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Population parameters and the relationships between environmental factors and abundance of the *Acetes americanus* shrimp (Dendrobranchiata: Sergestidae) near a coastal upwelling region of Brazil

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Financial Support: The authors are indebted to the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) for providing financial support during field collections and visiting activities (Grants 2009/54672-4, 2010/50188-8 to RCC; Scholarships 2012/14874-0 to APFS; 2014/01632-3 to SMS) and to CNPq (Research Scholarships PQ 305919/2014-8 to RCC).

ABSTRACT

The population dynamics of *Acetes americanus* was investigated, focusing on the sex ratio, individual growth, longevity, recruitment and relationship between abundance and environmental factors in the region of Macaé, strongly influenced by coastal upwelling. Otter trawl net samplings were performed from July 2010 to June 2011 at two points (5 m and 15 m). Nearly 19,500 specimens, predominantly females (77.15%), were captured. Their sizes, larger than that of males, indicated sexual dimorphism. Shrimps at lower latitudes present larger sizes and longer longevity than those from higher latitudes. This difference is probably due to low temperatures and high primary productivity. Though no statistical correlation was found between abundance and environmental factors, the species was more abundant in temperatures closer to 20.0º C and in months with high chlorophyll-*a* levels. Due to the peculiar characteristics of this region, *A. americanus* showed greater differences in size and longevity than individuals sampled in other studies undertaken in the continental shelf of Southeast Brazil.

Descriptors: Pelagic, Growth, Longevity, Macaé - RJ, Decapoda.

RESUMO

Foi investigada a dinâmica populacional de *Acetes americanus*, enfocando a razão sexual, crescimento dos indivíduos, longevidade, recrutamento e a relação da abundância com dos fatores ambientais na região de Macaé, a qual é fortemente influenciada pela ressurgência costeira. Foram realizadas coletas de julho de 2010 a junho de 2011, em dois pontos (5 m e 15 m), utilizando uma rede *otter trawl*. Cerca de 19.500 indivíduos foram capturados com predominância de fêmeas (77,15%) e essas foram maiores que os machos indicando dimorfismo sexual. Houve inversão do paradigma latitudinal, onde os camarões apresentaram maiores tamanhos e longevidade quando comparados a outras regiões de maiores latitudes e isso provavelmente se deve às baixas temperaturas e alta produtividade primária. Apesar de não apresentar correlação estatística entre a abundância e os fatores ambientais, a espécie foi mais abundante em temperaturas próximas aos 20,0º C e nos meses com alta concentração de clorofila-*a*. Devido às características peculiares da região, os espécimens de *A. americanus* apresentarem diferenças em relação a tamanho e longevidade quando comparados aos indivíduos amostrados em outros estudos realizados na plataforma continental do sudeste brasileiro.

Descritores: Pelágico, Crescimento, longevidade, Macaé - RJ, Decapoda.

http://dx.doi.org/10.1590/S1679-87592015086206303

INTRODUCTION

Shrimp of the genus *Acetes* H. MILNE EDWARDS, 1830, inhabit estuaries and coastal waters in tropical, subtropical, and temperate regions around the globe (XIAO; GREENWOOD, 1993). They are small, transparent or semitransparent, and pelagic, and their length averages 10 to 40 mm (OMORI, 1975). These organisms play an important role in ocean productivity: they are the link between phytoplankton, zooplankton, and animals at higher trophic levels in the food chain (XIAO; GREENWOOD, 1993). In some Asian and African countries, *Acetes* species are of economic importance (OMORI, 1974, 1975; UNG; ITOH, 1989; XIAO; GREENWOOD, 1993), the reason being that the most studies on the species more frequently distributed around Malaysia (ARSHAD et al., 2008; AMIN et al., 2009a; 2009c; 2012; AZIZ et al., 2010; SAINI et al., 2011).

In Brazil, *Acetes americanus* ORTMANN, 1893, is the most frequently described sergestid shrimp in studies on marine biodiversity, particularly in those from the southeastern region of the country (COSTA et al., 2000; COSTA et al., 2003; REIGADA et al., 2006). The species is distributed around the western Atlantic, from Praia de Guayanes, Puerto Rico to the north to Rio Grande do Sul, Brazil (D'INCAO; MARTINS, 2000). Little is known of the biology of *A. americanus*, and the studies that have been performed in Brazil have focused on faunal composition, descriptions of the larvae, and geographical distribution (CALAZANS, 1992; OSHIRO; OMORI, 1996; D'INCAO; MARTINS, 2000). SIMÕES et al. (2013a; 2013b) undertook two studies on the spatio-temporal distribution, juvenile recruitment period, and growth of the species along the northern coast of São Paulo state. The greatest abundance of *A. americanus* was observed in shallow waters less than 10 meters deep, at temperatures between 16.0 and 30.0º C, and in waters with salinity levels between 22.0% and 38.0%. Species longevity was estimated to be 0.61 years for females and 0.50 years for males (SIMÕES et al., 2013a; 2013b).

