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ORIGINAL ARTICLE

Temporal variations in biomass and size of seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) (Decapoda: Penaeoidea) on the southern coast of São Paulo state, Brazil

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ABSTRACT

Xiphopenaeus kroyeri (Heller, 1862) is the third most common species caught by fishing boats in the state of São Paulo, Brazil and production of this shrimp in the Cananéia region located on the southern coast of this state ranks second in the nation. The aim of this study was to investigate the temporal variation of the total biomass and size of *X. kroyeri* and analyze this variation against environmental factors in order to suggest some information about the best periods to fish this species. Samples were caught monthly from four sampling stations in Cananéia between July 2012 and June 2014 using a fishing boat equipped with otter-trawl nets. Temperature and salinity were monitored using a multiparameter probe, and sediment samples were also taken using a Van Veen-type gripper for particle size analysis. The shrimp were weighed, quantified, and carapace length was measured (mm). In general, the highest total biomass values were recorded when the fishery was closed in the southeast and south regions, and the highest catch of smaller individuals was also observed during this period. In contrast, in November 2013 the fishing is permitted and high biomass composed of large individuals was observed. The monthly biomass showed a positive relationship with sediment texture, because this species prefers very fine sediments to burrow as a defense against predators.

KEY WORDS

Abundance, closed season, fishery, Penaeidae, weight.

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INTRODUCTION

The seabob shrimp, *Xiphopenaeus kroyeri* (Heller, 1862), is a Penaeidae of great commercial importance with a wide geographic distribution. According to Gusmão *et al.* (2006), who conducted a study using molecular biology tools, this species is distributed through the western Atlantic from the United States (Virginia) to Brazil (Amapá to Rio Grande do Sul). These shrimp are not dependent on estuaries for the development of their juveniles and their populations are not stratified, juveniles and adults commonly occur in the same area (Branco *et al.*, 1999; Costa *et al.*, 2007).

Since the first statistical fishing data in São Paulo (SP) were recorded in 1959, the seabob shrimp already figured among the main captured species (Braga *et al.*, 1966). In 2010, 2013, 2014, and 2015, *X. kroyeri* was the third most traded species on the São Paulo coast (Ávila-da-Silva *et al.*, 2011; 2014; 2015; 2016). In 2011 and 2012 it was the second most frequently caught species, second only to the fish species *Sardinella brasiliensis* (Steindachner, 1879) (Ávila-da-Silva *et al.*, 2012; 2013).

Historically, *X. kroyeri* is the main landed product in the region of Cananéia, a city located on the southern coast of São Paulo state (Brazil), and is widely exploited as a major source of income for the local population (Mendonça and Barbieri, 2000). Because of its abundance in coastal Brazilian regions, ease of capture, and characteristics such as its ideal size for sale, this species has become attractive for small-boat fishermen (Severino-Rodrigues *et al.*, 1993).

Studies of *X. kroyeri* along the São Paulo coast have focused on aspects of their population biology (Nakagaki and Negreiros-Fransozo, 1998; Castro *et al.*, 2005), reproductive biology and recruitment (Almeida *et al.*, 2012; Heckler *et al.*, 2013a; Castilho *et al.*, 2015), population dynamics (Heckler *et al.*, 2013b), and abundance and distribution (Costa *et al.*, 2007; Simões *et al.*, 2010; Heckler *et al.*, 2014a; 2014b). However, most of these studies did not address variation in biomass and individual size through monthly samples. These data are still scarce, especially for the Cananéia region.

From this perspective, the present study aimed to determine the temporal variation of the total biomass and the individual size of *X. kroyeri* samples, and analyze this variation against environmental factors. The results may provide important information about the best periods for fishing this shrimp.

MATERIAL AND METHODS

Biological samples

Samples were collected monthly between July 2012 and June 2014 from the coastal marine area of Cananéia, in the southern region of São Paulo state (Brazil) with authorization from the Instituto Chico Mendes de Biodiversidade (ICMBio) and Sistema de Autorização e Informação em Biodiversidade (SISBIO), number 23012-1. Because of adverse environmental conditions such as strong winds and high waves in March 2013 and February 2014, there was no sampling during these months. Samples were taken from four sampling stations in the coastal marine area: E1: 14 m, E2: 9 m, E3: 10 m, and E4: 7 m (Fig. 1).

