6.71; p<0.05) and biomass (H = 6.76; p<0.05) among the three sampling areas were significant only in June, with the highest values registered in the upper estuary. The results showed that spatial and seasonal variability registered in the occurrence and distribution of *P. marshi* was strongly regulated by salinity, with the highest density and biomass recorded concomitantly to the lowest salinity values.

Key-words: Biomass, copepod, salinity, Amazon estuary.

RESUMO

DINÂMICA POPULACIONAL DE *Pseudodiaptomus marshi* (CRUSTACEA: COPEPODA) NO ESTUÁRIO DO CAETÉ (BRASIL)

O presente estudo tem por objetivo principal avaliar a distribuição espacial e temporal da densidade e biomassa do copépodo planctônico *Pseudodiaptomus marshi* no Estuário do Caeté (Pará, Brasil), durante os meses de junho e dezembro de 1998 (estação seca), fevereiro e maio de 1999 (estação chuvosa). O Estuário do Caeté caracterizou-se por uma ampla variação espacial e temporal da salinidade (0,7±0,55 a 37,2±0,21). A análise de correlação de Spearman revelou uma correlação negativa significativa (rs = -0,75; p<0,05) entre a salinidade e a densidade de *P. marshi*, sugerindo a preferência desta espécie por áreas estuarinas onde foram dominantes os regimes oligohalino-mesohalino. A relação peso-comprimento foi do tipo linear, sendo expressa pela equação: PS = 125,46 + 0,1467CP (r = 0,32; p<0,05). No presente estudo, os valores de densidade e biomassa variaram respectivamente de 0,0 a 21,4±18,26 ind.m^{-3} e 0,0 a 0,583±0,51 mg PS. m^{-3}. As diferenças mensais na densidade (H = 6,71; p<0,05) e biomassa (H = 6,76; p<0,05) entre as três áreas de amostragem foram significativas somente em junho, com os maiores valores registrados no estuário interno. Os resultados revelaram que a variabilidade espacial e sazonal na ocorrência e distribuição de *P. marshi* foi fortemente regulada pela salinidade, com as maiores densidades e biomassas registradas simultaneamente aos menores valores de salinidade.

Palavras-chave: Biomassa, copépodo, salinidade, estuário amazônico.

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INTRODUCTION

With regard to the organisms that comprise the zooplankton of coastal and marine environments, copepods are one of the most important in terms of density and biomass (Froneman 2002, Kibirige & Perissinotto 2003). In these environments, copepods are among the mainly secondary producers (Islam et al. 2006), playing a relevant role in nutrient recycling and in the transfer of energy between phytoplankton and bacterioplankton to the highest trophic levels (Parsons et al. 1984, Banse, 1995). Furthermore, they are well known as a natural food source for fish larvae (Schipp et al. 1999).

The variability observed in composition, distribution, density and biomass of estuarine copepods is spatially and temporally heterogeneous. In mangrove estuaries, this variability is due to environmental parameters such as salinity, turbidity, tidal regime, local pluviometric patterns, food availability, etc. (Revis 1988, Mckinnon & Klumpp 1998, Ara 2004, Osore et al. 2003).

The calanoid copepods of the genus *Pseudodiaptomus* inhabit fresh to hypersaline waters and are widely distributed around the world (Walter 1986). *Pseudodiaptomus marshi* Wright, 1936 is observed along the western coast of the Central and South Atlantic (Almeida Prado Por & Lansac-Tôha 1984, Walter 1989, Reid 1990, Artigas et al. 2003, Suárez-Morales 2003). In Brazil, this species has often been reported as an important component of the mesozooplankton communities in many estuaries and tidal creeks from the North (Peres 1999, Krumme & Liang 2004) and Northeast regions (Bonecker 1995, Silva et al. 1996). In the Caeté Estuary, some studies on zooplankton such as Barletta-Bergan et al. (2002), who evaluated structure and seasonal dynamics of larval fish assemblage and Magalhães et al. (2006) which studied spatial and temporal variations of two *Pseudodiaptomus* species, observed that the variability in density and biomass distribution of those groups were associated with seasonal periods, as well as with sampling sites. Therefore, in order to better understand the dynamics of these organisms in Amazonian estuaries, the present study aimed to know the spatial and temporal distribution patterns, in terms of density and biomass, of the planktonic copepod *P. marshi* regarding the salinity gradient in the Caeté Estuary.

