REPRODUCTION AND RECRUITMENT OF THE SEABOB SHRIMP: A THREATENED EXPLOITATION SPECIES IN SOUTHEASTERN OF BRAZIL

Evelyn Raposo da SILVA[1]; Gustavo Sérgio SANCINETTI[2]; Adilson FRANSOZO[2]; Alexandre AZEVEDO[1]; Rogério Caetano da COSTA[3]

ABSTRACT

This study evaluated the reproductive period and recruitment of the threatened exploitation shrimp *Xiphopenaeus kroyeri* (Heller) in the southeast coast of Brazil. Monthly samples were carried out from March 2008 to February 2010 distributed in stations located inside (5, 10 and 15 m depth) and outside (25, 35 and 45 m depth) areas using a fishery boat equipped with an otter-trawl net. Water samples were taken for determination of temperature and salinity, and sediment samples for determination of texture and organic matter content. The reproductive period was determined by monthly amount (%) of females with mature gonads (ED+DE). The differences in sex ratio were tested using a Chi-square (χ^2) test. A Principal Components Analysis (PCA) was performed for an overview of the environmental variables and Redundancy Analysis (RDA) was performed to assess the relationship between abiotic factors and reproductive activity and recruitment. The size (carapace length) at the onset of sexual maturity was 10 mm and 12 mm for males and females, respectively. Reproductive females (based on gonad development) were found in all sampled months, with remarket or conspicuous peaks during winter and summer. The input of young recruits occurred one to two months after the increase of reproductive females. It was verified an optimal of temperature range for reproductive females, from 21 to 24 °C. These results provide subsidies that can assist making decisions about protecting priorities and in monitoring the population stocks of this important fishery resource.

Keywords: *Xiphopenaeus kroyeri*; reproductive biology; Macaé

REPRODUÇÃO E RECRUTAMENTO DO CAMARÃO SETE-BARBAS: UMA ESPÉCIE AMEAÇADA PELA EXPLOTAÇÃO NO SUDESTE DO BRASIL

RESUMO

Este estudo avaliou o período reprodutivo e o recrutamento do camarão ameaçado pela explotação, *Xiphopenaeus kroyeri* (Heller), na costa sudeste do Brasil. Amostragens mensais foram realizadas de março de 2008 a fevereiro de 2010 em estações localizadas na área interna (5, 10 e 15 m de profundidade) e na área externa (25, 35 e 45 m de profundidade) utilizando-se um barco de pesca equipado com uma rede de arrasto. Amostras de água foram coletadas para determinação da temperatura e da salinidade, e amostras de sedimento para determinação da textura e teor de matéria orgânica. O período reprodutivo foi determinado através da quantidade (%) mensal de fêmeas com gônadas maduras (ED+DE). Para verificação da proporção sexual foi utilizado o teste Chi–quadrado (χ^2). Análise de Componentes Principais (PCA) foi realizada para uma análise geral das variáveis ambientais e Análise de Redundância (RDA) foi realizada para avaliar a relação entre os fatores abióticos e atividade reprodutiva e o recrutamento. O tamanho (comprimento da carapaça) da maturidade sexual foi de 10 mm e 12 mm para macho e fêmea, respectivamente. Fêmeas reprodutivas (com base no desenvolvimento das gônadas) foram encontradas em todos os meses amostrados, com os principais picos no inverno e no verão. A entrada de recrutas ocorreu 1-2 meses após o aumento de fêmeas reprodutivas. Verificou-se um intervalo ótimo de temperatura para as fêmeas reprodutivas, de 21 a 24 °C. Estes resultados fornecem subsídios que podem auxiliar

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na tomada de decisões sobre áreas com prioridades de proteção e no monitoramento dos estoques populacionais deste importante recurso pesqueiro.

Palavras chave: *Xiphopenaeus kroyeri*; biologia reprodutiva; Macaé

INTRODUCTION

The seabob shrimp, *Xiphopenaeus kroyeri* (Heller), commonly known in Brazil as "sete-barbas shrimp", is widely distributed in the Western Atlantic from North Carolina (USA) to southern Brazil (State of Rio Grande do Sul) (COSTA *et al.*, 2003). Studies on their population dynamics have been carried out, including population structure (FRANSOZO *et al.*, 2000; CASTRO *et al.*, 2005; HECKLER *et al.*, 2013a), maturity size and reproductive period (NAKAGAKI and NEGREIROS-FRANSOZO, 1998; HECKLER *et al.*, 2013b), mainly in southeastern coast of Brazil.

This species plays an important ecological role in trophic relationships, contributing to the stability of benthic communities (PIRES, 1992). Furthermore, it is the second most important fishery resource in southeastern Brazil. It has been heavily exploited over the past few decades, reaching 90% of all penaeoid shrimps caught in shallow waters down to 20 m (FRANSOZO *et al.*, 2002; CASTILHO *et al.*, 2008). The global catch average of this shrimp has increased considerable during the last five decades with captures ranging from 3,000 tons in the 1960s to 44,607 tons in the 2011s and approximately 51% of this catch was extracted from the Brazilian coast (FAO, 2011). The Brazilian government has classified the *X. kroyeri* as threatened exploitation because of the high capture rates for all size groups throughout the range of its distribution (BRASIL, 2004).

In the late 1970's and early 80's driven by monopoly oil state company in the country, many maritime platforms were built, configuring the currently landscape of the Bacia de Campos (RJ). There are currently over 80 platforms of exploration and production acting in that region. Most of the marine oil reserves are located at the Bacia de Campos, totaling 95% of the marine production (GOMES *et al.*, 2001). With the increasing oil exploration, and consequently with the accident increasing, the coastal zone is more vulnerable to damage. Despite the constant progress of security technology operating in exploration and transportation of oil, the risk of accidents still exists and the damage caused are still a threat to coastal areas around the world (ALCÂNTARA and SANTOS, 2004).