Individuals were captured using a shrimping boat equipped with otter-trawl nets (5 m mouth width, 10 m long, and 20 mm mesh size, 18 mm mesh at the cod end). At each station, the sampling effort was 30 minutes/trawl (sample area ≈ 10,000 m^2).

The collected shrimp were identified according to Costa *et al.* (2003), quantified, and carapace length was measured (CL mm), and they were preserved in 80% ethanol and some specimens are deposited in the Crustacean Collection of the Department of Biology, Faculty of Philosophy, Sciences and Letters at Ribeirão Preto, University of São Paulo (catalogue number: CCDB 3237). The total biomass for each month was obtained by wet weight, using a digital scale (precision 0.01 g). Subsamples equivalent to 300 g were selected at random and the specimens were counted and measured. Consequently, the data from the subsample and the total biomass permitted estimation of the total number of seabob individuals for each sample (Costa *et al.*, 2007).

Temperature values and background salinity were monitored during each sampling effort using a multiparameter probe. The sediment was also sampled at each sampling station using a Van Veen grab. In these samples we used sieving to determine sediment texture and incineration to determine the content of organic matter (for methodological details see Costa *et al.*, 2007; Bochini *et al.*, 2014).

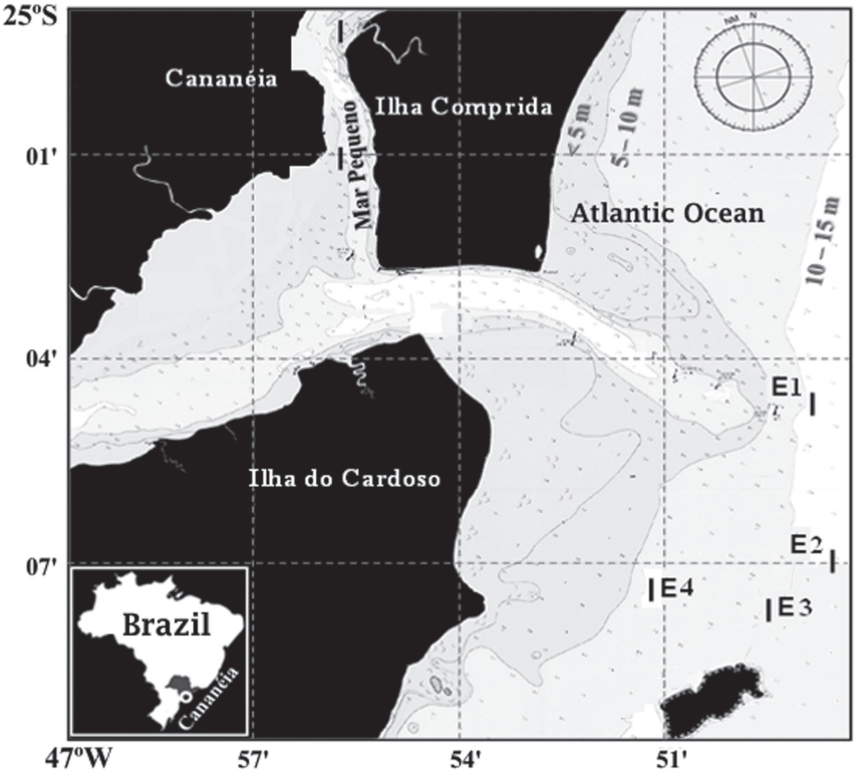

Figure 1. Cananéia region, São Paulo, Brazil, showing sampling stations of *Xiphopenaeus kroyeri* (Heller, 1862) on the coastal marine area (E1, E2, E3, and E4).

Data Analysis

Tests for homoscedasticity (Levene tests) and normality (Shapiro-Wilk tests) were first performed as prerequisites for the statistical test. Data were log-transformed prior to analysis (Zar, 1999). All data sets were normally distributed, with homogeneous variances.