MATERIAL AND METHODS

Study area

This study was performed in the Caeté Estuary (0°45'- 1°07'S e 46°50'- 46°30'W) located on the Northern Brazilian littoral (Figure 1). The climate is equatorial warm and humid. Mean annual pluviometric precipitation is approximately 2,500 mm with most precipitation occurring in the rainy season (January at May) (INMET 2003) (Figure 2). The Caeté Estuary is influenced by a semidiurnal macro-tide regimen with tidal heights greater than 5 m (Diele 2000). This ecosystem is bordered by mangrove forests, composed of 20 m tall trees (Lara & Dittmar 1999), dominated by *Rhizophora mangle* Linnaeus, 1753, *Avicennia germinans* Linnaeus, 1764 and *Laguncularia racemosa* Linnaeus, 1807 (Menezes et al. 2003). A detailed description of the study area can be found in Diele et al. (2005). The studied area was divided in three sampling sites, according to the salinity gradient: upper (A), middle (B) and lower estuary (C) (Figure 1). The lower estuary is strongly influenced by seawater. The opposite is verified to the upper estuary, which is directly affected by Caeté River discharges. In the middle estuary, intermediate salinity values can be observed.

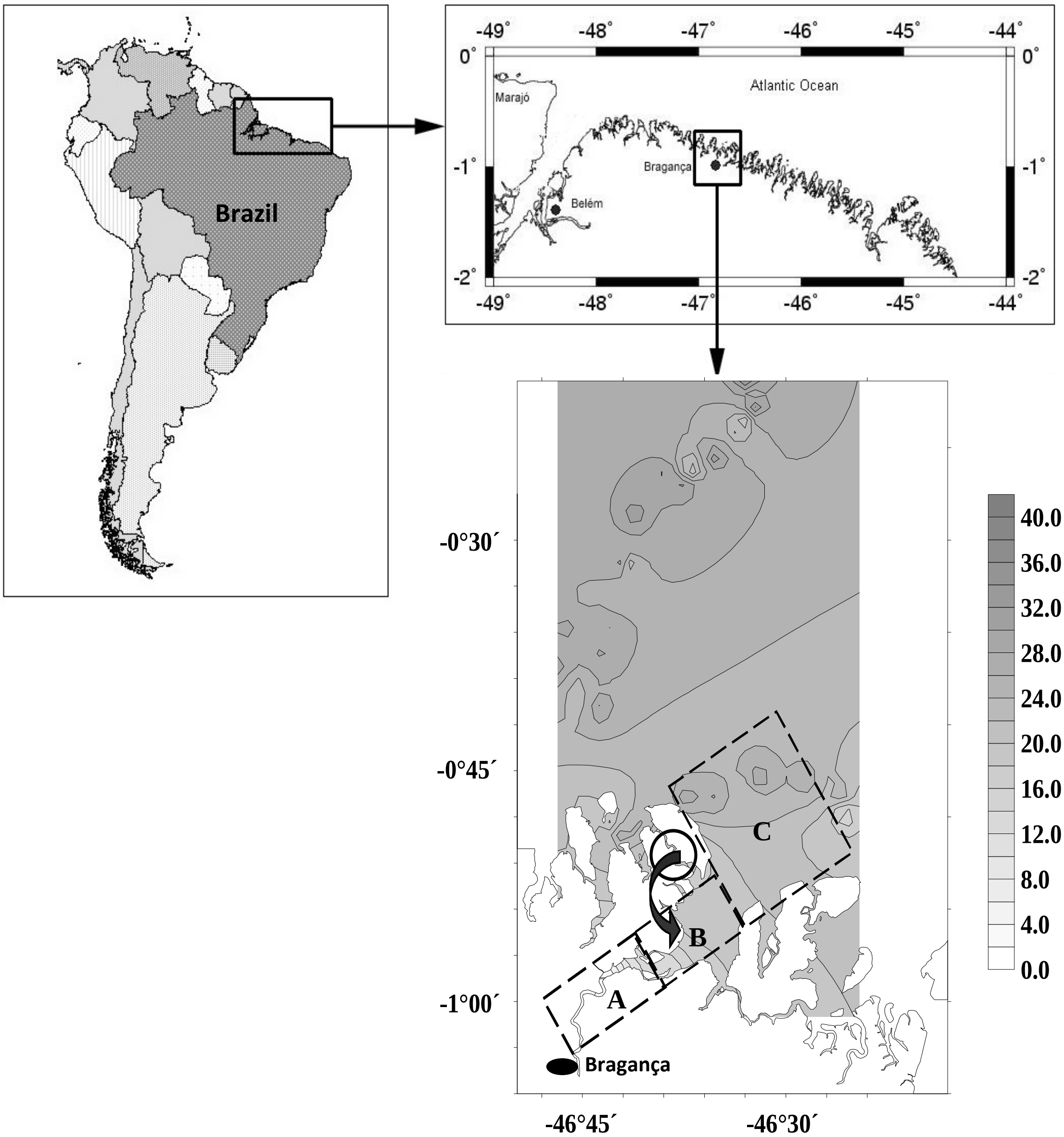