Due to its proximity to Cabo Frio in the state of Rio de Janeiro the region of Macaé in Rio de Janeiro state (RJ) (22ºS) presents oceanographic characteristics affected by coastal upwelling. A large temperature anomaly (low temperatures that vary between 18.0º and 24.5º C) occurs throughout most of the year at this location, and significant biological enrichment takes place. This enrichment is caused by the surface outcropping of the deep waters of the continental slope during coastal upwelling. It makes nutrients such as nitrogen and phosphorus, which have accumulated in deep regions, available to primary producers in the euphotic zone (VALENTIN et al., 1975; 1984). Primary productivity is affected by time and space, and it leads to variations in growth, reproduction, and survival of organisms that live at a given location (BAKUN; PARRISH, 1990; FRANCHITO et al., 2007).

Previous studies have shown that an understanding of the parameters of growth and of the population structure of decapod crustaceans is fundamental for a better understanding of the biology and life cycle of these species (FONSECA; D'INCAO, 2003; KEUNECKE et al., 2007; LOPES-LEITZKE et al., 2009; ARCULEO et al., 2011). Thus, the goal of this study is to discern the patterns of the population dynamics of *Acetes americanus* - particularly the sex ratio, growth of individual specimens, longevity, and recruitment - in terms of the abundance of species and the influence of environmental factors in the region of Macaé, RJ.

MATERIAL AND METHODS

Sampling

Sampling was undertaken along the coastal region that borders the city of Macaé, in the state of Rio de Janeiro (Figure 1) at depths of 5 m (22º23' 69'' S 41º44' 96'' W) and 15 m (22º25' 30'' S 41º44' 78'' W) between July 2010 and June 2011. Collections were made with an otter trawl type net (with a 2 m opening and 3 m length), and the organisms captured were stored in a collection cup attached to the far end. The mesh size diameters (inter-node distance) were 5 mm in the first half and 2 mm at the end of the net that included the collection cup. At each end point, monthly, a trawl of 10 minutes (at a speed of two knots) was undertaken, thus covering a sample area of 1200 m^2.

The biological material was stored and labeled in plastic bags containing seawater and 10% formol. The organisms were identified in the laboratory, in accordance with D'INCAO; MARTINS (2000), and COSTA et al. (2003). The sex of each specimen was identified by its morphological characteristics: males possess petasma, while females do not (XIAO; GREENWOOD, 1993).

All of the animals were counted monthly to calculate abundance. For the purpose of measurement, a subsample of 200 specimens was used for sampling; when total abundance was fewer than 200 specimens, all of the shrimp were measured. The measurements taken included total