The biomass of *X. kroyeri* (dependent variable) was compared temporally between years; seasons: winter I (July 2012 to September 2012), spring I (October 2012 to December 2012), summer I (January 2013 and February 2013), autumn I (April 2013 to June 2013), winter II (July 2013 to September 2013), spring II (October 2013 to December 2013), summer II (January 2014 and March 2014), and autumn II (April 2014 to June 2014) using an analysis of variance (nested ANOVA) ($\alpha = 5\%$) model with seasons nested within years. A post-hoc Tukey test was used to assess differences between years and seasons. We chose to use the average for the seasons because summer I and II did not contain all the sampled months.

In order to compare the monthly variation in biomass, we applied analysis of variance (one-way ANOVA), complemented by Tukey's multiple comparison test at a 5% significance level. Multiple linear regression analysis ($p < 0.05$) was performed to investigate the relations between environmental factors and biomass per year, season, and month of sampling.

RESULTS

The total biomass recorded was 368.6 kg and 113,795 individual shrimp were estimated. In the first year (July 2012 to June 2013) the biomass obtained was 118.4 kg, and in the second year (July 2013 to June 2014) there was a substantial increase in biomass, reaching 250.2 kg with a significant difference between the years ($p < 0.05$) (Tab. 1).

The biomass also differed between seasons ($p < 0.05$) (Tab. 1). The lowest biomass occurred in winter

Table 1. Results of nested ANOVA for biomass (log+2 transformed) of *Xiphopenaeus kroyeri* (Heller, 1862) collected in the region of Cananéia from July 2012 to June 2014. Season (year) = seasons nested in years. d.f., degrees of freedom; MS, mean square; *F*, MS factor/MS residual; *P*, probability of significance; $\alpha = 0.05$.

Source of variation	d.f.	MS	*F*	*P*
Year	1	2.1346E+16	5.6482	0.0199
Season (year)	6	1.0816E+16	2.8620	0.0141

I (2.3 kg) and the highest in autumn I and II, 30.7 kg and 36.2 kg, respectively (Fig. 2), but only autumn II differed from winter I and spring I ($p <0.05$). When the biomass was grouped by seasons, no correlation to environmental factors was seen ($p >0.05$).

There was a significant difference between the monthly biomass (one-way ANOVA, $p <0.05$). The lowest captured biomass was observed in July 2012 (1.1 kg) and the highest in May 2014 (74.3 kg), and this differed from July 2012/2013, August 2012/2013, September 2012, October 2012, November 2012, December 2012/2013, January 2013, February 2013, and June 2013 (Tukey, $p <0.05$). Large quantities of biomass were also sampled: April 2013 (42.0 kg), May 2013 (37.5 kg), November 2013 (31.5 kg), and March 2014 (33.9 kg) (Fig. 3). The monthly biomass variation was positively correlated with the diameter of the sediment (phi) ($p <0.05$). This means that the increased capture of biomass could be related to the presence of fine and very fine sediment (phi > 3). The lowest mean values for phi occurred in the winter I (2.99 ± 0.65), and the highest values during spring I (4.59 ± 0.92) (Fig. 4). Although biomass has not shown a relation with other factors, it is possible to graphically portray its increase as temperatures rise (Fig. 3).

