



## Changes after 20 years in the population structure of the South American endemic shrimp *Artemesia longinaris* (Crustacea, Decapoda) on the southeastern Brazilian coast

CAMILA HIPOLITO BERNARDO<sup>1\*</sup>, KÁTIA APARECIDA NUNES HIROKI<sup>1,2</sup>, ARIÁDINE CRISTINE DE ALMEIDA<sup>1,3</sup>, FABIANO GAZZI TADDEI<sup>1,4</sup>, ALINE NONATO DE SOUSA<sup>1</sup>, GUSTAVO MONTEIRO TEIXEIRA<sup>1,5</sup> & ADILSON FRANSOZO<sup>1</sup>

<sup>1</sup> Núcleo de Estudos em Biologia, Ecologia e Cultivo de Crustáceos (NEBECC), Instituto de Biociências de Botucatu, Departamento de Zoologia, Universidade Estadual Paulista “Júlio de Mesquita Filho”. Rua Professor Doutor Antonio Celso Wagner Zanin, s/n, Distrito de Rubião Junior, Botucatu, São Paulo, Brasil.

<sup>2</sup> Universidade Federal do Triângulo Mineiro, Departamento de Ciências Biológicas, 38025-440, Uberaba (MG) – Brazil.

<sup>3</sup> Universidade Federal de Uberlândia, Instituto de Biologia, Campus Umuarama, 38400-902, Uberlândia, Minas Gerais, Brazil.

<sup>4</sup> Amazon Crustacean Studies Laboratory (LECAM), Universidade do Estado do Amazonas, Estrada Odovaldo Novo, Km 1, 69151-470, Parintins, Amazonas (AM), Brazil.

<sup>5</sup> Universidade Estadual de Londrina (UEL), Campus Universitário. Rodovia Celso Garcia Cid, Km 380, s/n Londrina, Paraná, Brasil.

\* Corresponding author: [caah.hipolito05@gmail.com](mailto:caah.hipolito05@gmail.com)

**Abstract.** The present study compared the population structure of the shrimp *A. longinaris* during two distinct periods (November/1988 to October/1989 and November/2008 to October/2009) in the Fortaleza Bay. We used Pearson correlation analysis to verify a possible association between temperature and cephalothorax length (CL) of the obtained individuals. 2412 females and 676 males of *A. longinaris* were captured in the first period; 843 females and 409 males, in the second. The mean size of shrimp was 15.6 mm CL in the first period and 14.3 mm CL, in the second ( $U=1066671.0$ ;  $p<0.05$ ). Larger individuals were sampled at lower temperatures (Pearson's correlation;  $r^2=-0.80$ ;  $p<0.05$ ). In both periods of sampling, we have got adult females larger (mean sizes) than adult males. In addition, for both periods the sex ratio was in favor of females ( $p<0.05$ ). The intense trawling activity as well as the water temperature may have caused a sampling of smaller individuals in the second period. The sex ratio favoring females is possibly a result of migration of females to shallower regions, just after mating. After 20 years, only the mean size of the shrimp has changed among the analyzed aspects for *A. longinaris*.

**Key words:** Southwestern Atlantic; endemic shrimp; sex ratio; carapace size; Ubatuba

**Resumo:** Mudanças após 20 anos na estrutura populacional do camarão endêmico da América do Sul *Artemesia longinaris* (Crustacea, Decapoda) na costa sudeste do Brasil O presente estudo comparou a estrutura populacional do camarão *A. longinaris* durante dois períodos distintos (novembro/1988 a outubro/1989 e novembro/2008 a outubro/2009) na Enseada de Fortaleza. Utilizamos análise de correlação de Pearson para verificar uma possível associação da temperatura com o comprimento do cefalotórax (CC) dos indivíduos. Um total de 2412 fêmeas e 676 machos de *A. longinaris* foi capturado no primeiro período; 843 fêmeas e 409 machos, no segundo. O tamanho médio do camarão foi de 15,6 mm (CC) no primeiro período; 14,3 mm (CC), no segundo ( $U=1066671,0$ ;  $p<0,05$ ). Camarões maiores foram