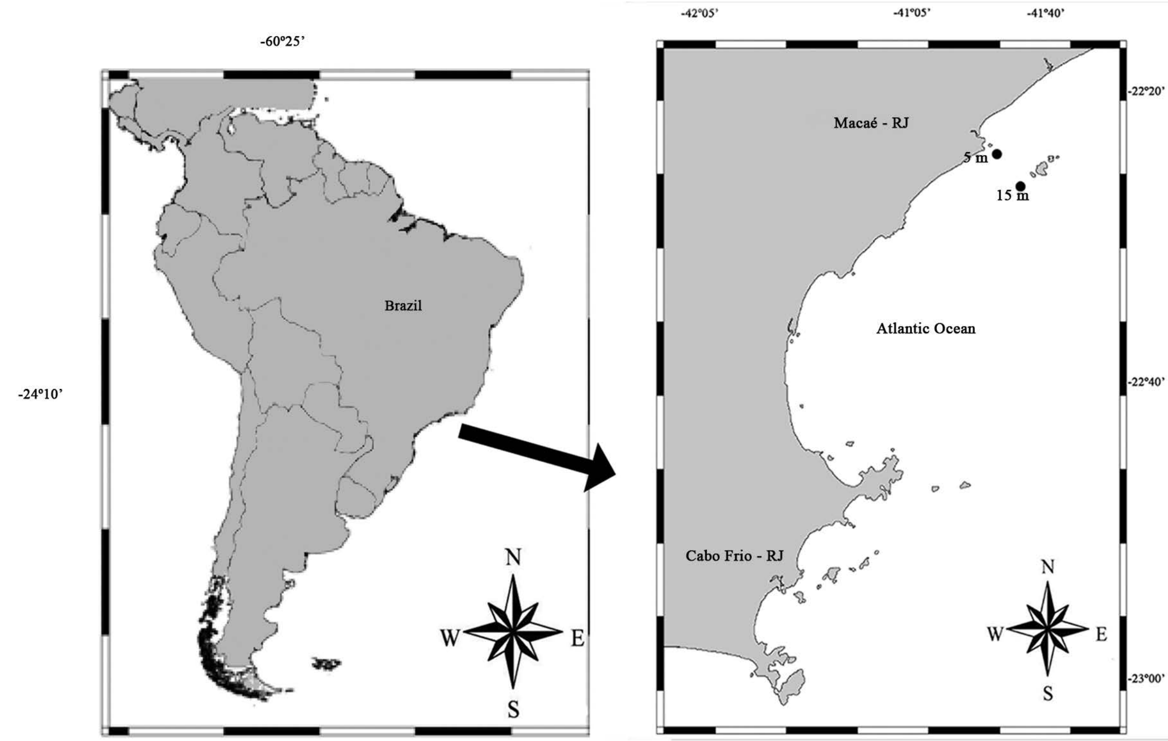

Figure 1. Map of the region, indicating the collection sites at depths of 5 m (22º23' 69'' S 41º44' 96'' W) and 15 m (22º25' 30'' S 41º44' 78'' W) sampled from July/10 to June/11 in region of Macaé/RJ.

length in millimeters (TL), which was defined as the linear distance from the post-orbital angle to the end of the telson. An optical stereo microscope connected to a 0.01-mm imaging system was used for this step. In all of the samplings, bottom water was collected using a Van Dorn sampling bottle in order to obtain temperature values (with a mercury thermometer) and salinity values (with a salinity refractometer). Surface water samples were also obtained from the euphotic zone in order to determine the concentration of chlorophyll-*a* (µg. L-1).

The concentration of chlorophyll-*a* was obtained according to the method of GOLTERMAN et al. (1978), in which 2 liters of water were filtered in a Millipore filter, AP40. The filter that contained the material was kept in the laboratory at -20º C until concentrations were determined through extraction. Chlorophyll-*a* was extracted into a volume of 10 ml of a cold 90% acetone solution through maceration. The 10-ml extract solutions were transferred to test tubes and kept under refrigeration for approximately 12 hours, being protected from light during that time. After this period, the samples were centrifuged for 10 minutes at 4900 rpm. Next, absorbances were measured at 663 nm and 750 nm using a Femto 600 Plus spectrophotometer. Total pigment concentration was determined using the following formula: Pt = UE663 x (1000/K) x (VE/VF), where Pt = total pigments, UE663 = extinction at 663 nm, using 1-cm optical glass cuvettes; in addition, UE663 = (UE663-UE750)/cuvette path length; k = 89 (coefficient of chlorophyll extraction), VE = volume of chlorophyll extraction (mL), and VF = volume of filtered water per sample (L).

Data Analysis

Population Parameters

Tests for homoscedasticity (Levene tests) and normality (Shapiro-Wilk tests) were first performed as pre-requisites for the statistical tests. Data were log-transformed prior to analysis (ZAR, 1999). All the data sets were normally distributed, with homogeneous variances. Because the presupposed data were not parametric, the Mann-Whitney test was used to compare the average size of the specimens of each sex to a 5% level of probability (ZAR, 1999).

The monthly male-female proportion was calculated (males/total), and the results were tested using the Chi-squared analysis (χ^2 test). A Chi-squared test for goodness of fit (α = 5%) was performed to verify whether the sex ratio in the population departed significantly from 1:1 (SOKAL; ROHLF, 1995) throughout the sampling period and among the size classes.