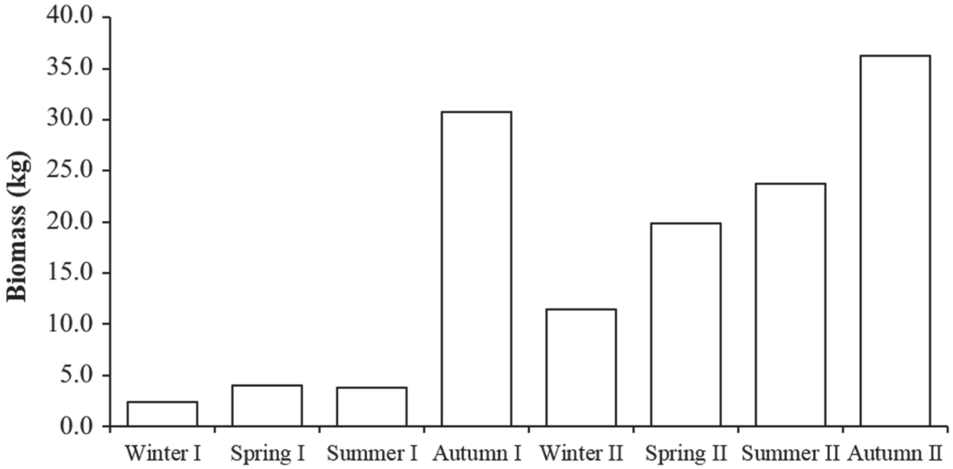

Figure 2. *Xiphopenaeus kroyeri* (Heller, 1862). Mean temporal values for biomass (kg) sampled during the period July 2012 to June 2014 in Cananéia, São Paulo, Brazil.

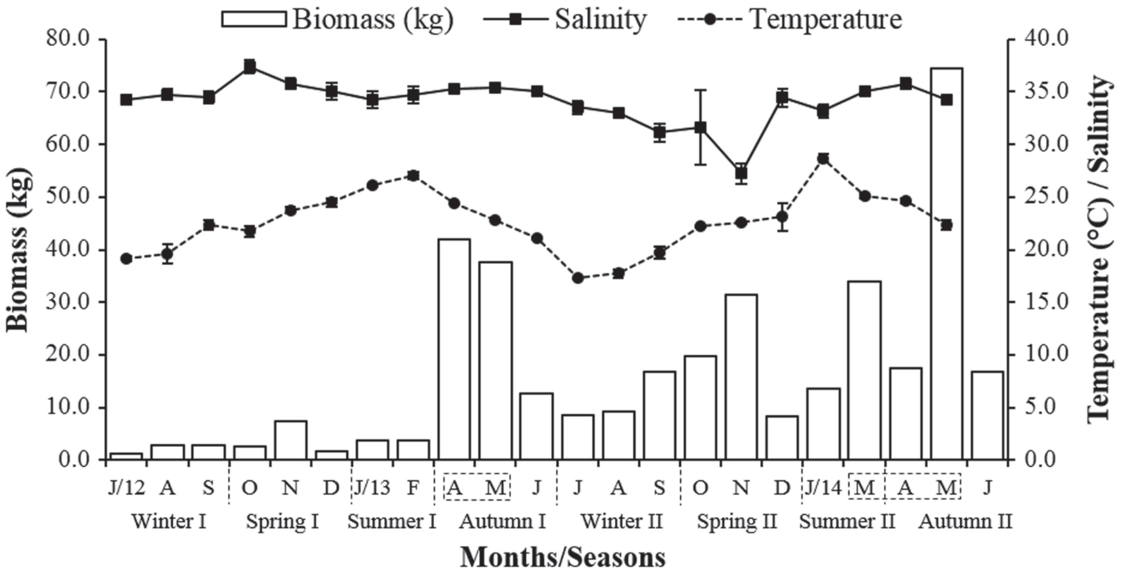

Figure 3. *Xiphopenaeus kroyeri* (Heller, 1862). Average monthly temperature variation and salinity related to sampled biomass during the period July 2012 to June 2014 in Cananéia, São Paulo, Brazil. The highlighted months represent the closing of the marine shrimp fishery in the southeast and south of Brazil.

The smallest shrimp (4.9 mm) was captured in November 2012 and the largest (33.0 mm) in July 2012; the general mean was 16.1 ±4.1 mm. The smallest and highest mean sizes were registered in November 2012 (13.1 ±4.2 mm) and December 2013 (22.7 ±3.9 mm), respectively (Fig. 5).