At just over 30 years, Macaé, a small agricultural and fishing municipality, became the operation base of oil and gas exploration in the Bacia de Campos, consolidating its position as a leading center of activities of this sector in Brazil (LIANZA and ADDOR, 2005). However, part of the population still lives in the fishing activity, especially by the exploitation of seabob shrimp, an important fishing resource of the municipality (BRASIL, 2012). Considering the importance of this resource, an oil disaster during periods of spawning and recruitment may result in reduction in the number of recruits, since exposure to oil may affect your development, and consequently reduction in the shrimp stocks (GOMES *et al.*, 2001; BERTI *et al.*, 2009). Thus, know the population dynamics of organisms that are captured by fishing activities is essential for the protection of species overexploited or at risk of extinction and also important in the formation of databases, especially in places with high risks of suffering from environmental disasters such as those that occur due to oil exploration activities (DALL *et al.*, 1990; GOMES *et al.*, 2001; SHIH *et al.*, 2009; ALMEIDA *et al.*, 2012).

The knowledge of reproductive biology of marine species provides subsidies that can assist making decisions, to facilitate the identification of priority areas for protection, and mitigate impacts caused by environmental disasters (GOMES *et al.*, 2001; NOERNBERG *et al.*, 2008).Thus, this study evaluated the sex ratio, reproductive parameters and recruitment of the threatened exploitation shrimp, *X. kroyeri* in the southeastern coast of Brazil.

MATERIAL AND METHODS

Sampling

Samples were obtained monthly from March, 2008 to February, 2010(Autumn: March-May; and so on) in the Macaé municipality, state of Rio de Janeiro (22°22′33″S and 41°46′30″W) in six stations (5, 10, 15, 25, 35, and 45 m depth) parallel to the coast line (Figure 1). The shallowest stations were categorized in this study as the "inside area", whereas the deepest ones were categorized as "outside area". All samplings were carried out in accordance with Brazilian state and federal laws (Instituto Chico Mendes de Biodiversidade/ICMBio n° 11274).

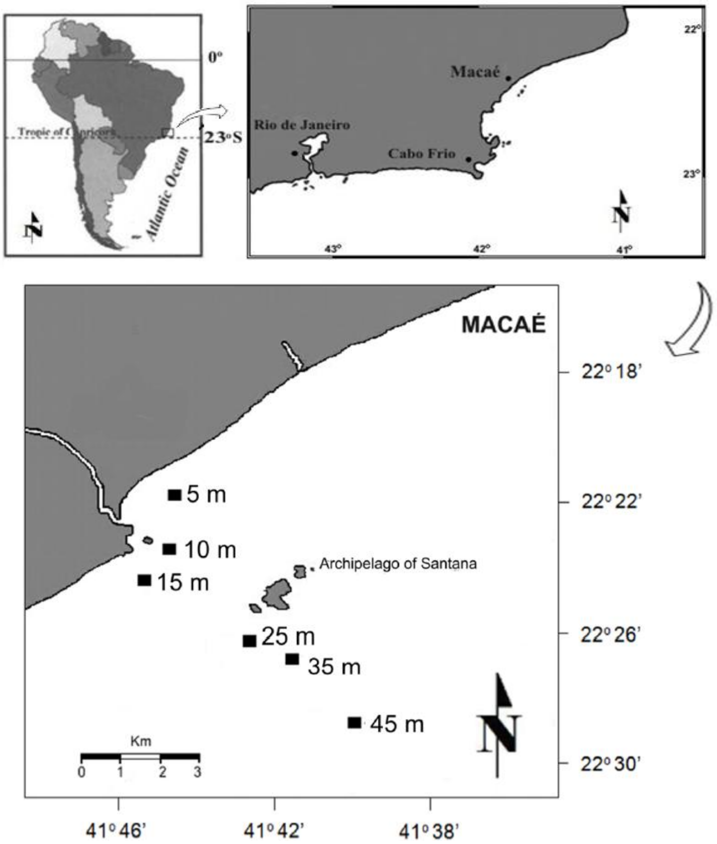

Figure 1. Macaé's coast line (RJ) and the locations of sampled sites in the "inside area" (5, 10 and 15 m) and "outside area" (25, 35 and 45 m).

A shrimp fishing boat equipped with an otter-trawl net (3.5 m of mouth width, 20 mm of mesh size and 15 mm in the cod end) was used for trawling. The trawls were standardized in 15 minutes at 2.0 knots. It was verified the depth and environmental factors. Depth was determined using an ecobathymeter coupled with a GPS (Global Positioning System).

Salinity and temperature (°C) were measured from the sample on the surface of the water column and the bottom layer at each station (5, 10, 15, 25, 35 and 45 m). It was obtained monthly in each station using a Van Dorn bottle. In the laboratory, the salinity was verified with a manual refractometer calibrated with distilled water. The water temperature was verified with a mercury thermometer immediately after sampling in a thermic isolated container in the shade. Sediment samples were also collected in each station and season of the year using a Van Veen grab (0.06 m^2).

Grain-size categories followed the American standard, and sample sediments were sieved at 2.0 mm (gravel), 1.0 mm (very coarse sand), 0.5 mm (coarse sand), 0.25 mm (intermediate sand), 0.125 mm (fine sand), 0.0625 mm (very fine sand) and smaller particles, which were classified as silt-clay. Grain-size fractions were expressed on the phi (Φ) scale, accounting for the central tendency of sediment samples. Procedures for sediment analysis followed HÁKANSON and JANSSON

(1983) and TUCKER (1988). The sediment texture was represented using the three most important grain size classes, as in MAGLIOCCA and KUTNER (1965). Class A corresponds to sediments in which coarse sand (CS), very coarse sand (VCS), and gravel (G>0.25 mm) account for more than 70% by weight. In class B, fine sand (FS) and very fine sand (VFS) make up more than 70% by weight of sediment samples. More than 70% of sediments in class C are silt and clay (S+C). The organic matter content (%) was obtained by ash weighing: three aliquots of 10 g each per station, placed in porcelain crucibles for 3 h at 500 °C, and the samples were weighed one more time (MANTELATTO and FRANSOZO, 1999).