amostrados em temperaturas mais baixas (correlação de Pearson;  $r^2 = -0,80$ ;  $p < 0,05$ ). Em ambos os períodos de amostragem, tivemos fêmeas adultas maiores (tamanhos médios) do que os machos adultos. Além disso, para ambos os períodos, a razão sexual foi favorável ao sexo feminino ( $p < 0,05$ ). A intensa atividade de arrasto e a temperatura da água podem ter provocado uma amostragem de indivíduos menores no segundo período. A razão sexual favorecendo as fêmeas é possivelmente um resultado da migração das fêmeas para regiões mais rasas, logo após o acasalamento. Após 20 anos, apenas o tamanho médio dos camarões mudou entre os aspectos analisados para *A. longinaris*.

**Palavras-chave:** Atlântico Sudoeste; camarão endêmico; razão sexual; tamanho da carapaça; Ubatuba.

## Introduction

Fishing stocks are strongly influenced by climate change (Gillett 2008), which can have a number of direct and indirect impacts with diverse implications in the economy, to the species as well as to fishing communities (Daw *et al.* 2009). The temperature of the sea surface, for instance, plays a fundamental role in the regulation of climate and its variability (Deser *et al.* 2010), which has been investigated worldwide in connection with El Niño Southern Oscillation (ENSO) (Trenberth 1997). The effect of the variation of several environmental factors, in different latitudes related to the population dynamics of some shrimp species, has been studied by several authors (Bauer 1992, Gavio & Boschi 2004, Castilho *et al.* 2007a, Costa *et al.* 2010). Variations of environmental factors such as temperature and nutrient availability may also change the population structure of the species (Castilho *et al.* 2007b).

Associated to these environmental oscillations, there are those caused by anthropic action. In recent years, the number of fishing boats in the Southeastern of Brazilian coast has almost tripled (Fishery Institute of São Paulo State 2017). Despite the socioeconomic importance of fishing activity, it is known that it can strongly affect the structure of many populations, as well their reproductive capacity (Dayton *et al.* 2002). According to Vazzoler (1996), Kaiser *et al.* (2002) and Keunecke *et al.* (2012), populations under intense fishing pressure may be reduced in size, becoming necessary to analyze the population structure of exploited species, since this action could help the understanding of the distribution patterns of the different demographic groups in the time, space, and size classes.

It is known that due to the reduction in the landing of more profitable shrimp species such as pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. paulensis* (Pérez-Farfante, 1967), the