As for percentages of abundance, these values were found to be similar to those for biomass over the sampling period. However, in September 2012/2013, October 2012/2013, November 2013, December 2013, March 2014, and May 2014 the biomass values exceeded those of abundance (Fig. 6). In general, these months correspond to the end of winter and spring, when larger individuals were greatly abundant, resulting in a higher average size value. In contrast, the corresponding months in summer and autumn had lower mean size values, significantly different from winter and spring (Mann-Whitney test, $p < 0.05$) (Fig. 5).

DISCUSSION

This study confirmed the preference of this species for fine sediments. During the first year of data collection, the biomass of captured *X. kroyeri* was lower than in the second year. The sediment texture (phi) for the same year showed a larger particle diameter, which may have influenced the shrimp's migration to regions dominated by fine and very fine sand and/or silt + clay. The seabob shrimp's preference for fine sediments has also been reported in studies conducted in the Brazilian regions of Ubatuba, on the north coast of São Paulo (Costa *et al.*, 2007; Simões *et al.*, 2010) and Santos Bay in São Paulo (Heckler *et al.*, 2014b); this has also been seen in other species in family Penaeidae such as *Artemesia longinaris* Spence Bate, 1888 (see Costa *et al.*, 2005; Carvalho-Batista *et al.*, 2011) and *Litopenaeus schmitti* (Burkenroad, 1936) (see Bochini *et al.*, 2014).