In the laboratory, shrimps were identified following HOLTHUIS (1980), PÉREZ-FARFANTE and KENSLEY (1997), and COSTA *et al.* (2003). A subsample of 300 g total biomass was separated randomly for examination of the sex and length of each individual. When the catch did not exceed 300 g, all shrimps were measured. Carapace length (to nearest 0.1 mm), corresponding to the distance from the orbital angle to the posterior margin of the carapace, was also determined for each shrimp. The specimens were macroscopically classified according sex. In males, individuals with no fused endopods were considered immature (juvenile), otherwise as mature (BAUER, 1986, 1991; FRANSOZO *et al.*, 2011). Females had their maturity stage verified based on their gonads developed. The criteria used to determine reproductive females were based on the size of the smallest female with developed gonad.

Females reproductive condition was determined by macroscopic observation of the degree of ovarian development (color and volume occupied by the gonads) based on BAUER and LIN (1994) and COSTA and FRANSOZO (2004). Ovaries categorized as immature (IM) varied from thin, transparent strands to thicker strands; rudimentary (RU), adult females with undeveloped gonads, were much larger and thicker, and colored white; developing (ED) were light green; or (DE) developed (near spawning), were green to olive green. The reproductive period was determined grouping the stages ED+DE as reproductive females.

Data Analysis

Abiotic factors (temperature, sediment texture and organic matter content), depth, and biotic factors (carapace length, juveniles, reproductive females, adult females and males) had the the normality examined by Shapiro–Wilk test and homogeneity of variances performed by Levene's test (ZAR, 1999).

Length frequency distributions of shrimps were constructed with 2 mm CL size classes for each sex, and the Student`s T-test was used to compare size between sexes. The null hypothesis was that size distribution between sexes did not differ significantly among months or stations samples. The differences in sex ratio were tested for significant divergence from the expected 1:1 ratio by using a Chi-square (χ^2) test (SOKAL and ROHLF, 1995).

A Principal Components Analysis (PCA) was performed with a maximum variation of the data obtained, to determine which factor (temperature, salinity, sediment texture, organic matter content and depth) explained most of the data variation. According to KOHLER and LUNIAK (2005), by evaluating the eigenvectors and eigenvalues, in addition to visual inspection of the biplot, it is possible to observe the strength of the variation in the data set, and the correlation among variables. Loadings of significant variation of environmental variables and modular values greater than 0.4 for principal components were considered. According to RAKOCINSKI *et al.* (1996), relationships between variables and axes with values above 0.4 have ecological importance. The axes to be analyzed were determined based on the criterion of "Proportion of Total Variance" suggested by JACKSON (1993).

It was performed a Redundancy Analysis (RDA) to assess the relationship between interest groups of juveniles, reproductive females, adult females and males with abiotic factors (temperature, sediment texture and organic matter content) and depth. The abiotic variables were correlated with the biotic matrix through a set of environmental vectors of ordination (function "envfit"), a routine that draws the maximum correlation of environmental variables with the data of an ordination. Despite the bottom temperature was not significant at the PCA; it was used in the RDA, since it can be a regulator environmental factor in abundance and spatial-temporal distribution of shrimp species. Abiotic factors that showed a high correlation coefficient of Spearman in the PCA were removed from the RDA analysis. The evaluation of the significance of the adjustment of vectors occurred by permutations (n = 9999) using the statistical "goodness of fit" of the correlation coefficient squared (r^2). For environmental variables, the coefficient was defined as:

$$r^2 = 1 - SSw/SSt,$$

where: SSw – sum of the squares within the groups, and SSt – total sum of squares (OKSANEN *et al.*, 2012).

The Principal Components Analysis (PCA) and the Canonical Redundancy Analysis (RDA) were performed using the R software (R DEVELOPMENT CORE TEAM, 2013) considering $\alpha = 0.05$ (ZAR, 2010).

RESULTS

Throughout the present study, a total of 3.655 individuals were analyzed. The monthly analysis indicated that except March and June 2008; July, October and December 2009; and January and February 2010, all months showed significant differences in sex ratio (χ^2, $p<0.05$) (Table 1). Except depths of 5 and 15m, higher percentages of females were also across sampling locations (χ^2, $p<0.05$) (Table 2).

Table1. Descriptive data of *Xiphopenaeus kroyeri* (Heller), sex ratio, *p* and chi-squared (χ^2) values. Data sampled from March, 2008 to February, 2010 along the coast of Macaé, RJ, Brazil (* significant differences).

Months	♂	♀	Total	χ^2	*p*	Sex Ratio
Mar/08	12	4	16	4.000	**0.0455***	1♂:0.33♀
Apr/08	42	58	100	2.560	0.1096	1♂:1.38♀
May/08	53	51	104	0.038	0.8445	1♂:0.96♀
Jun/08	113	44	157	30.325	**<0.0001***	1♂:0.39♀
Jul/08	82	69	151	1.119	0.2901	1♂:0.84♀
Aug/08	80	85	165	0.152	0.6971	1♂:1.06♀
Sep/08	38	47	85	0.953	0.3290	1♂:1.24♀
Oct/08	70	83	153	1.105	0.2933	1♂:1.19♀
Nov/08	41	40	81	0.012	0.9115	1♂:0.98♀
Dec/08	65	54	119	1.017	0.3133	1♂:0.83♀
Jan/09	61	70	131	0.618	0.4317	1♂:1.15♀
Feb/09	28	39	67	1.806	0.1790	1♂:1.39♀
Mar/09	0	1	1	_		_♂:1.00♀
Apr/09	66	88	154	3.143	0.0763	1♂:1.33♀
May/09	149	156	305	0.161	0.6886	1♂:1.05♀
Jun/09	112	127	239	0.941	0.3319	1♂:1.13♀
Jul/09	94	138	232	8.345	**0.00039***	1♂:1.47♀
Aug/09	121	133	254	0.567	0.4515	1♂:1.10♀
Sep/09	95	108	203	0.833	0.3615	1♂:1.14♀
Oct/09	75	180	255	43.235	**<0.0001***	1♂:2.40♀
Nov/09	87	108	195	2.262	0.1326	1♂:1.24♀
Dec/09	95	133	228	6.333	**0.0118***	1♂:1.40♀
Jan/10	111	65	176	12.023	**0.0005***	1♂:0.59♀
Feb/10	59	25	84	13.762	**0.0002***	1♂:0.42♀
Total	**1749**	**1906**	**3655**	**6.744**	**0.0094**	**1♂:1.09♀**

Table 2. Descriptive data of *Xiphopenaeus kroyeri* (Heller), sex ratio, *p* and chi-squared (χ^2) values. Data sampled by area and depth along the coast of Macaé, RJ, Brazil (* significant differences).

