

POPULATIONAL BIOLOGY OF THREE PENAEIDAE SHRIMPS (DECAPODA) IN THE CURUÇÁ ESTUARY ON THE NORTHERN COAST OF BRAZIL*

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ABSTRACT

Sex ratio, population structure, and relative growth of *Farfantepenaeus subtilis* (Pérez-Farfante, 1967), *Litopenaeus schmitti* (Burkenroad, 1936), and *Xiphopenaeus kroyeri* (Heller, 1862) were studied in the Curuçá estuary, State of Pará, northern coast of Brazil. Samples were collected bimonthly from July 2003 to July 2004 using a wing trawl net. Each shrimp was identified and weighed, carapace length was measured, and sex was determined. We obtained 4,818 specimens of *F. subtilis*, 732 specimens of *L. schmitti*, and 608 specimens of *X. kroyeri*. Mean carapace length and weight were 11.95 mm and 1.29 g for *F. subtilis*, 15.32 mm and 3.67 g for *L. schmitti*, and 12.78 mm and 0.97 g for *X. kroyeri*, respectively. The sex proportion (males/females) was 0.8 for *F. subtilis*, 0.7 for *L. schmitti*, and 0.6 for *X. kroyeri*, with significant differences ($P < 0.05$) for the three species studied. *Farfantepenaeus subtilis* and *L. schmitti* had positive allometric growth, while *X. kroyeri* had negative allometric growth. For *F. subtilis* two important recruitment periods were observed. The largest period occurred in March; and the other, less intense, began in September. For *L. schmitti*, recruitment occurred in July and in March. *Xiphopenaeus kroyeri* didn't occur in November, with recruitment in January. Results show the importance of the Curuçá estuary in the development of these shrimps, and the information obtained is important for future management plans for its capture in this area.

Keywords: Amazon; crustacean; Dendrobranchiata; relative growth; sex ratio

BIOLOGIA POPULACIONAL DE CAMARÕES PENAEIDAE (DECAPODA) NO ESTUÁRIO DE CURUÇÁ, COSTA NORTE DO BRASIL

RESUMO

A razão sexual, a estrutura populacional e o crescimento relativo de *Farfantepenaeus subtilis* (Pérez-Farfante, 1967), *Litopenaeus schmitti* (Burkenroad, 1936) e *Xiphopenaeus kroyeri* (Heller, 1862) foram estudados no estuário de Curuçá, Estado do Pará, costa norte do Brasil. As amostras foram coletadas bimestralmente, de julho de 2003 a julho de 2004, utilizando uma rede de arrasto *wing trawl*. Cada camarão foi identificado, mensurado pelo seu comprimento da carapaça, pesado, e teve o sexo determinado. Foram obtidos 4.818 espécimes de *F. subtilis*, 732 de *L. schmitti* e 608 de *X. kroyeri*. Os valores médios dos comprimentos da carapaça e dos pesos foram 11,95 mm e 1,29 g para *F. subtilis*, 15,32 mm e 3,67 g para *L. schmitti* e 12,78 mm e 0,97 g para *X. kroyeri*, respectivamente. A proporção sexual (machos/fêmeas) foi de 0,8 para *F. subtilis*, 0,7 para *L. schmitti* e 0,6 para *X. kroyeri*, com diferenças significativas ($P < 0,05$) para as três espécies estudadas. *Farfantepenaeus subtilis* e *L. schmitti* apresentaram crescimento alométrico positivo, enquanto *X. kroyeri* teve crescimento alométrico negativo. Para *F. subtilis* foram observados dois importantes períodos de recrutamento. O maior ocorreu em março; e o outro, menos intenso, iniciou em setembro. Para *L. schmitti*, o recrutamento ocorreu em julho e em março. *Xiphopenaeus kroyeri* foi ausente em novembro, com recrutamento em janeiro. Os resultados demonstram a importância do estuário Curuçá para o desenvolvimento desses camarões, sendo as informações obtidas importantes para futuros planos de gestão de sua captura na área.

Palavras chave: Amazônia; crescimento relativo; crustáceos; Dendrobranchiata; razão sexual

Original Article/Artigo Científico: Recebido em 24/03/2014 – Aprovado em 04/11/2015

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* Financial support: CNPq – Instituto do Milênio RECOS.