The coastal sediment dynamics are related to

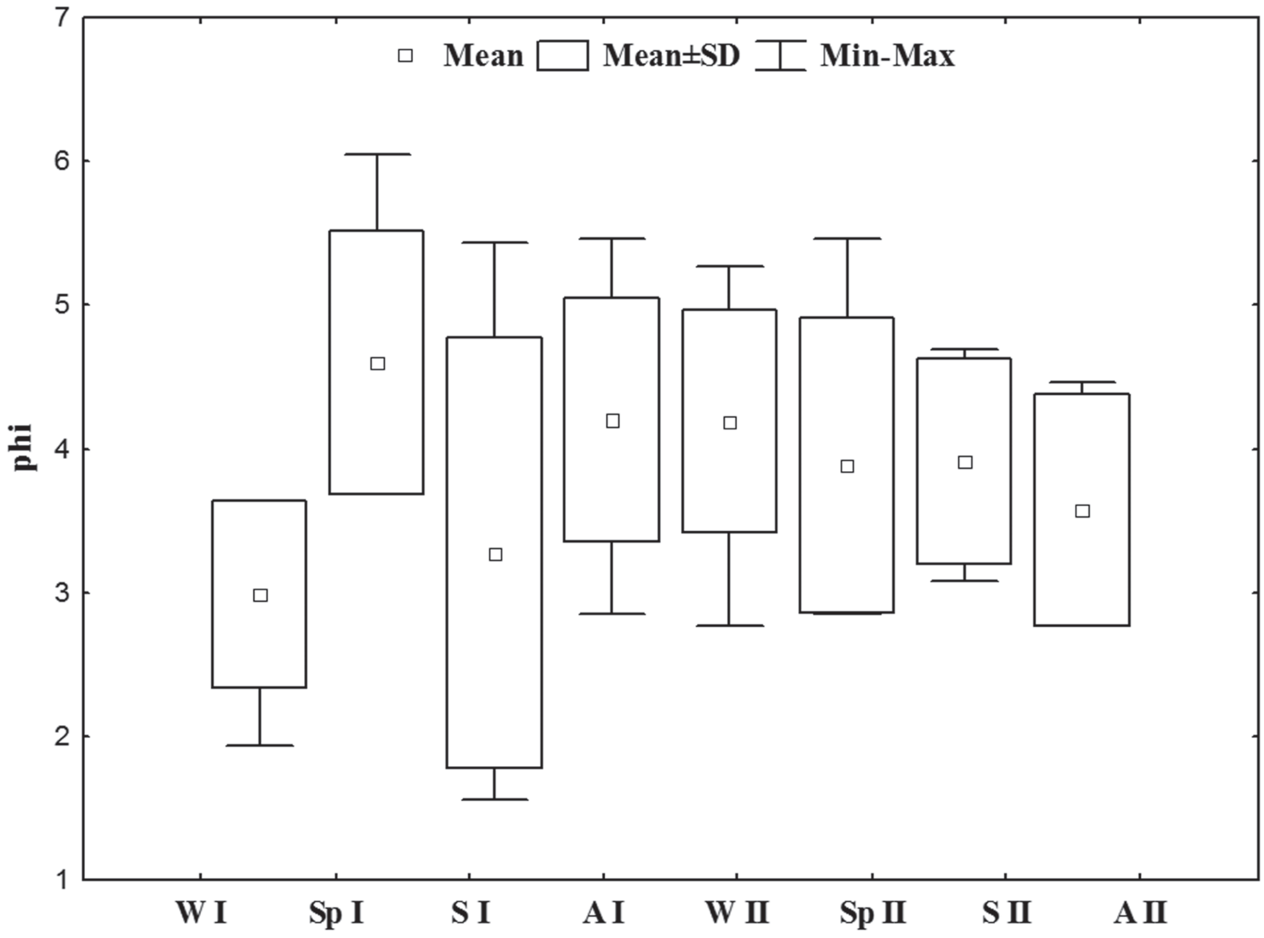

Figure 4. Box plot showing mean (±SD), maximum, and minimum diameter of substrate (phi) collected during the period July 2012 to June 2014 in Cananéia, São Paulo, Brazil. SD = standard deviation; W I = Winter I; Sp I = Spring I; S I = Summer I; A I = Autumn I; W II = Winter II; Sp II = Spring II; S II = Summer II; A II = Autumn II.