	Transects	♂	♀	Total Adults	χ^2	*p*	Sex Ratio	Juveniles
Inside Area	**5**	859	832	1691	431	0.5114	1♂:0.97♀	78
	10	421	516	937	9.632	**0.0019***	1♂:1.23♀	46
	15	361	391	752	1.197	0.2740	1♂:1.08♀	27
Outside Area	**25**	65	91	156	4.333	**0.0374***	1♂:1.40♀	0
	35	38	62	100	5.760	**0.0164***	1♂:1.63♀	0
	45	5	14	19	4.263	**0.0389***	1♂:2.80♀	0
	Total	**1749**	**1906**	**3655**	**6.744**	**0.0094**	**1♂:1.09♀**	**151**

The smallest reproductive female found had 12 mm of CL and the smallest adult male had 10 mm of CL. The largest female was 40.3 mm of CL, which was greater than of the largest male (35 mm). The data was normal distribution (Shapiro–Wilk test, $p = 0.9$). In general, mean sizes did not differed significantly between females (19.5 ± 4.0 mm) and males (19.6 ± 6.0 mm) (Figure 2, Student's test, t = 0.4, $p = 0.7$).

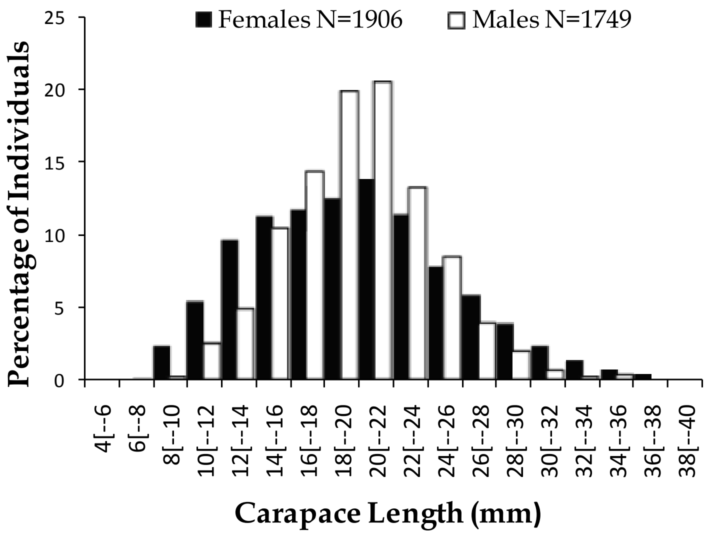

Figure 2. Size frequency distribution of male and female individuals of *Xiphopenaeus kroyeri* by size classes (mm), sampled from March, 2008 to February, 2010 along the coast of Macaé, RJ, Brazil.

The reproductive females (ED+DE) occur in all sampling months, except March 2009. During the fall and winter reproductive females were observed both "inside area" and "outside area". In the spring and summer reproductive females are mainly "inside area". The recruits were present only "inside area", being observed intensification in autumn and spring (April and October of each year) (Figures 3, 4 and 5). The depth of 5m showed the greatest number of recruits (n = 78) (Table 2).

During the present study, environmental factors varied in spatial-temporal gradients. The smallest mean bottom water salinity was registered during March/2009, mainly "inside area" (27.0 ± 1.0), when compared to "outside area" (31.7 ± 3.2). Contrarily, the greater mean values were verified in October/2009 (37.0 ± 1.0) in "inside area", and April/2009 (37.7 ± 0.6) in "outside area".

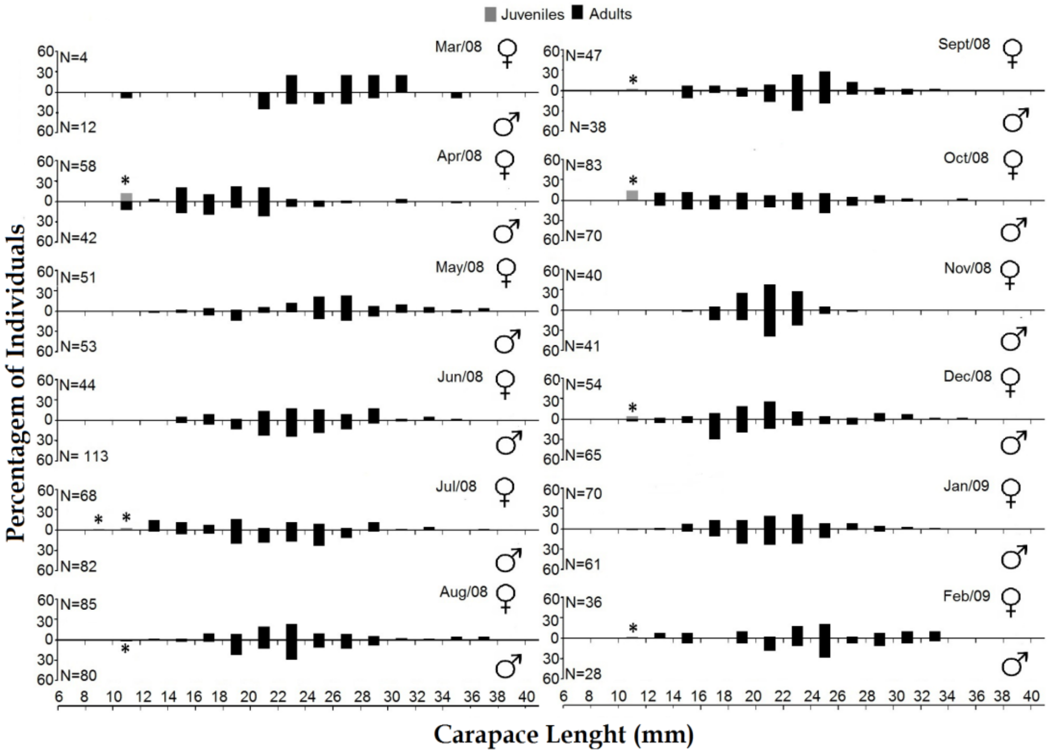

Figure 3. Size frequency distribution of *Xiphopenaeus kroyeri* according to size classes (mm), sampled at depths from 5 and 45 m and the periods from March, 2008 to February, 2009. The range of each size class was 2 mm (* Classes with juvenile individuals).