For each sample month, the total length frequency TL (mm) was distributed across size classes of 0.5 mm, and the modes were calculated using the PeakFit program. Specimen growth was identified for each sex, and the chosen cohorts were fitted into a Von Bertalanffy growth model (1938), given by $TLt = TL\infty\ [1\text{-}e\text{-}k\ (t - t0)]$, where TLt is the total length at age t, TL∞ is the asymptotic length, k is the growth coefficient and t0 is the theoretical age at length zero. The growth parameters of the different cohorts were estimated using the "Solver" tool and by varying the equation parameters (TL∞, k and t0). The criteria used to validate a cohort were the biological coherence with the life cycle of the species (the coherent estimate of longevity based on the duration of a cohort in time and growth parameter values suggested in the literature) (SIMÕES et al., 2013a). A comparison of the growth curves was performed using an F test (p = 0.05), according to CERRATO (1990).

Longevity was estimated using a Von Bertalanffy inverted equation with modifications suggested by D'INCAO; FONSECA (1999), in which t0 = 0 and TL/TL∞ = 0.99. The longevity equation is as follows: $Tmax = (t0 - (1/k)\ Ln\ (1 - TLt/TL\infty)$.

The number of juveniles can be estimated by considering the proportion of the population sample that falls into the smaller size classes of combined male/female size-frequency distributions and by then calculating the lower 25% of all of the possible size classes (BAUER; RIVERA VEGA, 1992; CASTILHO et al., 2008). The period of recruitment was defined by the percentage of juveniles per month found among the lower 25% of all of the possible size classes.

For estimation of how long the species takes to reach the juvenile stage, we used a Von Bertalanffy inverted equation with modifications suggested by KING (1995): $Tr = (t0 - (1/k)\ Ln\ (1 - TLr/TL\infty))]$, where TLr is the total length at the juvenile stage, TL∞ is the asymptotic length, k is the growth coefficient and t0 is the theoretical age at length zero.

Abundance

The relationship between the number of shrimp collected and the environmental factors was evaluated using multiple regression analysis with a significance level of 5%. Species abundance each season was compared using the Chi-squared test comparing adhesion with a significance level of 5% (SOKAL; HOLF, 1995). To detect the differences in the data from season to season, the Chi-squared test comparing adhesion was also used, though with a significance level that was corrected using the Bonferroni method ($\alpha' = \alpha$/number of comparisons); the significance level considered was 8% (SOKAL; ROHLF, 1995).

RESULTS

Population Parameters

A total of 19534 individuals were captured, and individuals were found during each of the months in which samples were collected. Out of these 19534 specimens, 2009 were measured: 1550 were female (77.15%) and 459 were male (22.84%). With the exception of the quantities collected in the March 2011 sample, the total number of females was generally significantly larger than that of males (χ^2 = 592.47, p = 7.25E-131) (Table 1).

The average size of the females was 15.76 ± 2.83 mm TL, and varied from 7.19 mm to 24.66 mm. The average size of the males was 14.35 ± 2.79 mm TL, and varied

Table 1. Number of *Acetes americanus* males (♂) and females (♀) with the resulting sex ratio and Chi-squared tests (χ^2) in Macaé/RJ region.

Month	(♂)	(♀)	Sex ratio (males/total)	χ^2 test	*p* value
Jul/10	64	136	0.32	25.92	3.55E-07
Aug/10	50	148	0.25	48.50	3.29E-12
Sep/10	43	156	0.21	64.16	1.14E-15
Oct/10	27	173	0.13	106.58	5.50E-25
Nov/10	50	150	0.25	50.00	1.53E-12
Dec/10	4	71	0.05	59.85	1.02E-14
Jan/11	33	167	0.17	89.78	2.66E-21
Feb/11	43	157	0.21	64.98	7.57E-16
Mar/11	8	17	0.32	3.24	0.071861
Apr/11	46	152	0.23	56.74	4.96E-14
May/11	27	87	0.23	31.57	1.91E-08
Jun/11	64	136	0.32	25.92	3.56E-07
Total	459	1550	0.22	592.47	7.25E-131

from 9.30 to 26.58 mm. The average size of the females was significantly larger than that of the males ($p < 0.05$). The greatest abundance of females was registered in the 13.25 - 17.25 mm size class, while the greatest abundance of males was registered in the 13.25 - 15.25 mm size class (Figure 2).