Figure 1 - Geographical localization of the Caeté Estuary and position of the three sampling areas, determined according the salinity gradient: upper (A), middle (B) and lower estuary (C). The circled area in the map was considered part of the middle estuary.

Field methods

For each sampling area three replicates were obtained downstream during spring tide, producing a total of 36 plankton samples. These samplings were carried out during the months of June and December of 1998 (dry season), February and May of 1999 (rainy season).

Zooplankton samples were collected by sub-surface hauls with duration of 5 minutes, using a conical plankton net (300 μm mesh size and 0.32 m mouth opening diameter) equipped with a digital flowmeter (*Hydrobios*, *Kiel*) attached to the mouth of the net. The hauls were performed using a small powerboat at an average speed of 1.5 knots. After collection, samples were immediately preserved in a 4% buffered formalin-seawater solution. Sub-surface salinity measurements were registered *in situ* during all sampling procedures using an optical refractometer (Atago, Model S/Mill-E).

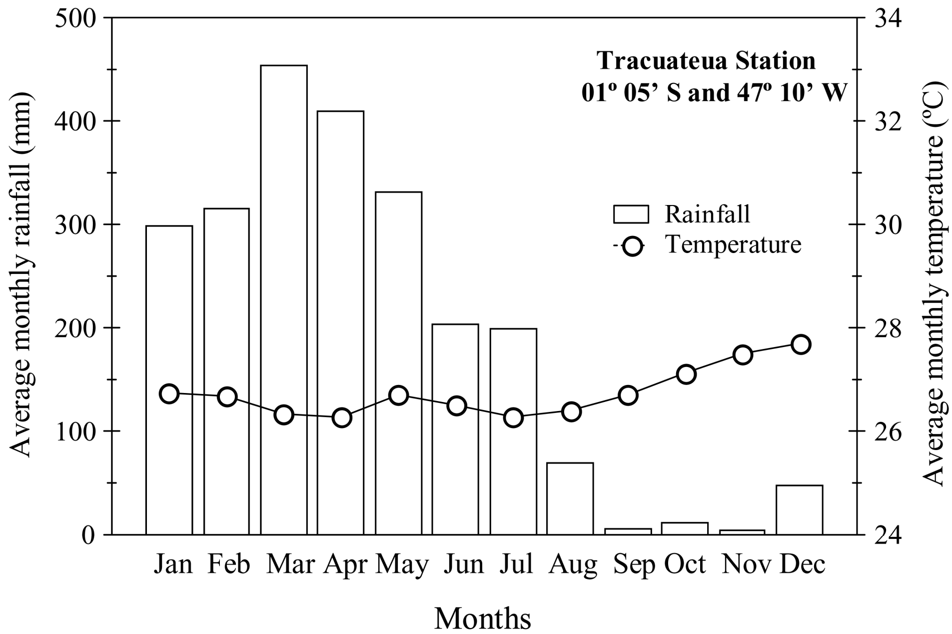

Figure 2 - Climate diagram of Tracuateua Meteorological Station. Average monthly between 1995 and 2002 (Source: INMET, 2003).

