

MORPHOMETRICS OF JUVENILE WHITE SHRIMP IN SANTOS (SP, BRAZIL) - AN ATLANTIC STRESSED ESTUARY*

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ABSTRACT

Shrimps are one of the world's most valuable fishing resources, with the Penaeidae family having the greatest economic importance. In the southwest Atlantic the white shrimp *Litopenaeus schmitti* plays an important socioeconomic role for small-scale fisheries, and juveniles are targeted as live bait for recreational fisheries. This study was carried out monthly along two periods (May/2009-January/2010 and March/2011-March/2015) at Santos estuary and aimed to investigate the relationship between morphometric and sex of the early development stages of *Litopenaeus schmitti*. A total of 6,978 individuals were caught and measured, with no differences ($p > 0.1$) between sexes shown regarding total length or weight. Differences between males and females were found for Total length (TL) x Carapace length (CL) and TL x Total weight (TW) and negative allometries ($b < 3$) were found for all relationships. The results indicate that morphometric differences among sexes seem to be more associated with total length, suggesting that TL could be a more appropriate body measurement to compare specimens of *L. schmitti*, at least when the analysis includes juveniles. The presence of *L. schmitti* specimens all year long inside the estuary reinforces the idea of a continuous reproductive cycle with peak periods. Both information comes to fulfill part of the lack of knowledge regarding this species estuarine phases.

Keywords: length-weight relationship; morphometry; sex-ratio; *Litopenaeus schmitti*.

MORFOMETRIA DE JUVENIS DO CAMARÃO-BRANCO EM SANTOS (SP, BRASIL) - UM ESTUÁRIO IMPACTADO DO ATLÂNTICO

RESUMO

Camarões são um dos mais valiosos recursos pesqueiros, com a família Penaeidae tendo a maior importância econômica. No Atlântico sudoeste o camarão-branco *Litopenaeus schmitti* desempenha um papel socioeconômico importante à pesca artesanal, e os juvenis são visados para utilização como isca-viva para pesca amadora. Este estudo foi conduzido mensalmente durante dois períodos (maio/2009-janeiro/2010 e março/2011-maio/2015) no estuário de Santos e visou investigar as relações entre morfometria e sexos dos estágios iniciais de desenvolvimento do *Litopenaeus schmitti*. Um total de 6.978 indivíduos foram capturados e medidos, mas no que diz respeito ao comprimento e peso total não foram encontradas diferenças ($p > 0,1$) entre os sexos. Diferenças entre machos e fêmeas foram encontradas para as relações comprimento total (CT) x comprimento da carapaça (CC) e CT x peso total (PT) e foi observada alometria negativa ($b < 3$) para todas as relações. Os resultados indicam que as diferenças morfométricas entre os sexos parecem estar mais associadas com o comprimento total, sugerindo que o CT seja uma medida corporal mais apropriada para comparar indivíduos de *L. schmitti*, ao menos quando a análise incluir juvenis. A presença de indivíduos de *L. schmitti* dentro do estuário ao longo de todo ano reforça a ideia de um ciclo reprodutivo contínuo com períodos de pico reprodutivo. Ambas as informações ajudam a suprir parte da lacuna de informações a respeito das fases estuarinas desta espécie.

Palavras-chave: relação peso-comprimento; morfometria; proporção sexual; *Litopenaeus schmitti*.

INTRODUCTION

Shrimps are the second most valuable fisheries resource in the world (FAO, 2016a, 2016b), with the Penaeidae family having the greatest economic importance (Holthuis, 1980; Tavares, 2002). Their life cycle lasts about 18-24 months (Dura, 1985). Some of the species reach estuaries as post-larvae and stay there at least a third of its life

cycle before returning to coastal waters as subadults, where they are subject to marine fisheries (Tavares, 2002). In the southwest Atlantic, the white shrimp *Litopenaeus schmitti* (Burkenroad, 1936) plays a key socioeconomic role for small-scale fisheries (Machado et al., 2009), and juveniles are targeted as live-bait for recreational fishers. Despite extensive knowledge about its life cycle (Carvalho et al., 2015; Boos et al., 2016), there is still a lack of information regarding its estuarine phase (Alfaro-Montoya, 2010). We highlight the studies of Chu et al. (1995) in a Chinese estuary, Pérez-Castañeda and Defeo (2002) in a Mexican coastal lagoon and Kaka et al. (2019) that approached both estuarine and marine areas from Kenya. The lack of fisheries data regarding its abundance, especially regarding small-scale fisheries, is one of the reasons that made the species be considered as *data deficient* in Brazil according to the IUCN (International Union for Conservation of Nature) criteria (Boos et al., 2016).