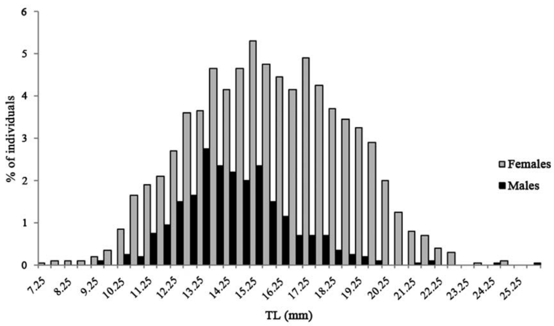

Figure 2. Percentage of male and female *Acetes americanus* by size (TL mm) captured in the bay of Macaé/RJ, Brazil. The size class interval was 0.5 mm, with mean values presented for each class.

Five cohorts were found for the males, and ten were found for the females (Table 2). The average growth curve, which grouped the curves of the cohorts of each sex, resulted in TL∞ = 20.27 mm, k = 0.013 and t0 = -0.26 days for the females and TL∞ = 18.55 mm, k = 0.019 and t0 = -0.12 days for the males (Figure 3). In accordance with the growth curves that were constructed, longevity (tmax) was estimated to be 330 days (0.91 years) for females and 241 days (0.66 years) for males. The F test among curves for both sexes showed no statistically significant difference (Fcalc = 0.75 > Ftab = 3.09).

The females that were less than 13.25 mm in TL were considered juveniles, as were the males that were less than 12.25 mm in total length (Figure 2). In addition, the time estimated for these specimens to reach this size was 81 days for females and 56 days for males. The juveniles were found in samples from every month; however, the greatest abundance occurred in February and April 2011 (Figure 4).

Correlation between Environmental Factors and Abundance

Out of the 19534 specimens collected, no individual was found at a depth of 15 meters between July 2010 and June 2011. The majority of the specimens were collected in July 2010 (57.07%). Conversely, the lowest abundance was registered in March 2011, at 0.16% (Table 3). Abundance differed statistically from season to season ($\chi^2 = 16225$, $p < 0.05$) (Table 3): the largest capture occurred in the winter (63.79%), followed by the summer (18.88%). The lowest abundance levels were registered in the fall and the spring, when they were 9.08% and 8.24%, respectively.

Table 2. Parametes of growth of *Acetes americanus*, for males and females sampled from July/10 to June/11 in region of Macaé/RJ.

Sex	Cohort	TL∞ (mm)	k (day)	t0 (day)	tmáx (year)
Females	1	23.48	0.012	-88.65	0.98
	2	22.33	0.014	-75.50	0.87
	3	21.56	0.012	-77.36	0.97
	4	19.94	0.013	-75.79	0.93
	5	19.55	0.012	-72.16	0.98
	6	19.05	0.013	-48.24	0.94
	7	18.64	0.013	-51.89	0.91
	8	19.94	0.014	-60.78	0.85
	9	17.43	0.013	-44.70	0.92
	10	18.15	0.014	-64.88	0.88
Males	1	19.71	0.024	-44.68	0.50
	2	19.18	0.020	-47.17	0.60
	3	18.18	0.020	-49.49	0.62
	4	18.13	0.015	-54.26	0.79
	5	17.25	0.019	-62.30	0.64

TL∞: total length; k: growth coefficient; t0: theoretical age at length zero; tmax: longevity.

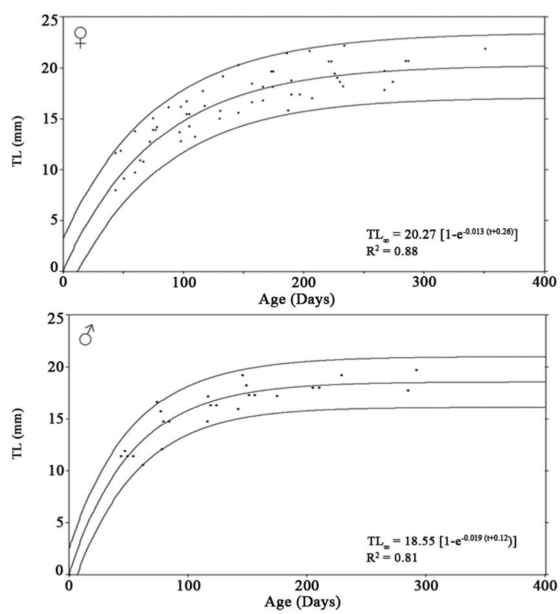

Figure 3. Growth curve estimated for females and males of *Acetes americanus* using the von Bertalanffy growth model (internal line). 95% prediction interval is shown (external lines) in region of Macaé/RJ.