INTRODUCTION

The most commercially exploited shrimp species in the northern coast of Brazil are fully or partially dependent on coastal ecosystems in at least one stage of their development. Among these species, penaeid shrimps stand out because they use estuaries as important areas of recruitment, where they remain for most of their life cycle. Thus, estuarine ecosystems are essential for the maintenance of coastal stocks (ISAAC *et al.*, 1992; CINTRA *et al.*, 2004).

Penaeid shrimps are the most abundant and best known resource among shrimps of high economic value (DALL *et al.*, 1990; ARAGÃO *et al.*, 2001; SILVA *et al.*, 2002b; BENTES *et al.*, 2012), mainly because there is a large number of species with potential for commercial exploitation. The species with highest occurrence in catches within estuaries of the State of Pará are: *Farfantepenaeus subtilis* (Pérez-Farfante, 1967), *Litopenaeus schmitti* (Burkenroad, 1936), and *Xiphopenaeus kroyeri* (Heller, 1862), and the predominance of one species over the others is related to the different areas, seasons, and environmental conditions of each region (ISAAC *et al.*, 1992; BENTES *et al.*, 2012).

Some biological aspects of these species along the Brazilian coast received special attention in studies conducted in the following regions: Northeast (PORTO, 1983-84; PORTO and FONTELES-FILHO, 1983-84; PORTO *et al.*, 1988; COELHO and SANTOS, 1993, 1994; SANTOS and COELHO, 1996; SANTOS and IVO, 2000; SANTOS *et al.*, 2003, 2004; SANTOS and FREITAS, 2004; SILVA *et al.*, 2010; LOPES *et al.*, 2014); Southeast (SEVERINO-RODRIGUES *et al.*, 1993; NAKAGAKI and NEGREIROS-FRANSOZO, 1998; FRANSOZO *et al.*, 2000; CASTRO *et al.*, 2005; GRAÇA-LOPES *et al.*, 2007; CASTILHO *et al.*, 2008; FREIRE *et al.*, 2011; CAPPARELLI *et al.*, 2012; GRABOWSKI *et al.*, 2014); and South (BRANCO *et al.*, 1994, 1999; BRANCO, 2005; MACHADO *et al.*, 2009; BRANCO *et al.*, 2014). The studies that stand out on the northern coast are those conducted by ISAAC *et al.* (1992), SILVA *et al.* (2002a), SILVA *et al.* (2002b) and CINTRA *et al.* (2004).

The choice for investigating basic issues on the biology of species in the Curuçá estuary is

based on the fact that Penaeidae shrimps are intensively fished both in open sea by the fishing industry, and in estuaries by artisanal fisheries, i.e., both juvenile and adult stocks are exploited. Moreover, despite being a widely studied topic, there is no information available in the literature on shrimps of the Amazon estuary, which is a region of extreme ecological importance.

The aim of this study was to analyze the population structure of penaeid shrimps *F. subtilis*, *L. schmitti*, and *X. kroyeri* in the Curuçá estuary (Brazilian Amazon), their sex ratio, temporal size-frequency distribution regarding months, and the relationship between weight and carapace length of each species. Hence, the purpose was to contribute to increasing the knowledge on the biology and dynamics of these species, creating a scientific basis that may assist in future management plans.

MATERIAL AND METHODS

Samplings were carried out bimonthly between July 2003 and July 2004 in eight locations of the Curuçá estuary on the northern coast of the State of Pará, in northern Brazil: C1 (0°44'08"S and 47°50'57"W); C2 (0°42'40"S and 47°49'30"W); C3 (0°40'33"S and 47°50'41" W); and C4 (0°40'24"S and 47°50'52"W) in the Curuçá River, and M1 (0°42'19"S and 47°53' 29"W); M2 (0°41'40"S and 47°52'35"W); M3 (0°40'50"S and 47°52'22"W); and M4 (0°39'59"S and 47°51'57"W) in the Muriá channel (Figure 1). A detailed description of the sampling methods is available in NEVIS *et al.* (2009). Collections were performed using a wing trawl with 13 mm mesh size decreasing to 5 mm in the cod-end. Trawls lasted for five minutes and were performed during the ebb tide of the last quarter moon and at daytime.

The specimens collected were identified according to CERVIGÓN *et al.* (1992) and PÉREZ-FARFANTE and KENSLEY (1997). Sex identification was based on female thelycum and male petasma. For each specimen, we measured carapace length (CL) – which extends from the orbital cavity to the posterior margin of the cephalothorax – using a caliper with 0.01 mm accuracy, and total wet weight (TW) with a digital measure of 0.01 g accuracy.