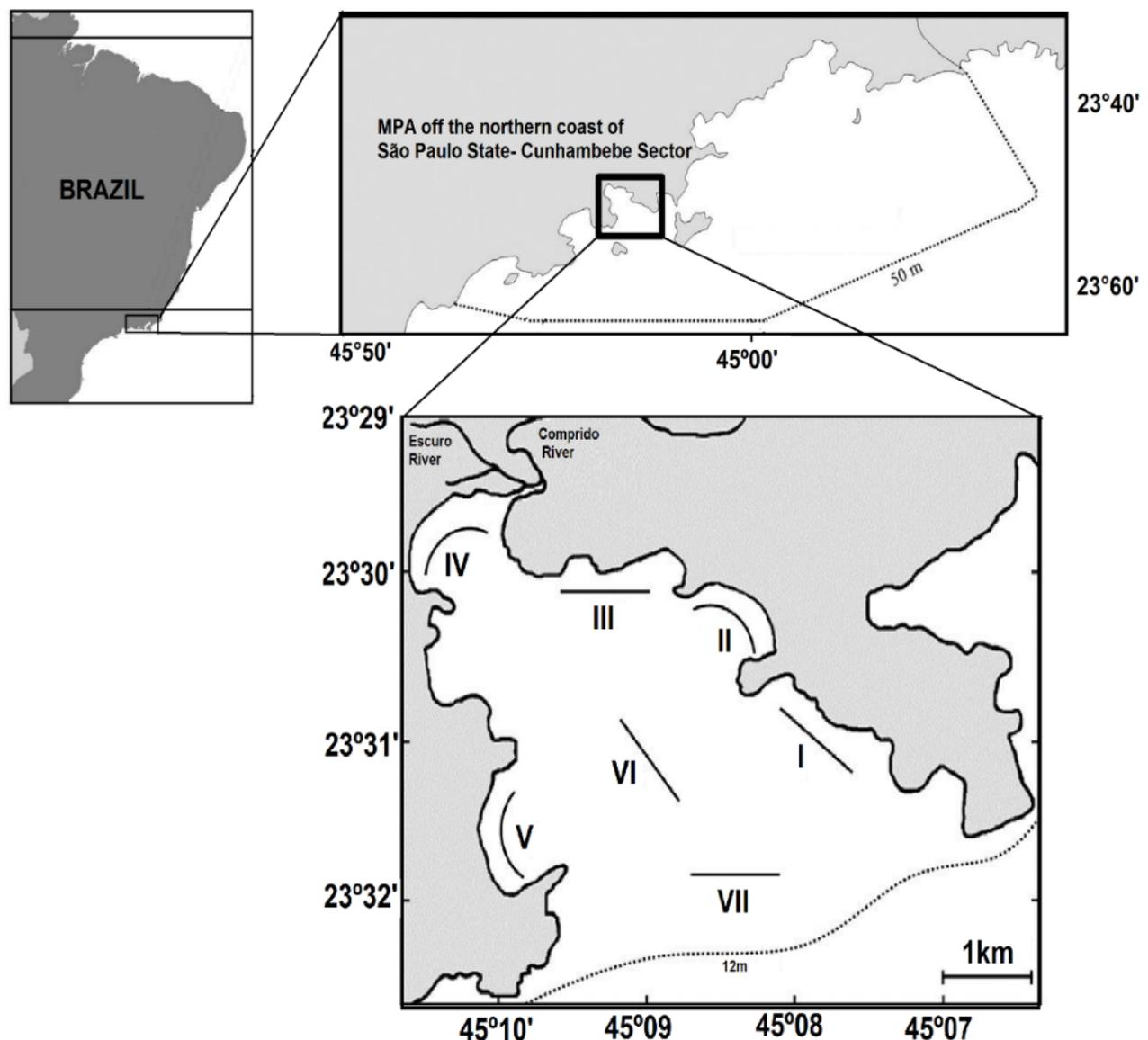
white shrimp *Litopenaeus schmitti* (Burkenroad, 1936), and the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862), there was an increase in the interest of endemic species of the Western South Atlantic, for example, the “barba-ruça” shrimp, *Artemesia longinaris* Spence Bate, 1888 which is distributed from Atafona in Rio de Janeiro (Brazil - 21°S) to the province of Chubut (Argentina - 43°S) (Perez-Farfante & Kensley 1997, Boschi 2000). The region of this study is under seasonal effects, during late Spring and early Summer (November-January), of the South Atlantic Central Water (SACW = temperature  $< 18^\circ\text{C}$ , salinity  $< 36$ ) (Castro-Filho *et al.* 1987). Costa *et al.* (2005) reported that the entrance of SACW causes the migration of *A. longinaris* to the north coast of the São Paulo State, Brazil.

Currently there are some studies related to *A. longinaris* species, among them we point the following ones: Boschi (1969a), Nascimento (1981), Ruffino (1991), Castilho *et al.* (2007 a, b), Semensato & Di Benedetto (2008), Costa *et al.* (2010), Batista *et al.* (2011), Sancinetti *et al.* (2014, 2015) and Bernardo *et al.* (2018 a, b). Although there are previous studies about endemic shrimp species from the Western South Atlantic, none deals with the population structure comparison of two distinct periods (interval of 20 years) in the same bay. According Dayton *et al.* (2002) and Gillett (2008), analyzing impacts caused by natural phenomena and anthropic activities on the population structure is essential to the comprehension of the coastal and marine ecosystems. Therefore, the objective of this study was to compare the population structure of the shrimp *A. longinaris* after twenty years in the Fortaleza Bay, Brazilian Southeastern coast, checking the variations in the size class distributions, mean (maximum and minimum) size of all demographic groups and sex ratio.