Laboratory procedures

Subsamples were obtained to determine numerical density and biomass using a Folsom plankton sample splitter (Mcewen et al. 1957), as described by Boltovskoy (1981). The frequency of occurrence (percentage of samples in which *P. marshi* occurred in relation to the total number of samples) was also determined. In the present study, only the adult stage of *P. marshi* (CVI) was investigated. The length of the specimens (prosome length) was measured through an eyepiece micrometer with the animals placed in a lateral position to avoid possible errors that could be triggered by the body curvature. After measurement, the organisms were quickly rinsed in distilled water and placed in minuscule (40 mm in diameter), pre-weighed, aluminum foil dishes. After, they were dried at a constant temperature (60ºC) in an electric oven for 24 hours and put in a desiccator with silica gel to cool at room temperature. Their dry weight measurements were taken using an electronic microbalance (Sartorius, Model BP-410S). Weight loss subsequent to formalin use was not taken into consideration (Chisholm & Roff 1990).

Biomass was estimated by the product of density (ind. m^{-3}) of each length class and the average dry weight of individuals sampled in each class (DW, µg), which was calculated from prosome length (PL, µm), by a linear length-weight regression equation, expressed as:

$$DW = a + bPL,$$

Where a and b are constant.

Data analysis

The raw data of density and biomass were log-transformed log (n+1) so that their distributions approached normality. If data remained non-normal, even after transformation, a Kruskal-Wallis non-parametric test was applied to evaluate the differences in density and biomass of *P. marshi* in spatial and temporal scale (Zar 1999). Correlation between density of *P. marshi* species and salinity were assessed using the Spearman rank correlation analysis. The analyses were performed with the computer software package STATISTICA, version 5.0.

RESULTS AND DISCUSSION

In the Caeté Estuary, a large variation of salinity was observed (0.7±0.55 to 37.2±0.21; average ± standard deviation). Independently from seasonal sampling period, the upper estuary always presented the lowest average salinity values, with a gradual downstream increase. An opposite trend was verified for the lower estuary (Figure 3). Similar observations were registered by Barletta et al. (2005). Significant differences between the three sampling areas were only reported in the month of May ($p<0.05$). The relatively high salinity (28.8), observed in the upper estuary in February may be due to the inundation of mangrove areas which remained exposed during the dry season, when salt crystal formations could be observed. During months of relatively high precipitation, the strong river flow leads to flooding in these areas, occasioning the increase of salinity in punctual zones of the estuary, which could explain the absence of *P. marshi* in the samples collected during this month.

In this survey, seasonal changes in salinity could be clearly noted, mainly when comparing data recorded in the upper estuary in May (rainy season) with those observed in December (dry season). This probably occurred due to differences in the amount of rainfall between the two seasons.

Although *P. marshi* is able to survive and even reproduce in hypersaline waters (Medeiros et al. 2006), the significant negative Spearman correlation ($r_s = -0.75$; $p<0.05$) between salinity and density suggests the species preference for estuarine areas where oligohaline-mesohaline regimes were predominant, as already reported for other estuaries of the Brazilian coast (Nascimento & Rocha 1984, Araujo 1996). Thus, the low intraspecific tolerance to high salinities was responsible by absence of *P. marshi* in the samples collected in different sampling areas, as well as in different seasonal periods (Figure 3). Madhu et al. (2007) showed that seasonal oscillations in salinity represent a major factor controlling the distribution and abundance of micro- and mesozooplankton in a tropical estuary (Cochin backwaters - India). In the present study, along with the decrease in the rainfall during the dry season, a gradual decrease in the river discharge is observed and a consequent increase in salinity throughout the estuary was registered. The rainfall influence on seasonal changes in salinity has been reported in several tropical estuaries worldwide (Habib Mohamed & Abdul Rahaman 1987, Thüllen & Berger 2000, Blaber 2002, Lam-Hoai et al. 2006, Giarrizzo & Saint-Paul 2008).