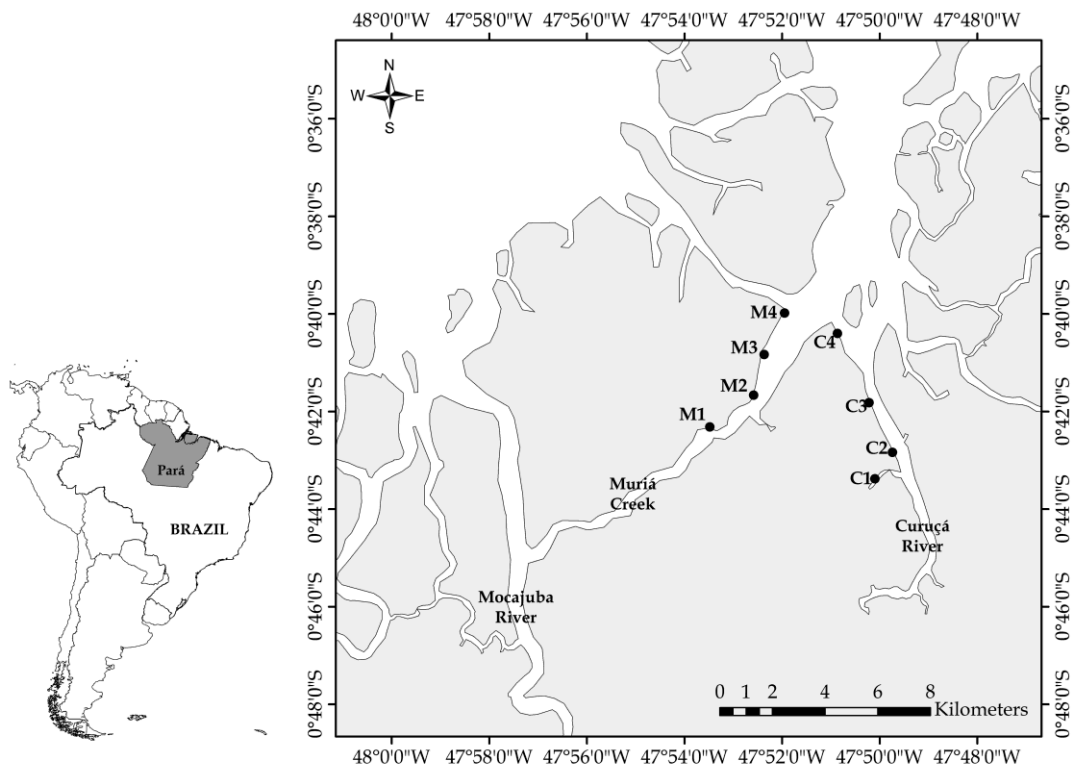


Figure 1. Sampling sites of Penaeidae shrimps in the Curuçá estuary, northern Brazilian coast, between July 2003 and July 2004.

Sex ratio (male:female) between the months and total collection period were calculated using Chi-square test (χ^2), at a significance level of 95%, to test the difference of 1:1 (ZAR, 2009).

To check population structure of the species, we distributed the specimens in 1-mm CL classes per month, determining class frequency of shrimps in relation to the total number of individuals. Initially, Sturges' formula was used to obtain the adequate number of size classes, and the calculation result was approximated to 1 mm, in order to enable graphic representation. The distinction criterion between juvenile and adult phases was the size at which half of the population is able to reproduce, according to MARTINELLI (2005), i.e., *F. subtilis* ($L_{50} = 22$ mm CL), *L. schmitti* ($L_{50} = 27$ mm), and *X. kroyeri* ($L_{50} = 16$ mm). This was confirmed based on the observation of petasma; when the petasma was not yet fully developed, nor attached, or easily separated against light pressure, specimens were considered juvenile (PÉREZ-FARFANTE, 1967).

The relationships between TW and CL were determined for each species, for males and

females separately, according to the equation $TW = a \cdot CL^b$, where TW = total wet weight; CL = carapace length; and 'a' and 'b' = growth parameters (WEATHERLEY and GILL, 1987). The F test was used to test the significance of the regression analysis. The weight growth rate was assessed by degree of allometry and confirmed by *t*-test as isometric ($b = 3$), positively allometric ($b > 3$), or negatively allometric ($b < 3$) (ZAR, 2009). Specimens whose appendages were not intact were excluded from weight and length analyses.