Morphometrics are a valuable tool to evaluate distinct growth phases, while measurements of allometric growth allows describing size changes as a function of other features (Clayton, 1990). The allometric coefficient (b), from the length-weight relationship, can be used to obtain the condition factor (King, 2007), an index of the well-being of a specimen from a specific area or time (Richter et al., 2000), which can be linked to physiological, ecological and fisheries data (Beyer, 1991; Konan et al. 2014). Those assumptions were exemplified by Pérez-Castañeda and Defeo (2002) that connected the highest peaks of condition within periods considered with optimal ranges for the growth of penaeid shrimps.

This study was carried out in Santos estuary, a heavily stressed environment by port activities (Santos Port, the biggest of Latin America), and urban and industrial sewage and waste, leading to deleterious effects over sediment, benthic and planktonic organisms (Medeiros and Bicego, 2004; Sousa et al., 2007). This note aims to

investigate the relationships between morphometric characteristics and sex of the early development stages of *Litopenaeus schmitti* from Santos estuary.

MATERIALS AND METHODS

Samples were taken monthly along two periods, May/2009 to January/2010 and March/2011 to March/2015, with a small-scale artisanal drifting trawl (known locally as gerival, described by Gamba, 1994) at five locations in the Santos Estuary (Figure 1). Samplings consisted in three drags of 10 minutes each. The taxonomic identification was based on Baéz (1997) and Pérez-Farfante and Kensley (1997). Total and carapace lengths (nearest 1 mm) and the weight (0.01 g) were obtained for each specimen, and sex was also reported by the presence of *petasma* in males and telic in females. Average length and weight from both sexes were tested using a t test to check if carapace and total lengths and total weight differ between sexes. To check if the proportion of males and females were 1:1 a Chi-square test (X^2) with Yate's correction (Zar, 2010) was applied within months and size (total length) classes. Three regressions were done from each sex: linear regression ($CL = a + bTL$; a : intercept, b : allometric coefficient) for carapace length (CL) x total length (TL), and potential regressions ($W = aL^b$; a : intercept, b : allometric coefficient) for total weight (TW) x total length (TL) and total weight (TW) x carapace length (CL). Prior to the $CL \times TL$ relationships data was log-transformed, and then compared through an *ANCOVA* (Zar, 2010). The length-weight relationships ($TW-TL$ and $TW-CL$) were adjusted through a non-linear method (Spiess, 2014), and then compared through a maximum likelihood analysis (adapted from Kimura, 1980).