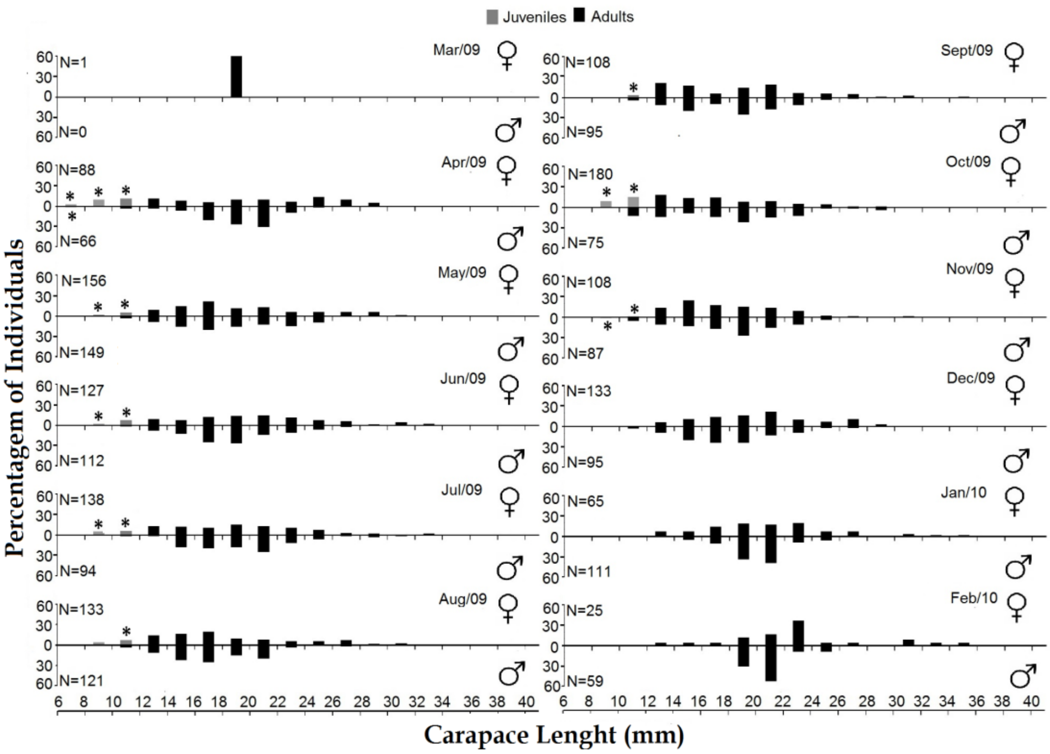

Figure 4. Size frequency distribution of *Xiphopenaeus kroyeri* according to size classes (mm), sampled at depths from 5 and 45 m and the periods from March, 2009 to February, 2010. The range of each size class was 2 mm (* Classes with juvenile individuals).

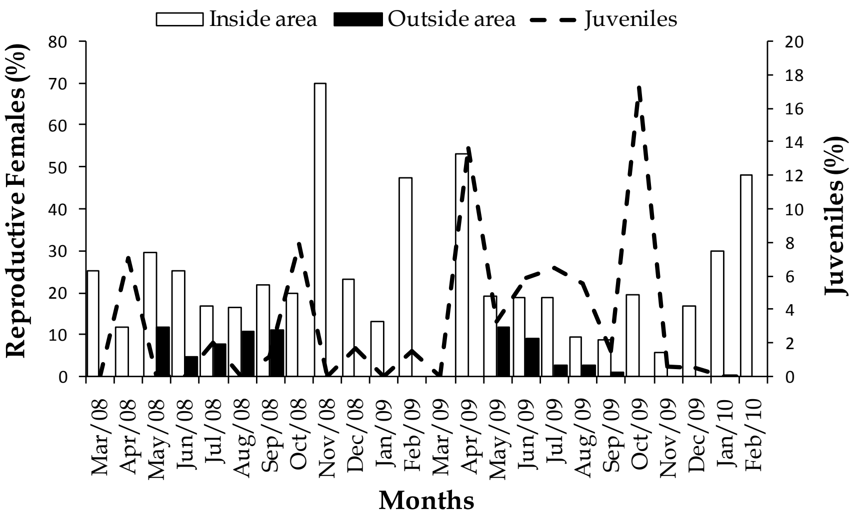

Figure 5. Percentage of reproductive females "inside area" and "outside area" and juveniles of *Xiphopenaeus kroyeri* sampled from March, 2008 to February, 2010 along the coast of Macaé, RJ, Brazil.

The smaller mean values of bottom temperature were registered in spring and summer of both years, mainly in January/2010 and November/2009 in inside and outside area, respectively. The opposite was observed in winter with greater mean bottom temperature values (Table 3).

Table 3. Mean, maximum and minimum values of salinity and temperature for each month in "inside area" and "outside area", sampled from March 2008 to February 2010 along the coast of Macaé, RJ, Brazil.