RESULTS

A total of 6,158 penaeid shrimps were collected, 4,818 *F. subtilis* (2,262 females, 1,959 males, and 597 individuals of undetermined sex), 732 *L. schmitti* (346 females, 231 males, and 155 individuals of undetermined sex), and 608 *X. kroyeri* (352 females, 242 males, and 14 individuals of undetermined sex). Total variation ranges in CL and TW were: CL = 2.67 to 33.48 mm (11.95 ± 3.74 mm) and TW = 0.02 to 22.82 g (1.29 ± 1.52 g) for *F. subtilis*; CL = 5.58 to 35.4 mm (15.32 ± 6.87 mm) and TW = 0.08 to 25.95 g ($3.67 \pm$

4.4 g) for *L. schmitti*; and CL = 5.92 to 26.26 mm (12.78 ± 2.43 mm) and TW = 0.1 to 6.47 g (0.97 ± 0.96 g) for *X. kroyeri*.

The total sex ratio (males:females) was biased towards females for the three species, with both sexes differing significantly (χ^2 test, $P < 0.05$) (Table 1). The highest proportion of *F. subtilis*

females was not observed in March and May 2004, when the proportions between sexes were similar. For *L. schmitti*, the proportion of males was higher than females only in May 2004, 2:1 (χ^2 test, $P < 0.05$). For *X. kroyeri*, it was significantly different with predominance of females in March and July, 2004 (Table 1).

Table 1. Sex ratio of *Farfantepenaeus subtilis*, *Litopenaeus schmitti*, and *Xiphopenaeus kroyeri* in the Curuçá estuary, northern coast of Brazil. M = males, F = females, χ^2 : Chi-square test.

| Species | Month year | Males | Females | Total | M - F | χ^2 |
|---------------------------------|------------|-------|---------|-------|-------|----------|
| <i>Farfantepenaeus subtilis</i> | July 2003 | 184 | 297 | 481 | 0.6:1 | 26.54 * |
| | Sept 2003 | 67 | 96 | 163 | 0.7:1 | 5.16 * |
| | Nov 2003 | 75 | 136 | 211 | 0.5:1 | 17.63 * |
| | Jan 2004 | 57 | 116 | 173 | 0.5:1 | 20.12 * |
| | Mar 2004 | 1247 | 1275 | 2522 | 1:1 | 0.31 ns |
| | May 2004 | 100 | 90 | 190 | 1.1:1 | 0.52 ns |
| | July 2004 | 229 | 242 | 471 | 0.9:1 | 0.35 ns |
| Total | | 1959 | 2252 | 4211 | 0.8:1 | 20.38 * |
| <i>Litopenaeus schmitti</i> | July 2003 | 73 | 111 | 184 | 0.6:1 | 7.84* |
| | Sept 2003 | 27 | 52 | 79 | 0.5:1 | 7.91* |
| | Nov 2003 | 29 | 43 | 72 | 0.7:1 | 2.72 ns |
| | Jan 2004 | 3 | 16 | 19 | 0.2:1 | 8.89 * |
| | Mar 2004 | 52 | 95 | 147 | 0.5:1 | 12.57* |
| | May 2004 | 30 | 15 | 45 | 2:1 | 5.00* |
| | July 2004 | 17 | 11 | 28 | 1.5:1 | 1.28 ns |
| Total | | 231 | 343 | 574 | 0.7:1 | 21.85* |
| <i>Xiphopenaeus kroyeri</i> | July 2003 | 9 | 9 | 18 | 1:1 | 0.00 ns |
| | Sept 2003 | 2 | 0 | 2 | 0:0 | 2.00 ns |
| | Nov 2003 | 0 | 0 | 0 | 0:0 | ns |
| | Jan 2004 | 19 | 29 | 48 | 0.6:1 | 2.08 ns |
| | Mar 2004 | 147 | 203 | 350 | 0.7:1 | 8.96* |
| | May 2004 | 12 | 9 | 21 | 1.3:1 | 0.42 ns |
| | July 2004 | 53 | 101 | 154 | 0.5:1 | 14.96* |
| Total | | 242 | 351 | 593 | 0.6:1 | 20.03* |

* $P < 0.05$; ns = no statistical difference.