P. marshi was present in only 27.8% of the thirty-six samples, and it was not observed in any of the three sampling areas during the month of February, besides being absent in lower estuary during June and December. Although this organism is characterized as a numerous species in northern and northeastern Brazilian estuaries (Björnberg 1981), in the Caeté Estuary *P. marshi* showed low density values that ranged from 0.0 to 21.4±18.26 ind.m^{-3} (Figure 3). Monthly differences in density among sampling areas (spatial study) were significant only in June ($H = 6.71$; $p<0.05$), with the highest values registered in the upper estuary. However, there were no significant differences between density registered within a same area, but in different months (temporal study).

Once several species of zooplanktophagous fish (e.g. *Stellifer rastrifer* Jordan 1889, *Stellifer naso* Jordan 1889, *Macrodon ancylodon* Bloch & Schneider 1801) feed preferentially on copepods, among them juveniles and adults of *P. marshi* (Keuthen 1998, Camargo & Isaac 2004), the biomass assessment through length-weight equations could be also useful to evaluate copepod contribution in the diet of these fish, and so better understand their role in the local aquatic food webs. In the present study, a significant linear relationship between dry weight and prosome length was obtained for *P. marshi* and described as: $DW = 125.46 + 0.1467PL$ ($r = 0.32$; $p<0.05$). This relationship was based on measurements from individuals collected in different sampling seasons. Therefore, it is assumed that possible seasonal variations in length-weight relationship of *P. marshi* had been buffered. According to Ara (2001), such variations cannot be significant as variations in temperature and food availability in tropical and sub-tropical regions are much less significant than in temperate and boreal areas.