Months	Temperature		Sanility	
	Inside Area	Outside Area	Inside Area	Outside Area
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Mar/08	24.5 ± 1.8	20.8 ± 0.3	33.3 ± 5.5	37.3 ± 0.6
Apr/08	23.8 ± 0.3	21.8 ± 0.3	33.0 ± 0.0	35.0 ± 0.0
May/08	24.2 ± 0.3	21.8 ± 0.8	34.3 ± 0.6	35.0 ± 0.0
Jun/08	23.8 ± 0.3	22.8 ± 0.3	33.7 ± 0.6	35.3 ± 0.6
Jul/08	21.7 ± 0.6	21.0 ± 1.0	36.7 ± 0.6	37.0 ± 0.0
Aug/08	21.3 ± 0.6	19.7 ± 1.2	33.3 ± 0.6	33.3 ± 1.5
Sep/08	22.3 ± 1.2	19.7 ± 1.5	36.0 ± 1.0	35.3 ± 2.1
Oct/08	20.7 ± 0.6	18.2 ± 0.3	36.0 ± 1.0	36.0 ± 0.0
Nov/08	20.3 ± 1.3	18.7 ± 0.3	36.5 ± 0.5	36.3 ± 0.3
Dec/08	20.5 ± 2.2	20.0 ± 1.7	36.8 ± 0.1	36.8 ± 0.5
Jan/09	21.7 ± 0.6	18.7 ± 0.3	33.3 ± 1.2	34.3 ± 0.6
Feb/09	20.7 ± 0.6	19.3 ± 0.6	33.0 ± 0.0	33.0 ± 1.0
Mar/09	23.5 ± 2.3	18.7 ± 0.3	27.0 ± 1.0	31.7 ± 3.2
Apr/09	23.8 ± 0.8	18.8 ± 0.3	36.7 ± 0.6	37.7 ± 0.6
May/09	23.0 ± 1.0	21.0 ± 1.0	36.0 ± 0.0	36.7 ± 0.6
Jun/09	22.7 ± 0.6	21.0 ± 0.0	34.0 ± 0.6	36.7 ± 1.2
Jul/09	22.5 ± 0.5	21.0 ± 0.0	35.7 ± 1.5	35.7 ± 1.2
Aug/09	23.3 ± 0.6	21.3 ± 0.6	35.3 ± 0.6	36.0 ± 0.0
Sep/09	22.3 ± 0.6	19.7 ± 1.2	34.7 ± 0.6	35.5 ± 0.5
Oct/09	21.7 ± 2.5	19.0 ± 0.0	37.0 ± 1.0	36.0 ± 1.7
Nov/09	21.3 ± 1.5	17.0 ± 0.0	32.7 ± 0.6	33.0 ± 0.0
Dec/09	22.0 ± 1.0	19.0 ± 0.0	34.7 ± 0.6	35.3 ± 0.6
Jan/10	19.3 ± 0.8	17.8 ± 0.3	35.7 ± 1.5	35.7 ± 1.2
Feb/10	22.8 ± 1.6	19.3 ± 0.6	34.7 ± 0.6	36.7 ± 1.5

Spatially, the temperature decrease with increasing depth; the inverse was obtained for salinity. The deeper areas presented fine sediment composed of silt and clay and high organic matter content (Figure 6).

The PCA performed with the abiotic data (B.T., B.S., O.M., phi) extracted two axes that explained 87.80% of the total data variance; axis 1 accounted for 72.35% and axis 2 for 15.45%. The environmental variables, organic matter, phi and salinity were able to explain the variation of the data, showing modular values above 0.4 (Figure 7). The results of the Spearman correlation coefficients generated by the PCA indicated a high correlation between organic matter and phi (Table 4).

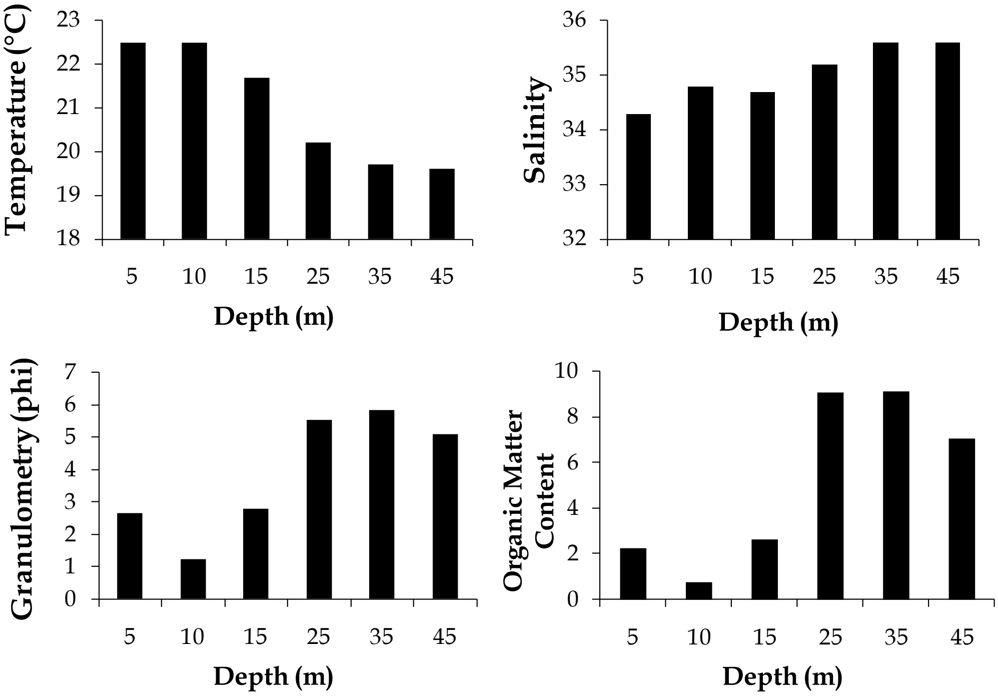

Figure 6. Mean values of abiotic factors at each transect sampled from March, 2008 to February, 2010 along the coast of Macaé, RJ, Brazil.