For *F. subtilis* two important recruitment periods were observed. The longest period occurred in March 2004, with 8 to 10 mm CL shrimps; they probably left the estuary between July and September with a 31 mm CL; and the other, which was less intense, begun in September 2003, with specimens of 8 mm CL, which left the estuary between January and March 2004 with a 25 mm CL (Figure 2A). For *L. schmitti*, recruitment occurred in July 2003, with individuals of 7 and 8 mm CL that left the estuary between November 2003 and January

2004 with a 31 mm CL, and in March 2004, leaving the estuary from July 2004 with a 33 mm CL (Figure 2B). *Xiphopenaeus kroyeri* didn't occur in November 2003, with recruitment in January 2004 and leaving the estuary from May 2004 onwards with a 26 mm CL (Figure 2C).

Farfantepenaeus subtilis and *L. schmitti* had positive allometric growth, corresponding to the increase in a higher proportion of TW compared to CL, and *X. kroyeri* showed negative allometric growth (Table 2).

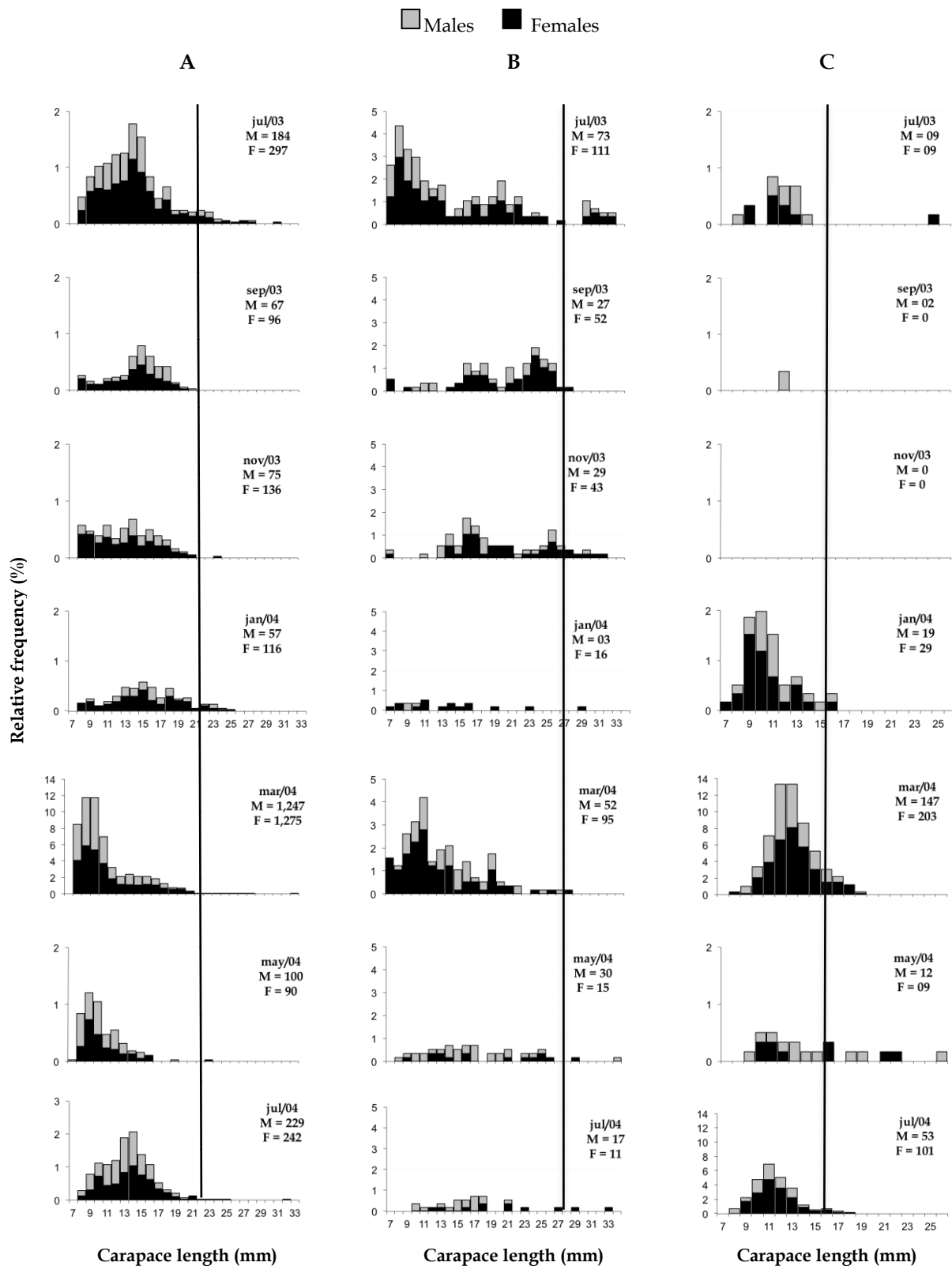


Figure 2. Size frequency (%) distribution (carapace length) of three penaeid shrimps (males and females) in the Curuçá estuary, sampled bimonthly from July 2003 to July 2004. A = *Farfantepenaeus subtilis*; B = *Litopenaeus schmitti*; C = *Xiphopenaeus kroyeri*. The black line symbolizes L₅₀. The frequency was plotted on different scales.