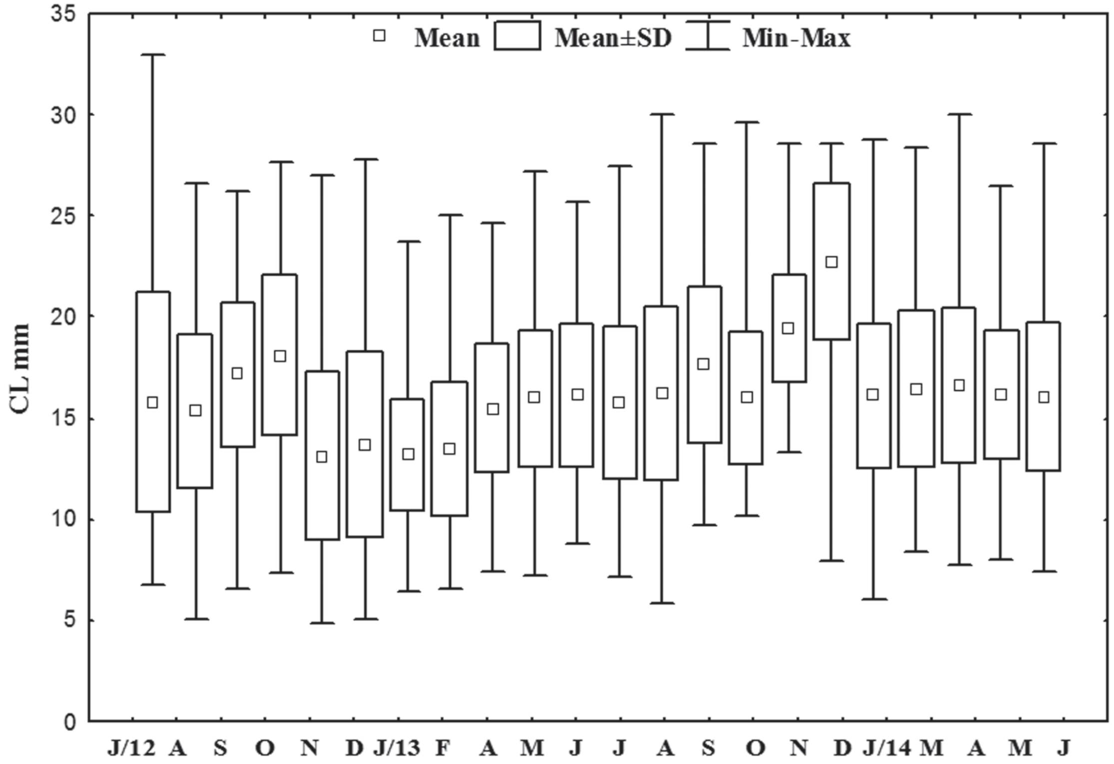

Figure 5. *Xiphopenaeus kroyeri* (Heller, 1862). Box plot showing mean (± SD), maximum, and minimum carapace length (CL mm) of shrimp collected during the period July 2012 to June 2014 in Cananéia, São Paulo, Brazil. SD = standard deviation.

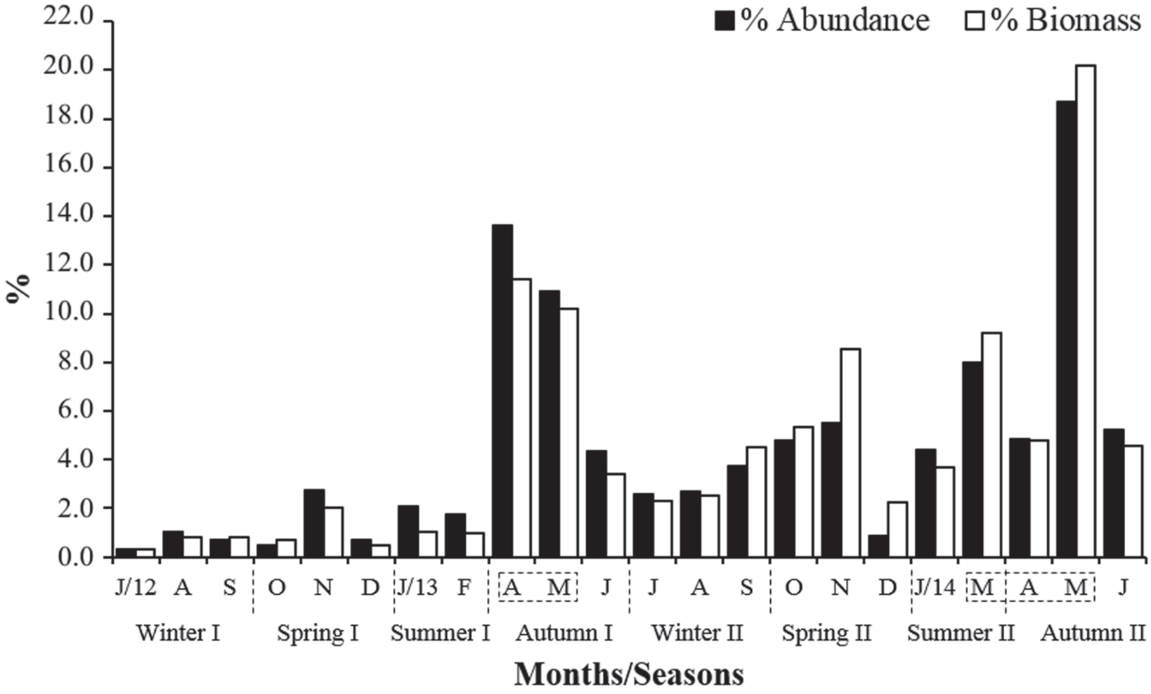

Figure 6. *Xiphopenaeus kroyeri* (Heller, 1862). Percentage of monthly abundance in relation to total abundance sampled (white bars) and percentage of monthly biomass in relation to total biomass sampled (black bars) during the period July 2012 to June 2014 in Cananéia, São Paulo, Brazil. The highlighted months represent the closing of the marine shrimp fishery in the southeast and south of Brazil.

continental water discharge coming from the estuaries to the bay (Tessler and Souza, 1998). Consequently, increased rainfall may cause further contributions to the "fresh water" coastal region, increasing sedimentation in these areas (Alber, 2002). Although rainfall data for the study period were not analyzed in this study, we hypothesize that the variation in sediment texture between the two years of the study may be associated with these factors, therefore contributing to the highest catch of individuals in the second year when the sediment had become thinner and stable. Many penaeid shrimp prefer sediments with particles measuring between 62 µm and 1 mm due to food availability and ease of burrowing to quickly escape from predators (Dall *et al.*, 1990).