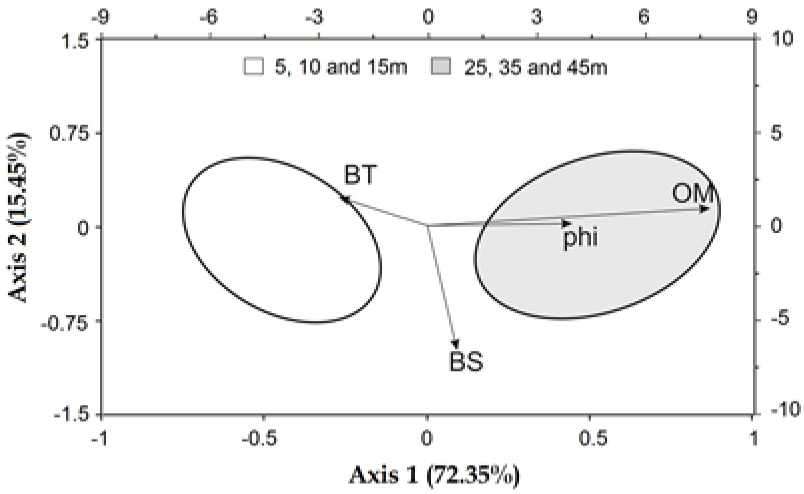

Figure 7. Principal Components Analysis showing the abiotic variables analyzed at Macaé coast (B.T. = bottom temperature; B.S. = bottom salinity; O.M. = organic matter content; phi = granulometry).

Table 4. Results of Spearman correlation coefficients generated by Principal Component Analysis.

	BT	BS	OM	phi
BT	1	-0.1456	-0.4529	-0.4884
BS	-0.1456	1	0.1664	0.1523
OM	-0.4529	0.1664	1	**0.9212**
phi	-0.4884	0.1523	**0.9212**	1

The RDA performed between abiotic data and interest groups extracted two axes that explained 98.16% of the total data variance; axis 1 accounted for 94.49% and axis 2 for 3.67%. The adjustment algorithm of the environmental variables in RDA identified B.T. and O.M. ($r^2 = 0.08$, $p<0.05$ and $r^2 = 0.17$, $p<0.005$, respectively) as significant variables for data variation (Figure 8).

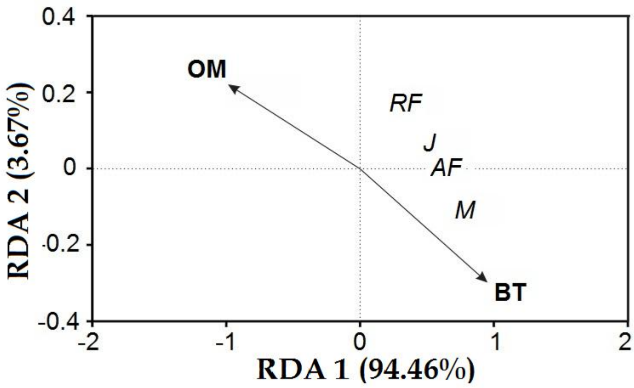

Figure 8. Redundancy Analysis showing the relationship between abiotic variables and species abundance (BT = bottom temperature; OM = organic matter content; J = juveniles; M = males; RF = reproductive females; AF = adult females).

Evaluating the average number of individuals by trawling distributed by abiotic factors intervals class of interest it was observed a higher average number of reproductive females and juveniles associated with shallower depth. The *X. kroyeri* was found in all classes of phi, being more abundant in the fraction with a prevalence of coarse sand ($0 < phi \geq 1$) and fine sand ($2 < phi \geq 3$). The greatest abundance of reproductive females and juveniles occurred in the classes with low organic matter content of sediment (0 to 6%). It was observed an increased number of specimens predominantly from 21 to 24 °C (Figure 9).

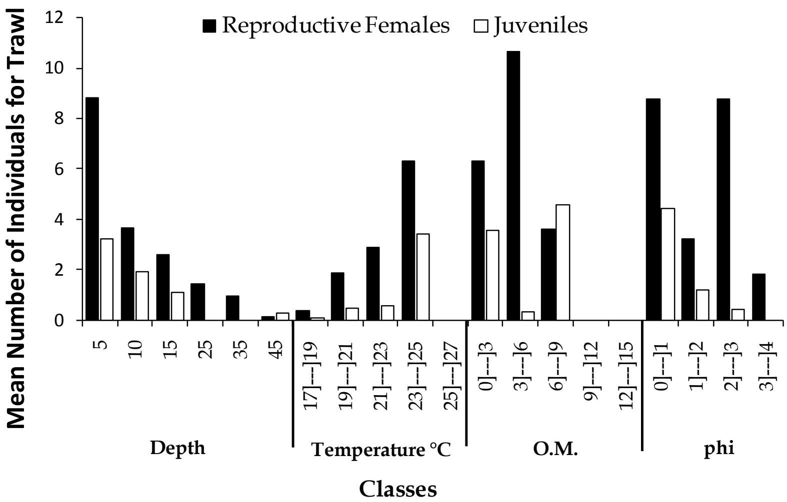

Figure 9. Mean number of individuals by trawling distributed by depth and abiotic factors intervals class of interest sampled from March 2008 to February 2010

DISCUSSION

The species tended to 1:1 ration over the two years of sampling, however, monthly disparity was found between the sexes. The sex ratio differences were found in most months in other studies (LOPES *et al.,* 2010; HECKLER *et al*., 2013a). Disproportion in sex ratio may occur due to migration events and differential use of habitat that are associated with reproductive processes. COSTA *et al*. (2010) found that *Artemesia longinaris* Bate migrated to deep regions after reproduction, whereas reproductive females sought shallow waters in search of food and were more easily caught than males during this period.

In the present study, disproportion in sex ratio may be due to greater demand for food resources by the females, once it was observed the presence of reproductive females in almost all sampling period, particularly "inside area". Females forage for a longer period in this areas becoming more vulnerable to capture. A differential migration of both males and females to areas above 45 meters depth does not seem feasible, since above this depth the mean of the bottom water temperature in "outside area", in almost all months sampled, did not exceed 21 °C. According to CASTILHO *et al*. (2007), water temperature may be a limiting factor for the sexual maturation of prawns. Furthermore, SANCINETTI *et al.* (in press) verified that periods under SACW, and consequently low temperatures, it was identified an increase in the total of individuals captured "inside area". Thus, temperatures below 21°C may represent a physical barrier to the establishment of the species in a particular region.