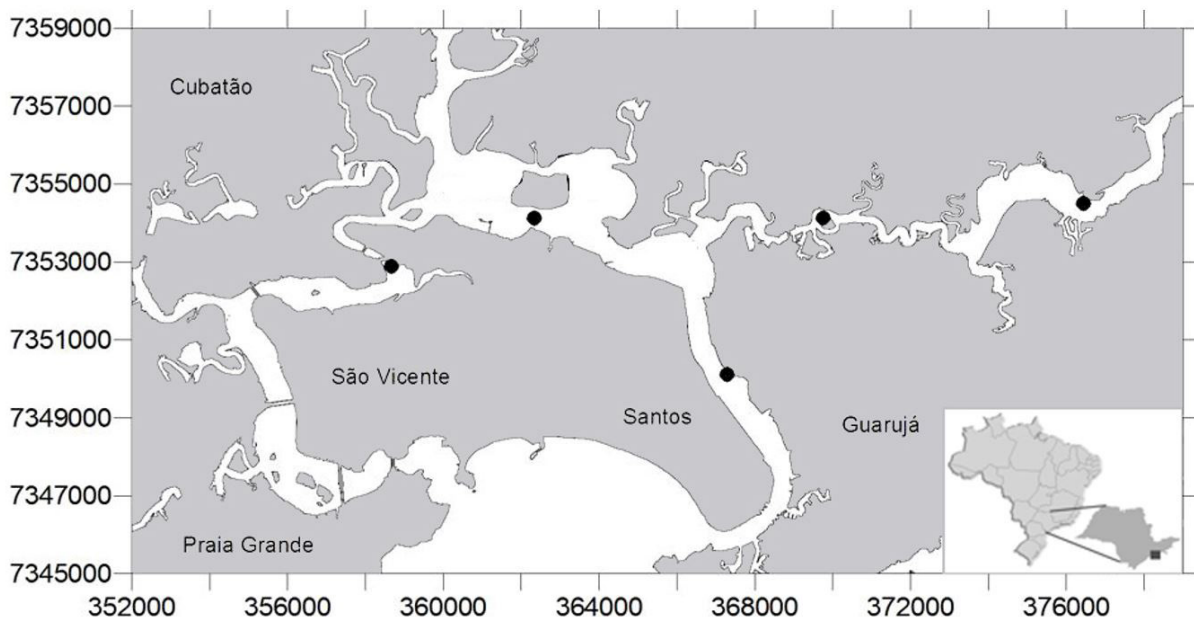


Figure 1. Location of the five sampling spots at the Santos Estuary, SP, Brazil. Datum UTM SAS 69.

RESULTS

Measurements were taken from 6,978 specimens of *Litopenaeus schmitti* (3,252 males and 3,727 females). Males showed larger amplitude for all measurements, but the data analysis suggests that there are no differences ($p > 0.1$) between males and females regarding their total length or weight. On the other hand, slight differences ($p = 0.05$) were observed for carapace length (Table 1). The population structure analysis demonstrated significant differences ($p < 0.01$) between the total proportions of males (46.59%) and females (53.41%), obtaining a sex ratio of 1:1.15 (Table 2). Females were more frequent for size classes under 75 mm and between 120 to 129 mm (Figure 2). Throughout the year, *L. schmitti* were more frequent from January to May (Table 2) and individuals larger than 129 mm CT were more frequent from July to November. Females were more frequent within months, except for January and November.

The comparisons between $TL \times CL$ ($p < 0.01$) and $TL \times TW$ ($p < 0.05$) relationships for males and females showed significant differences to both allometry coefficient (b) and interception coefficient (a), while no significant differences ($p > 0.1$) were found for $CL \times TW$ relationship among sexes (Table 3). Negative allometries ($b < 3$) were found for morphometric relationship on both sexes, while $TL \times TW$ allometric coefficients were close to 3 for males and females (Table 3).

DISCUSSION

The higher amount of *L. schmitti* individuals found from January through May was also observed by Santos et al. (2008) for this region, corroborating for the idea of a 'fishing season' on the Santos's estuarine waters during summer and fall. Santos et al. (2008) also found at São Paulo's coast a higher incidence of *L. schmitti* between

Table 1. Average lengths (mm), weight (g), with standard errors, and range of *Litopenaeus schmitti* caught at the Santos Estuary from May 2009 to March 2015. TL: total length, CL: carapace length, TW: total weight.

| | TL (mm) | CL (mm) | TW (g) |
|----------|-----------------------|--------------------------|-------------------------|
| Males | 87.78±0.33 (53 - 174) | 17.91±0.07 (3.89 - 44.7) | 4.26±0.04 (0.40 - 32.4) |
| Females | 87.68±0.34 (48 - 170) | 17.72±0.07 (7.35 - 40.8) | 4.16±0.04 (0.15 - 25.1) |
| <i>P</i> | 0.839 | 0.053 | 0.104 |