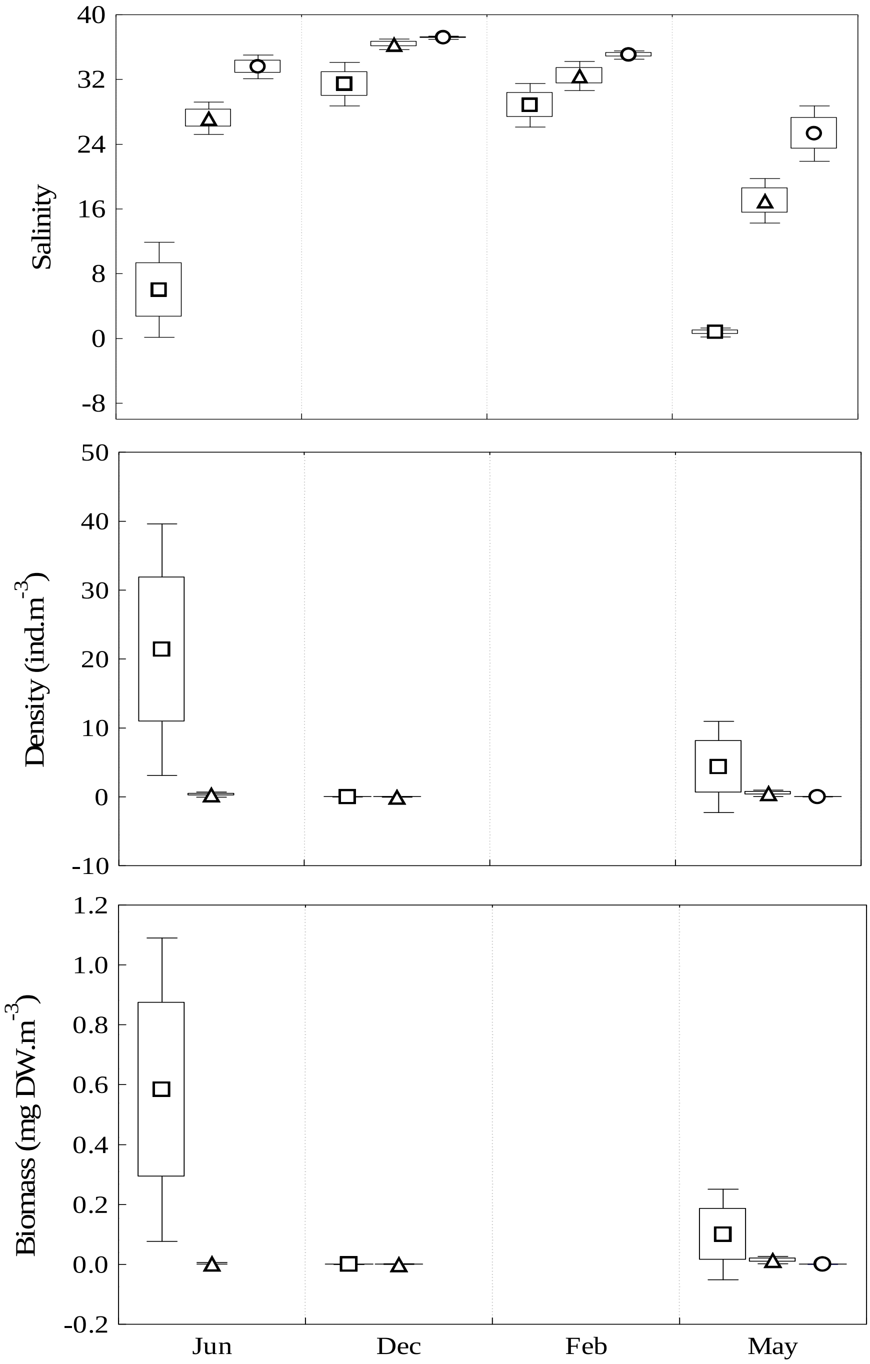

Figure 3 - Spatial and temporal variation in salinity, density and biomass values of *P. marshi* in the Caeté Estuary (□ upper, Δ middle and ○ lower estuary). These values are expressed as mean ± standard deviations (vertical bars) and standard errors (box).

Information regarding the estuarine copepods biomass (dry weight), in special *P. marshi*, is still scarce. Due to the large mesh size of the plankton net employed in this survey, the overall biomass estimations were performed exclusively for the adult stages. Adult dominance, in the case of *Pseudodiaptomus* genus specimens, was previously reported (Uye et al. 1983, Uye & Sano 1995). Biomasses obtained in this study oscillated between 0.0 to 0.583±0.51 mg DW. m^{-3} (Figure 3). Similarly as observed for density, monthly differences in biomass between sampling areas were significant only in June ($H = 6.76$; $p<0.05$), while differences recorded within the same area, but in different months, were significant only for the upper estuary ($H = 8.19$; $p<0.05$).

In the Caeté Estuary, density values of *P. marshi* were lower than those reported in other Brazilian estuaries (Silva et al. 2003, Lucas 2006). The low values registered in the studied area may have occurred due to the characteristic of the net mesh (300 μm) employed in the plankton samplings that captured predominantly adult individuals (CVI). Consequently, naupliar and copepodits stages that could have influenced the overall population density and biomass were not taken into consideration. In conclusion, the present data are useful to understand the population structure of *P. marshi* planktonic copepod in the Caeté Estuary, although future ecological studies should be also carried out on a short and long-time scale, with the employment of not only 300 μm, but also 64 and 120 μm mesh size nets, in order to capture the early development stages (nauplii) as well as juveniles (copepodits).

CONCLUSIONS

The Caeté River Estuary was characterized by an accentuated variation in surface water salinity, which influenced spatial and temporal occurrence and distribution of *P. marshi*. The significant negative Spearman correlation between salinity and density suggests the species preference for estuarine areas where oligohaline-mesohaline regimes were predominant. Therefore, a low intraspecific tolerance to high salinities was responsible by absence of *P. marshi* in the samples collected in different sampling areas, as well as in different seasonal periods, as was evidenced during the months of June, December and February. A linear length-weight regression equation was determined and the dry weight for *P. marshi* assessed using this equation. The relatively low density and biomass values reported in the Caeté Estuary could be explained by the selectivity of the net used in this study that captured predominantly adult individuals.

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