The species *X. kroyeri* showed maximum carapace length (CL) greater than those observed in other studies in the south-southeastern Brazil (CAMPOS *et al*., 2011; HECKLER *et al*., 2013a). This pattern, lengths greater, was also found in the same region of the present study for *A. longinaris* (SANCINETTI *et al*., in press). Some authors suggest that size variations are regulated by environmental conditions (*e.g.*, primary production, sediment type, salinity and water temperature) (COSTA *et al*., 2005; CASTILHO *et al*., 2007; SANCINETTI *et al*., in press). In the study region, the primary productivity was the potential factor that regulating the growth of organisms due to greater availability of food. In Macaé, the intrusion events of the SACW and therefore the resurgence phenomenon cause an increase chlorophyll values and consequently increasing phytoplankton production. This increased primary production stimulates subsequent production of zooplankton, raising the availability of food for shrimps (VEGA-PÉREZ, 1993; DE LÉO and PIRES-VANIN, 2006).

Reproductive females of *X. kroyeri* were found throughout the study period, except in March 2009, when there was no record, and in September and November, when the abundance of mature females was considerably lower than other months. These results reflect a pattern described by DALL *et al.* (1990) that the penaeid generally exhibit a tropical/sub-tropical reproduction pattern. According to this, the relatively constant conditions in tropical/subtropical and the high temperatures throughout the year are important factors in the initiation and maintenance of gametogenesis, thus individuals tend to continuous reproduction with annual peaks (SASTRY, 1983; BAUER and LIN, 1994; COSTA and FRANSOZO, 2004).This pattern was also observed in Ubatuba/São Paulo, with two main reproductive female peaks of *X. kroyeri*, one in spring and the other in summer (NAKAGAKI and NEGREIROS-FRANSOZO, 1998; CASTRO *et al*., 2005).

In the present study, *X. kroyeri,* adults and juveniles, occurred at high salinities, which corroborates that juveniles are not estuarine dependent and complete their life cycles in salinities above 30. Similar results were verified by CASTRO *et al*. (2005) and COSTA *et al.* (2007) in Ubatuba/São Paulo. The present results contradict other studies that suggest that *X. kroyeri* is euryhaline but only tolerates salinities between 21 and 36 (GUNTER *et al.,* 1964; CORTÉS and NEWMARK, 1992).

The coast of Macaé is strongly influenced by the intrusion of SACW that occurs in spring and summer (SANCINETTI *et al*., 2014; DE LÉO and PIRES-VANIN, 2006). It has as main characteristic the lower temperature of the bottom water (ACHA *et al*., 2004; DE LÉO and PIRES-VANIN, 2006). In the study area it was found that during spring (September, October and November) and summer (December, January and February) there is a retreat of reproductive females for shallower areas where the bottom water temperature remains higher average, and juveniles remain year-round in the shallower areas where the higher average bottom water temperature is more suitable for their development. Thus, this study had different results found by HECKLER *et al.* (2013a) in the Bay of Santos (SP), which suggests that *X. kroyeri* females come close to shallow areas to spawn and juveniles return to deeper regions along with the adults of both sexes.

The negative correlation with organic matter and abundance of *X. kroyeri,* regardless of the interest group (J, M, RF, AF), demonstrated by the RDA and by the analysis of the number of reproductive females and juveniles per classes of organic matter and phi, not coincides with that reported by previous studies in other regions. Shrimps mostly inhabit fine/very fine sand and/or silt/clay along the Brazilian coast (COSTA *et al.*, 2000, 2007, 2011; FRANSOZO *et al.*, 2002; CASTILHO *et al.*, 2008; SIMÕES *et al.*, 2010; FREIRE *et al.*, 2011). It suggests that this result reflect of the particular sediment pattern of the studied region. Between the beach and the Santana archipelago, there is the formation of a submarine submerged sandy strip that allows for the removal of finer sediments through the action of waves in shallow areas (GARCÊZ, 2007). This leads to the establishment of a pattern of medium and very coarse sand in the "inside areas" (where *X. kroyeri* was more abundant) and a sediment composed of finer grains at depths higher than 15 meters. Therefore, in the region of Macaé the sediment is not a regulating factor of the distribution of *X. kroyeri* which reinforces the importance of temperature in the studied region.

The species has no population stratification and it is common occurrence of juveniles and adults in the same area (BRANCO, 2005; HECKLER *et al*., 2013b). The results of this study suggest that the juvenile recruitment peaks, during autumn (March, April and May) and spring (September, October and November), are a consequence of reproductive investment in previous months. It can be verified by the higher abundance of mature females during winter (June, July and August) and summer (December, January and February). The juvenile recruitment may be related to the circulation of water masses in the region. The SACW also elevates the chlorophyll *a* values, resulting in the increase of phytoplankton and zooplankton (DE LÉO and PIRES VANIN, 2006), being of great importance for the growth and survival of larvae of decapod (COSTA and FRANSOZO, 2004). It is suggested that the availability of food in the spring, due to the presence of SACW on the coast of Macaé (SANCINETTI *et al*., 2014) provided the more effective recruitment during this period compared to the rest of the year.

Studies indicate that the water temperature is the main influencer of the maturation and spawning of the shrimp Penaeoidea (DALL *et al*., 1990; BAUER and RIVERA VEGA, 1992; CASTILHO *et al*., 2007). According to the results, the reproductive activity of females was more intense in periods of the year when the temperature was between 21 °C and 24 °C. The increase temperature values and availability of food in previous months of the peak of juveniles indicates that those factors act as initiator of reproductive activity.

CONCLUSION

The region of Macaé presents ideal conditions for the development of the *X. kroyeri* and the temperature was the main regulating factor of the population. The optimal temperature (21-24 °C) in shallow areas favored the presence of reproductive females and juveniles and permitted the species present continuous reproduction and annual peaks of juvenile recruitment.

The results obtained in this study are knowledge basis for a better understanding of the biology of *X. kroyeri* in the region and may be a reference in monitoring this important natural and fishery resource and in an area characterized by environmental fragility resulting from oil activities.

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