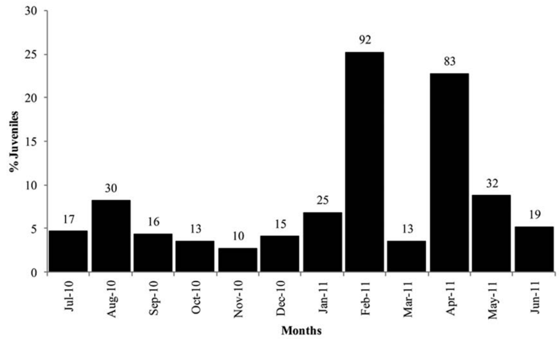

Figure 4. Percentage of juveniles of *Acetes americanus* captured from July/10 to June/11 in region of Macaé/RJ. The number above of histrogram corresponds to the absolute abundance of juveniles.

At a depth of 5 m, the temperature of the bottom water varied from 19.0º C in February 2011 to 24.5º C in March 2011, with an average value of 21.2 ± 1.7º C. (Table 3). The average salinity of the bottom water was 37.1 ± 0.6‰. The highest level occurred in February, April, and May 2011 (38.0‰), and the lowest level in December 2010 and January 2011 (36.0‰).

At a depth of 15 m, the average temperature was 20.7 ± 1.8º C, with a variation from 18.0º C to 24.5º C; salinity varied from 35.0‰ to 38.0‰, with an average level of 36.9 ± 0.8‰. The concentration of chlorophyll-*a* was found to be similar at the two depths. It varied from 0.31 µg to 3.13 µg. L-1, and the average concentration was 1.33 ± 0.77 µg. L-1 (Table 3).

There was no correlation between the number of specimens collected and the environmental factors (multiple linear of regression, $p > 0.05$); however, there was a greater abundance at lower temperatures (those closest to 20.0º C) and at salinities between 36.0‰ and 37.0‰ (Table 3). There was an increase in the number of specimens when the highest quantities of chlorophyll-*a* were registered.

DISCUSSION

The predominance of females within the *Acetes americanus* samples seems to be a tendency among populations of this genus studied in different regions. Similar results were found in the cases of *A. chinensis* HANSEN 1919 (OH; JEONG, 2003), *A. intermedius* Omori, 1975 (ARSHAD et al., 2007), *A. indicus* H. Milne Edwards, 1830 (AMIN et al., 2009b), and *A. japonicus* Kishinouye, 1905 (AMIN et al., 2010). The deviations in the sex ratio from 1:1 in favor of females may be related to the gregarious behavior exhibited by the females during the spawning period (OH; JEONG, 2003). JOHNSON (2003), however, has suggested that many factors (differential growth rate, differential reduction of gametes, and differential mortality between sexes) may influence the sex ratio balance. In addition, the results found in the present study support the hypothesis suggested by SIMÕES et al. (2013a), which correlates the less frequent capture of males with their greater growth constant (k), thus resulting in smaller specimens that are less susceptible to being caught.

The relatively greater length of *A. americanus* females has been corroborated by other studies on *Acetes* species (Table 4), which argues for the existence of a standard of sexual dimorphism in terms of size (OH; JEONG, 2003; ARSHAD et al., 2008; AMIN et al., 2009a; AMIN et al., 2012; SIMÕES et al., 2013a). In studies on other

Table 3. Number of individuals of *Acetes americanus* sampled and the values of environmental factors chlorophyll-*a* (µg L1), bottom temperature (ºC) and bottom salinity, at depths of 5 m in region of Macaé/RJ.

Season	Months	Number of individuals	Chlorophyll-*a*	Bottom Temperature	Bottom Salinity
	Jul/10	11150	3.13	20.0	37.0
Winter	Aug/10	420	1.19	20.5	37.0
	Sep/10	891	1.96	20.5	37.5
	Oct/10	1046	1.22	22.0	37.0
Spring	Nov/10	488	1.04	19.5	37.0
	Dec/10	76	0.93	21.0	36.0
	Jan/11	1587	1.66	19.5	36.0
Summer	Feb/11	2069	0.50	19.0	38.0
	Mar/11	33	1.95	24.5	37.0
	Apr/11	964	0.31	23.5	38.0
Autumn	May/11	130	1.34	22.5	38.0
	Jun/11	680	0.74	22.0	37.0

Sergestoidea, including *Lucifer faxoni* Borradaile, 1915 (ALVAREZ, 1988; TEODORO et al., 2012), *Sergestes arcticus* Kroyer, 1855, and *Sergia robusta* (SMITH, 1882) (COMPANY; SARDÁ, 2000), the same result has been observed. This finding is connected to the type of fertilization in question: in all Dendrobranchiata, this process occurs externally. Thus, a larger cephalothorax volume corresponds to a greater production of oocytes, which guarantees that a higher proportion of them will be fertile (GAB-ALLA et al., 1990; CASTILHO et al., 2007a). In addition, the hypothesis that sexual dimorphism in terms of size may be influenced by the genetic characteristics of the species cannot be ruled out.