Table 2. Statistical regression between carapace length and total weight for *Farfantopenaeus subtilis*, *Litopenaeus schmitti*, and *Xiphopenaeus kroyeri* in the Curuçá estuary from July 2003 to July 2004. (N) number of individuals; (Y) dependent variable; (X) independent variable; (TW) total wet weight; (CL) carapace length; (a) line intersection; (b) line slope angle and allometry coefficient; (r^2) coefficient of determination; (F) F test; (A) allometry; (F) females; (M) males; (U) undetermined sex; (T) total.

| SPECIES | GROUPS | N | Y = a.X ^b | r ² | F | A |
|---------------------------------|--------|------|---|----------------|-----------|---|
| <i>Farfantopenaeus subtilis</i> | F | 2062 | TW = 0.0003.CL ^{3.24} | 0.87 | 13,807.84 | + |
| | M | 1731 | TW = 5.10 ⁻⁷ .CL ^{3.73} | 0.84 | 9,167.03 | + |
| | U | 547 | TW = 0.0002.CL ^{3.31} | 0.44 | 443.18 | + |
| | T | 4340 | TW = 0.0003.CL ^{3.25} | 0.87 | 30,677.79 | + |
| <i>Litopenaeus schmitti</i> | F | 329 | TW = 0.0005.CL ^{3.08} | 0.92 | 3,933.57 | + |
| | M | 222 | TW = 0.0005.CL ^{3.12} | 0.93 | 3,459.72 | + |
| | U | 155 | TW = 0.0007.CL ^{3.02} | 0.56 | 204.31 | + |
| | T | 706 | TW = 0.0007CL ^{3.01} | 0.94 | 12,350.19 | + |
| <i>Xiphopenaeus kroyeri</i> | F | 339 | TW = 0.0007.CL ^{2.77} | 0.69 | 769.41 | - |
| | M | 237 | TW = 0.0009.CL ^{2.67} | 0.54 | 284.38 | - |
| | U | 14 | TW = 6.10 ⁻³ .CL ^{5.26} | 0.82 | 62.94 | + |
| | T | 590 | TW = 0.0005.CL ^{2.89} | 0.68 | 1,266.35 | - |

The analysis of coefficient 'a', which represents the condition factor of the species, indicated that *L. schmitti* had the highest degree of fattening ($a = 0.0007$) among the three species, followed by *X. kroyeri* and *F. subtilis*, with coefficients $a = 0.0005$ and 0.0003 , respectively.

DISCUSSION

Females had higher carapace length for the three penaeid shrimps species. This sexual size dimorphism - in which females typically feature larger CL than males (BOSCHI, 1969; EUTROPIO *et al.*, 2013; LOPES *et al.*, 2014) - can be explained by the fact that females have their gonads in the cephalothorax cavity, which develops considerably, especially during reproductive season (RODRÍGUEZ, 1987).

The average CL attained by *F. subtilis* and *L. schmitti* in Curuçá were lower than those observed by MARTINELLI (2005) in the Caeté estuary, northern coast of Brazil. Only juveniles with 8.31 and 10.71 mm CL were caught for the species, respectively. However, mean CL values for *X. kroyeri* specimens were higher than those found in Caeté and lower than in Bahia littoral, northeastern Brazil (COUTO *et al.*, 2013) and in Babitonga Bay, southern Brazil (GRABOWSKI *et al.*, 2014).

The sex ratio - with predominance of females over males - observed for the three species is consistent with the trend observed by previous works published on Penaeidae shrimps. For *F. subtilis*, predominance of females is consistent with studies conducted by ISAAC *et al.* (1992); however, it differs from studies by SILVA *et al.* (2002a), who observed the same proportion between sexes.