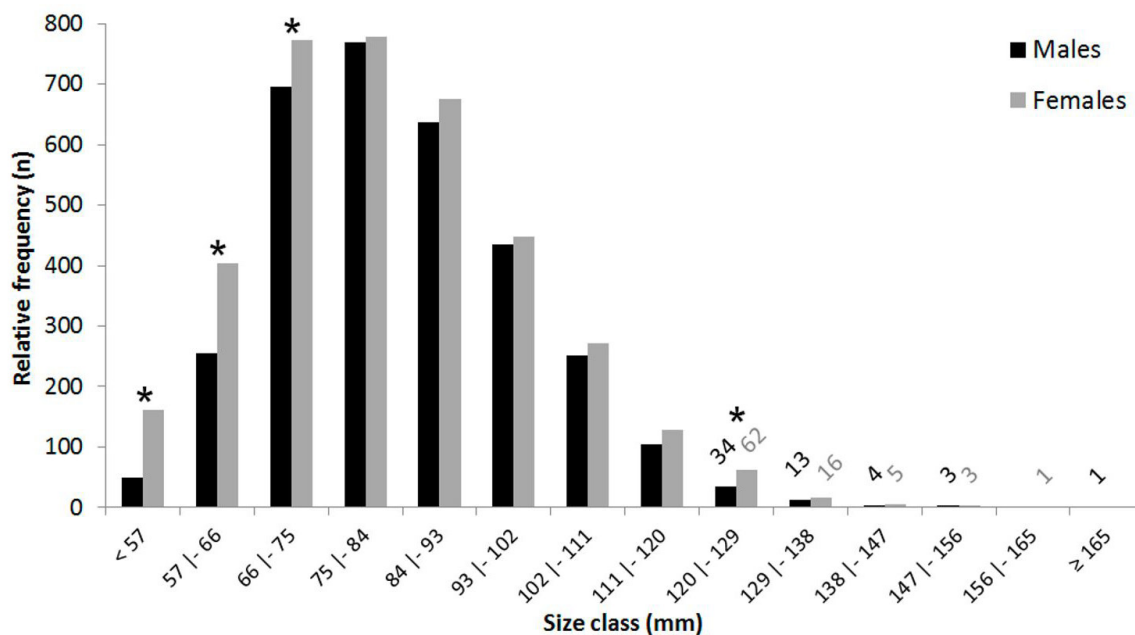


Figure 2. Relative frequency of males and females of *Litopenaeus schmitti*, within total length (TL) size classes, caught at the Santos Estuary from May 2009 to March 2015. Significant differences ($p < 0.05$) between male and females, within size classes, are indicated with asterisks.

April and September, which reinforces the idea that the estuarine part of its life cycle lasts for 6 to 9 months, and considering that its marine and coastal larval time took, approximately, one month (Pérez-Farfante, 1970a, 1970b; Santos et al., 2004; Boos et al., 2016) with this in mind we may consider a reproductive peak, as described by Santos et al. (2008), from October to March. Nevertheless, the presence of individuals of the white-shrimp at the Santos's Estuary throughout the year corroborate the assumption that this specie reproduces all year long with some reproductive peaks (Coelho and Santos, 1995; Peixoto et al., 2018), which could be related to an increase at environmental factors, like temperature (as reviewed by Hartnoll, 2001).

A higher incidence of females of *L. schmitti* seems to be the trend for this specie for both estuarine and coastal environments. For the southeastern Brazilian coast, Carvalho et al. (2015) found a sex

ratio of 1:0.81 (male:female - not statistically different from 1:1) from the Sepetiba Bay (Rio de Janeiro State). On the other hand, Santos et al. (2008) caught a higher amount of females than males at the Santos Estuary (1:3.02) and at the adjacent coastal area (1:2.57), both statistically different from 1:1. Although the proportions are different, our results (1:1.15) and those found by Santos et al. (2008) may have occurred due to different temporal coverage of the samples of each work. But both points to a higher occurrence of females, compared to males, in the region, which seems to be a pattern for this species on coastal areas from Venezuela (Díaz-Lugo et al., 2014) and northeastern Brazil (Coelho and Santos, 1994; Santos et al., 2005; Carvalho et al., 2015; Silva et al., 2018; Peixoto et al., 2018; Craveiro et al., 2019).

Chu et al. (1995) found similar results for some Chinese penaeid shrimp species with significant statistical differences between morphometric relationships. Andrade and Pérez (2004) reported slightly similar size ranges for estuarine individuals of *L. schmitti*, but with females larger than males. The fact that the comparisons between male and female regressions showed statistical differences for carapace length could suggest that differences in morphometric relationships between sexes start with the expression of anatomic sexual dimorphism. Some authors highlighted that differences between males and females relationships could be due to degree of maturity (Chu et al., 1995; Primavera et al., 1998), location or seasonality (Pérez-Castañeda and Defeo, 2002). For example, Coelho and Santos (1994) reported, for size comparisons, that females are larger than males after the age of 4 months.

Estimates of b from $TL \times TW$ indicate negative allometry ($b < 3$) for estuarine males and females, which evidence that *L. schmitti* found at the Santos Estuary have a higher gain in size than weight. Silva et al. (2018) found similar results for growth type: negative allometry for $TL \times TW$ and $TL \times CL$ relationships for both sexes. Those relationships may act as a useful tool to evaluate the health of this stratum of the population, using b of $TL \times TW$ for the condition, and also for comparing growths and weight gains between sexes and age classes (Pinheiro and Taddei, 2005) as between distinct habitats, which can be evaluated in future.