The hypothesis of latitudinal effect on population dynamics has been proposed for penaeoidean shrimps. According to this hypothesis, the higher the latitude, the greater the size, the longer the longevity and the greater the values of sexual maturity and marked reproductive seasonality of the species (BAUER, 1992; CASTILHO et al., 2007a; 2007b). The size and longevity of *A. americanus* specimens obtained in Macaé (22ºS) in this study were compared to those found by SIMÕES et al. (2013a) in the Ubatuba region, in São Paulo state (23ºS) (Table 4), and an inversion of this pattern became evident. Our results revealed that two environmental factors may be considered most relevant in this situation: temperature and primary productivity.

Although Macaé region is located at a lower latitude than Ubatuba, it presents lower temperatures during the year due to its proximity to the upwelling area of Cabo Frio, RJ. According to TIMOFEEV (2001), in general marine crustaceans follow Bergmann's principle (1848): as temperature decreases, the crustaceans' life span increases, since these animals continue to grow throughout life (which is a characteristic of crustaceans); they get bigger than those of warmer waters (which are generally found under lower latitudes). TEROSSI et al. (2010) also found differences in the embryo volume of *Hippolyte obliquimanus* Dana, 1852, between Brazilian and Costa Rican populations. They suggested this difference may be explained by the marked differences in local water temperatures: mean water-surface temperatures at the Brazilian location are substantially lower than in Costa Rica. Bergmann's principle can, therefore, also be applied to the sergestid *A. americanus*, since this organism has been found to be larger and to have greater longevity than specimens in warmer regions.

Table 4. Growth parameters ($L\infty$ and K) of the genus *Acetes* from different countries.

Location	Species	L∞ (mm)	K (year-1)	Longevity (year)	Methods	Reference
Macaé, Brasil (22º23' S)	*Acetes americanus* (F)	20.27 (TL)	4.74	0.88	Peak Fit	Present study
	Acetes americanus (M)	18.55 (TL)	6.93	0.66		
Ubatuba, Brasil (23º25' S)	*Acetes americanus* (F)	19.33 (TL)	7.30	0.61	Peak Fit	SIMÕES et al. (2013,a)
	Acetes americanus (M)	15.13 (TL)	10.65	0.50		
Malacca, Malaysia (02º13.09' N)	*Acetes indicus* (F)	40.95 (TL)	1.20	2.50	Fisat	AMIN et al. (2012)
	Acetes indicus (M)	29.93 (TL)	1.60	1.88		
Malacca, Malaysia (02º13.09' N)	*Acetes indicus* (F)	42.00(TL)	1.20	1.76	Fisat	AMIN et al. (2009,a)
	Acetes indicus (M)	29.40 (TL)	1.70	2.50		
Malacca, Malaysia (02º13.09' N)	*Acetes japonicus* (C)	29.08 (TL)	1.4	2.14	Fisat	AMIN et al. (2009,b)
Malacca, Malaysia (02º13.09' N)	*Acetes intermedius* (C)	34.65 (TL)	1.50	-	Fisat	ARSHAD et al. (2007)
Sarawak, Malaysia (03º18' N)	*Acetes intermedius* (C)	43.05 (TL)	1.90	1.58	Fisat	SAINI et al. (2011)
Kutubdia channel, Bangladesh (21º54' N)	*Acetes chinensis* (C)	40.00 (CL)	1.60	-	Fisat	ZAFAR et al. (1998)
Kutubdia, channel, Bangladesh (21º54' N)	*Acetes erythraeus* Nobili, 1905 (C)	37.00 (TL)	1.20	-	Fisat	ZAFAR; AMIN (2002)
Korea (34º48' N)	*Acetes chinensis* (F)	13.51 (CL)	0.69	-	Fisat	OH; JEONG (2003)
	Acetes chinensis (M)	10.48 (CL)	0.84	-		

(F): Female; (M): Male; (C): Combined sexes.