The largest proportion of *L. schmitti* females in the Curuçá estuary differs from results obtained by SILVA *et al.* (2002a), who found lower proportions compared to males in other estuarine regions of the State of Pará. However, these data are in agreement with studies conducted by SANTOS (2000) and SANTOS and FREITAS (2000), who also observed the highest proportions of females in the coastal areas of northeastern Brazil. For *X. kroyeri*, the highest proportion of females agrees with the findings by SILVA *et al.* (2002a). Although the results found by COELHO and SANTOS (1993), SEVERINO-RODRIGUES *et al.* (1993), BRANCO (2005), and HECKLER *et al.* (2013) indicate a balance in the sex ratio of this species, they were able to observe that the average abundance of females was higher than males, in general. An opposite result was found in Ilhéus (Bahia), where the highest percentage of males in almost all size classes was attributed to female

migration to other areas (LOPES *et al.*, 2010). These authors suggested that oscillations observed in proportions related to shrimp sizes are due primarily to the intrinsic behavior of the species in the studied area.

The difference in sex ratio with predominance of penaeid females can be associated with the reproductive biology of this group (COELHO and SANTOS, 1993; SILVA *et al.*, 2015), according to which a higher number of females tends to increase reproductive success. JAYAWARDANE *et al.* (2002) observed that differentiated mortality, with higher rates for males, might also contribute to differences in sexual involvement of the species during catches. For SILVA *et al.* (2015), the mortality of *F. subtilis* females was higher than males as a result from its higher exploitation rates.

Frequency distribution of *F. subtilis* in the Curuçá estuary follows the pattern described by other authors in the northern region. CINTRA *et al.* (2004) described a high catching of small specimens from December to March. This trend was also observed in the present study as there was a high frequency of pink shrimps observed between 8 and 11 mm length classes in March 2004. The frequencies of specimens with more than 21 mm CL were very low in the captures, suggesting that the average size of this species migrating from the Curuçá estuary to the ocean is close to the value described by MARTINELLI (2005) for the Caeté estuary. This author states that 20.7 mm CL is the average size with which these shrimps reach the onset of sexual maturity. *Farfantepenaeus subtilis* juveniles were found for the first time in an oligohaline estuary by NÓBREGA *et al.* (2013), restricted to two periods: one in the months with less rainfall (October to December), with higher density, and the other in February. In this habitat, the shrimp population was exclusively comprised of juvenile individuals and the largest individuals were found by the end of the less rainy period, in agreement with the study carried out by CORRÊA and MARTINELLI (2009), who described a migration to open sea by the end of this period. The presence of small sized shrimps and the high density of *F. subtilis* in estuarine salt marshes prove that these are important areas for juvenile recruitment (SAMPAIO and MARTINELLI-LEMOS, 2014).

Litopenaeus schmitti also had a bi-yearly frequency distribution pattern with highest peaks in July 2003 and March 2004, different from *F. subtilis*, which maintained a high frequency of adults from July to November 2003. It can be inferred that two main recruitment seasons for juveniles of this species occurred in the Curuçá estuary. The first season, beginning in July 2003, was characterized by a high frequency of small shrimps between 7 and 13 mm CL until November 2003, when the migration of individuals into the sea occurs, and the second one, less intense, possibly beginning February through June 2004. This species remained in the coastal estuarine environment in the northeast of Brazil for approximately five months (COELHO and SANTOS, 1994) and the main recruitment season for *L. schmitti* in southeastern Brazil occurred in warmer months (CAPPARELLI *et al.*, 2012), which reinforces our inferences on this shrimp in the Curuçá estuary.

The occurrence of juveniles and adults of *X. kroyeri* in the same region is rather common, since this species inhabits more coastal regions. Juvenile recruitment was evident from January to July for this species, which corresponds to the rainiest period in this region, when the mean estuarine salinity ranged from 10.8 (January) to 22.1 (July), (NEVIS *et al.*, 2009). A research carried out in the coast of São Paulo (Brazil) (HECKLER *et al.*, 2014) showed absence of *X. kroyeri* in the estuary due to low salinity. According to HOLTHUIS (1980), the presence of *X. kroyeri* in estuarine environments seems to be related to the input of saline water. However, the low frequency of individuals during dry period (August to December) in the Curuçá estuary demonstrates that they have an opposite seasonal pattern from the one proposed here and their distribution is better explained by migration towards deeper areas in the spawning season. The occurrence of *X. kroyeri* in the estuary, contradicting all other data in literature, might be explained by the fact that the Amazonian estuarine environment is quite peculiar, with marine water input due to high current speeds in this macro-tidal area (approximately 4-meter tides). This occurrence cannot be considered occasional, since this species is found in all months and has also been found in other estuaries (MARTINELLI, 2005).