Table 2. Monthly frequency and sex ratio from males and females of *Litopenaeus schmitti* caught at the Santos Estuary from May 2009 to March 2015. Significant differences ($p < 0.05$) are indicated with asterisks.

| Month | Males | Females | Total | Ratio | $p < 0.05$ |
|--------------|-------------|-------------|-------------|----------------|------------------|
| January | 914 | 827 | 1741 | 1: 0.90 | 0.037* |
| February | 240 | 339 | 579 | 1: 1.41 | <0.01* |
| March | 467 | 650 | 1117 | 1: 1.39 | <0.01* |
| April | 447 | 485 | 932 | 1: 1.09 | 0.213 |
| May | 529 | 662 | 1191 | 1: 1.25 | <0.01* |
| June | 141 | 147 | 288 | 1: 1.04 | 0.724 |
| July | 106 | 138 | 244 | 1: 1.30 | 0.041* |
| August | 72 | 102 | 174 | 1: 1.42 | 0.023* |
| September | 93 | 109 | 202 | 1: 1.17 | 0.260 |
| October | 29 | 36 | 65 | 1: 1.24 | 0.385 |
| November | 30 | 27 | 57 | 1: 0.90 | 0.691 |
| December | 183 | 205 | 388 | 1: 1.12 | 0.264 |
| Total | 3251 | 3727 | 6978 | 1: 1.15 | <0.01* |

Table 3. Parameters of the relationships between carapace (CL) and total lengths (TL) and weight (W) by sexes of *Litopenaeus schmitti* caught at the Santos Estuary from May 2009 to March 2015. M: male; F: female; a : interception coefficient; s_a : standard error of a ; b : allometric coefficient; s_b : standard error of b ; r^2 : coefficient of determination; *: $p < 0.05$; **: $p < 0.01$.

| | Sex | a | s_a | b | s_b | r^2 |
|-----------------------------|-----|------------------------|------------------------|------------------------|------------------------|-------|
| CL = a + bTL | M | -1.229 | 2.637×10^{-1} | 2.298×10^{-1} | 2.974×10^{-3} | 0.770 |
| | F | -1.616 | 2.584×10^{-1} | 2.364×10^{-1} | 2.913×10^{-3} | 0.781 |
| | p | <0.01** | | <0.01** | | |
| TW = aTL^b | M | 5.071×10^{-6} | 5.968×10^{-7} | 3.026 | 2.538×10^{-2} | 0.858 |
| | F | 7.463×10^{-6} | 9.706×10^{-7} | 2.943 | 2.798×10^{-7} | 0.828 |
| | p | 0.033* | | 0.034 | | |
| TW = aCL^b | M | 1.013×10^{-2} | 7.583×10^{-4} | 2.071 | 2.435×10^{-2} | 0.648 |
| | F | 8.884×10^{-3} | 6.375×10^{-4} | 2.112 | 2.314×10^{-2} | 0.660 |
| | p | 0.206 | | 0.232 | | |

As morphometrics can be used to obtain the condition factor or to help the understanding of physiological, ecological and fisheries data they should be considered to compare populations and how fishable species will respond to anthropic impacts (Beyer, 1991; Pérez-Castañeda and Defeo, 2002; Konan et al., 2014). Once the allometric coefficient can also be understood as the type of growth showed, we can assume that for the $TL \times TW$ relationship males have higher gain in length than in weight, while the opposite occurred for females. For both sexes the $TL \times CL$ of *L. schmitti* showed negative allometry indicating higher increase in carapace length relative to total length. Negative allometry was also found for $CL \times TW$ for on sex, indicating less gain in weight than in length.

We expect that our findings, hereafter, can be used to evaluate the resilience of penaeid shrimps due to anthropic impacts on their estuarine phases. The results indicate that morphometric differences among sexes seem to be more associated with total length, suggesting that TL could be a more appropriate body measurement to compare specimens of *L. schmitti*, at least when the analysis includes juveniles. In addition, the lack of studies dealing with this species in its estuarine phase, highlighted by Alfaro-Montoya (2010), results shown here are critical for better understanding and conservation of the *Litopenaeus schmitti*.

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