Another factor that may have influenced the size of *A. americanus* in the region studied here is the increased amount of primary production, which makes a greater quantity of food available, thus favoring the presence of larger organisms than those found in Ubatuba. DE LEO; PIRES-VANIN (2006) affirmed that, at certain times of the year, primary productivity in the region of Cabo Frio is close to ten times greater than in the region of Ubatuba because of the occurrence of coastal upwelling.

Even with the low temperatures in Macaé, the recruitment pattern of *A. americanus* remains continuous, as is expected for species in tropical and subtropical regions. In the light of the fact that the time estimated for organisms to become adults was approximately 80 days, it can be inferred that the reproductive and recruitment periods were close together and coincided with the beginning of the increase in temperatures in the region. This increase may have stimulated spawning. Water temperature is considered an important proximal factor, one which acts directly on both the maturation of gametes and the spawning period of penaeid shrimp (SASTRY, 1983; BAUER, 1992; BAUER; LIN, 1994).

In the present study, the greatest abundance of *A. americanus* was recorded close to 20º C. The temperatures recorded were similar to those recorded in Lagoa dos Patos, in the Brazilian state of Rio Grande do Sul (32ºS), a subtropical region (CALAZANS, 2002). In the Lagoa dos Patos study, the temperature varied from 13.2 to 24.9º C, and the greatest abundance of *A. americanus* larvae was registered at 20.7º C. In Ubatuba, SIMÕES (2013b) found that the temperature varied from 21.9 to 26.2º C, and that the greatest abundance of *A. americanus* occurred at temperatures closest to 24.5º C. We suggest that, because the region of Macaé (22ºS) experiences low temperatures throughout most of the year, the species' preference for this region may be due to the fact that the population can tolerate this variation in temperature. Laboratory experiments performed by Bhattacharya (1988) (apud XIAO; GREENWOOD, 1993) have shown that *A. indicus* can tolerate temperatures between 14.0º C and 34.0º C. XIAO; GREENWOOD (1993) reported that *A. chinensis* from Laizhou Bay in the south of Pohai tolerates an annual temperature variation from -0.1º C to 29.5º C. In addition to environmental factors such as temperature, the presence or absence of predators may also be responsible for variations in the collected quantities of sergestid shrimp (XIAO; GREENWOOD, 1993).

Decrease in abundance in the months subsequent to the massive sampling (July/12) cannot be attributed to the impact of the sampling, since the methodology used in the present study followed SIMÕES et al. (2013a; 2013b). One reason for this greater abundance could be the period of increased availability of food (measured by the concentration of chlorophyll-*a*). This factor may influence abundance substantially. According to XIAO; GREENWOOD (op. cit), when values of chlorophyll-*a* increase, more *Acetes specimens*, whose diets are mainly composed of diatoms and copepods, are captured. Increases in primary production promote a larger production of herbivorous zooplankton, which leads to an increase in food availability, and, consequently, to a higher density of planktonic organisms (CASTRO FILHO et al., 1987). Similar results have been found by AIDAR et al. (1993) and by SIMÕES et al. (2013b), who reported that, in the region of Ubatuba, a greater abundance of *A. americanus* occurred during periods with increased availability of nutrients. In that region, the penetration of South Atlantic Central Water (SACW) during the spring or summer promotes an increase in nutrients, leading to a surge in chlorophyll-*a* values (CASTRO FILHO et al., 1987).

Based on these reports and the results found here, the environmental factors observed in the Macaé region as a result of the influence of upwelling alter the biological parameters that have been reported in the literature on *A. americanus* thus far, particularly in terms of the size, longevity, and abundance of the species. This location has, therefore, supplied new biological information that offers a better understanding of the abundance and population dynamic of this species.

ACKNOWLEDGEMENTS

The authors are indebted to the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) for providing financial support during field collections and visiting activities (Grants 2009/54672-4, 2010/50188-8 to RCC; Scholarships 2012/14874-0 to APFS; 2014/01632-3 to SMS) and to CNPq (Research Scholarships PQ 305919/2014-8 to RCC). Thanks are extended to the Universidade Federal do Rio de Janeiro/NUPEM (Macaé/RJ) for the infrastructure necessary to carry out this work, especially to Dr. Alexandre Azevedo. We also thank the co-workers of LABCAM for their help during the fieldwork and Danielle Deremo for her revision of the English text.

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