As determined by the Interministerial Normative Instruction MPA/MMA n. 15 of November 28, 2012 (BRASIL, 2012), shrimp fishing is prohibited for the target species *F. subtilis*, *Farfantepenaeus brasiliensis*, *L. schmitti*, and *X. kroyeri* in the northern Brazilian coast in the period ranging from December 15 to February 15, either with trawling or by artisanal fishing using other fishing methods. However, no effective monitoring on artisanal fisheries is conducted in Pará estuaries where this practice occurs continuously. Thus, juvenile recruitment fisheries suffer constant pressure throughout the year. Despite the great exploitation by artisanal fishing in estuaries, the survival of juvenile shrimps has been enabled by their presence in different habitats (mangroves, salt marshes, and rocky outcrops). For example, there is a high abundance of *F. subtilis* in salt marshes of areas close to our study area, where there was a significant catch of this shrimp in tide pools (SAMPAIO and MARTINELLI-LEMOS, 2014), locally unexploited by fishing.

The relationship between weight and length of a species has been widely used in population dynamics studies and fishery stock assessment, in order to estimate the weight of a specimen as a function of its length and thus determining the growth type of the species (BRANCO *et al.*, 2002). In general, penaeid shrimps tend to have difference in allometric growth between sexes (BRANCO, 2005), even though their biometric relationships have been poorly studied in the northeastern (SANTOS *et al.*, 2004) and northern regions of Brazil. In this study, the positive allometric growth of *F. subtilis* indicates that the higher proportion of weight gain compared to cephalothorax growth is in accordance with the pattern evidenced by ISAAC *et al.* (1992) and the positive and negative allometries observed for *L. schmitti* and *X. kroyeri*, respectively, match the observations made by MARTINELLI (2005). This negative allometry may be related to the onset of sexual maturity and gonadal development, which represent a considerable energetic demand for the individual during breeding season (LOPES *et al.*, 2014). Variations in body size, sexual maturity, and longevity are influenced by habitat conditions, water temperature, and food/nutrient supplies (CASTILHO *et al.*, 2007). The three

shrimp species in Marapanim had a positive "a" allometric coefficient, which indicates that this estuary is a suitable site for the growth and increase in weight of juvenile recruits, since weight gain reflects shrimps' "well-being".

Studies on the population biology of penaeid shrimps in estuarine regions are of utmost importance because they tackle a relevant socio-cultural resource of high economic value (BRANCO, 2005). According to the results of this study, we can consider the Curuçá estuary as an important nursery area for the development and maintenance of this fishery resource in the northern coast of Brazil.

CONCLUSIONS

The total sex ratio (males:females) was biased towards females for the three species studied. *Farfantepenaeus subtilis* had two important recruitment periods: March, with shrimps of 8 to 10 mm CL which probably left the estuary between July and September; and the other, which was less intense and begun in September, with specimens of 8 mm CL that left the estuary between January and March. For *L. schmitti*, recruitment occurred in July, with individuals of 7 and 8 mm CL which left the estuary between November and January, and in March, leaving the estuary from July onwards. *Xiphopenaeus kroyeri* had recruitment in January and left the estuary from May onwards. Regarding the relationship between weight and length, *F. subtilis* and *L. schmitti* had positive allometric growth and *X. kroyeri* showed negative allometric growth. The results obtained in this study are an important source of information for the preparation of species management plans in the Amazon estuary.

ACKNOWLEDGMENTS

The authors are especially grateful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (*Brazilian Coordination for the Improvement of Higher Level Personnel*) for the Master's scholarship granted to the first author; to Instituto do Milênio - RECOS/CNPq (*National Council for Scientific and Technological Development*) for the financial resources for field collections; to the Department of Agriculture of the State of Pará

for the support to fieldwork logistics through the Curuperé Shrimp Farming Station; to colleagues who helped in field collections; to Leiliane Souza Silva for map editing; and to Daniela Tannus for the English version supported by the Vice-rectory Office of Research, Federal University of Pará (PROPEP/UFPa) and Fundação de Amparo e Desenvolvimento da Pesquisa - FADESP (*Research Development and Support Foundation*). All experiments conducted in this study complied with current applicable state and federal laws (IBAMA/MMA Process number 02001.003954/01-16). The authors thank the editor and the reviewers for their critical reviews and suggestions, which have improved the manuscript.

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