The lack of statistical correlation between biomass and other environmental factors does not mean that they did not influence the distribution of the species. Changes in salinity and temperature are of paramount importance in the spatial and temporal distribution of penaeid shrimp, and studies suggest that temperature has been especially significant in the temporal distribution of *X. kroyeri* (Castro *et al.*, 2005; Costa *et al.*, 2005; 2007; Santos *et al.*, 2008). In Cananéia we found low variation in salinity, and for most months the temperature averaged above 20°C, conditions preferred by the species under study (Costa *et al.*, 2007; Simões *et al.*, 2010); this demonstrates that other factors such as fishing may influence the variation in biomass throughout the year.

The occurrence of the highest biomasses during the months comprising autumn I and II should result from the closing of the marine shrimp fishery in the southeast and south of Brazil, and this measure goes into effect from March 1 to May 31 of each year (IBAMA, 2008). During the same period, increased abundance of other species of great economic interest has been reported, such as juveniles of *Farfantepenaeus brasiliensis* (Latreille, 1817) and *Farfantepenaeus paulensis* (Pérez Farfante, 1967) and individuals of *L. schmitti* in the Ubatuba region (Costa *et al.*, 2008; Bochini *et al.*, 2014). In addition to the clear recovery of biomass during those months, there was also an abundance of smaller individuals, certainly juveniles, which shows a more intense recruitment period as well as the importance of this closure to the biomass recovery of this important fishery resource. Later in the winter, marine shrimp fishing was reopened, and a drastic decrease in biomass can be seen. In addition, the decrease in biomass may be associated with a greater number of fish landings during this period for the replenishment of local fish markets, since this species is one of the main sources of income for the population of Cananéia.

Most studies about this shrimp have been conducted along the northern coast of São Paulo; during the spring or summer water mass from the South Atlantic Central Water (SACW) often intrudes, promoting a marked decrease in temperatures (<19°C) and also a marked decrease in shrimp abundance during these periods (Costa *et al.*, 2005; 2007). However, evidence of this mass of water were not reported in our study, since no reversals of temperature values were seen in the sampled seasons. Spring and summer showed higher temperatures than autumn and winter.

In the months in which the percentage of biomass was observed to be higher in relation to the number of individuals, particularly in November 2013 and December 2013, there was a high catch of larger individuals, and these periods were ideal for fishing. However, during the same period (spring and summer), the major reproductive peaks of the species were reported for Ubatuba (Almeida *et al.*, 2012).

D'Incao *et al.* (2002) conducted a study spanning the period 1965–1999 and found a high fluctuation of *X. kroyeri* production exceeding the maximum sustainable yield, showing approximately 8900 tons (t) in 1981 and 1000 t in 1999. According to data from the São Paulo Fisheries Institute (http://www.propesq.pesca.sp.gov.br/relatorio/30), for the period 2000–2015 subsidiary capture of *X. kroyeri* ranged from 643 t (2000) to 3250 t (2012). There was a considerable recovery of natural stocks since the species was included on the off-season list, but the biomass values are still far from those previously reported.

In light of these observations, we also may note that the biomass values varied widely during the sampling period, as was also reported by the São Paulo Fisheries Institute for the previous years for the entire coast of the São Paulo state. Among the abiotic factors influencing biomass variation in this region, sediment texture and possibly temperature affected the biomass of *X. kroyeri* most significantly. Salinity and other factors such as organic matter, rainfall, competition, and predation, which were not sampled in this study, may have had a secondary influence. We can therefore infer that the current closed season is efficient and important in the recovery of seabob shrimp biomass and in protecting smaller shrimp when they are abundant. As for the best time for fishing, the end of winter and spring showed a high number of large individuals, which are most commercially significant. However, further studies addressing the reproductive biology of this species are necessary to make further conclusions on this approach.

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