## Material and Methods

**Sampling procedure:** The data were collected in two distinct periods (interval of 20 years): first period (P1), (from November/1988 to October/1989) and second period (P2); (from November/2008 to October/2009). In both periods, months were grouped in the following seasons: Spring (November, December and October), Summer (January, February and March), Autumn (April, May and June) and Winter (July, August and September). The same procedure was used in both periods. Samples of shrimp were performed monthly during P1 and P2, using a shrimp fishing boat with a double-rig net with length of 7.5 m, aperture of 2 m, net mesh size of 15 mm and width 10 mm in the cod end. Seven sampling stations were established inside

the bay (I to VII, Fig.1), covering an extension of 1 km, and an area of 4 km<sup>2</sup>, approximately, per trawl. Bottom water samples were obtained with a Nansen bottle. The surface and bottom water temperatures were measured with a mercury thermometer (accuracy: 0.5 °C). At the end of each trawl, the collected shrimps were transported in a thermal box to the laboratory where they were identified (Pérez-Farfante & Kensley, 1997, Costa *et al.* 2003). Samples in which the total weight per species was greater than 250g, we separated subsamples (250g) for analysis. After that, the data of the subsamples were extrapolated from the total weight for analysis. In samples of 250g or less, all specimens were analyzed.



**Figure 1.** Map of the study region showing the Marine Protection Area - MAP (Sector Cunhambebe) and Fortaleza Bay with sampled stations (I to VII) (adapted from Almeida *et al.* 2012).

The individuals were separated according to sex (presence of petasma in males and thelycum in females). The shrimps were measured with regard to cephalothorax length (CL) with a precision caliper (0.01 mm). The shrimps were separated into three demographic categories: juveniles, adult males and adult females. During both period, females smaller than 13.3 mm CL and males smaller than 11.0 mm were considered juveniles, according to the size at which 50% of the population reached the sexual maturity (Castilho *et al.* 2007 b).

**Data Analysis:** The premises of homoscedasticity (Levene test) and normality (Shapiro-Wilks test) were tested. Population structure was represented in size classes defined following the method suggested by Sturges (1926) and the abundance of both periods were distributed. Each class with 2 mm intervals were established, starting from 6 mm to 24 mm for *A. longinarius*. The Kolmogorov-Smirnov two-sample (KS) test was used to detect difference between the population size from P1 and P 2. The statistical software Peakfit was used to identify the number of modal peaks. The differences in the mean size of the demographic groups and bottom temperature between the two periods were analyzed by the Mann-Whitney test (U). Pearson correlation was performed to verify the relation between bottom temperature and mean size of individuals (CL). Sex ratio was obtained by dividing the number of males by the number of females. The binomial test (Wilson and Hardy 2002) was applied to evaluate whether the sex ratio differed from the 1:1 ratio in size classes and months in both periods. The Mann-Whitney test was used to compare the bottom temperature between two periods.

## Results

A total of 3,088 and 1,252 specimens of *A. longinarius* were sampled in P1 and P2, respectively. The Shapiro-Wilk test for cephalothorax length (CL) for P1 and P2 showed non-normal distribution

[P1 = (W=0.99; p <0.05) and P2 = (W=0.95; p <0.05)]. The sizes (mean and standard deviation, minimum and maximum) of CL of juveniles, males and females can be seen in Table I.

The individuals presented distinct frequency distributions between the two studied periods (Kolmogorov-Smirnov two-sample test; KS = 453.940; d. f. = 2 p <0.05) characterizing a unimodal distribution in P1 and polymodal distribution (3 peaks) in P2 (Fig. 2). It is possible to observe that in P1, individuals presented a peak of abundance in higher classes of CL from 13 to 17 mm, whereas in P2, the peak occurred in smaller classes from class 10 to 13 mm (Figure 2). The mean size of shrimp was  $15.6 \pm 2.5$  mm in P1 and  $14.3 \pm 2.8$  mm in P2 (Mann-Whitney test; U = 23.167; d. f. = 1; p <0.05) (Table I).

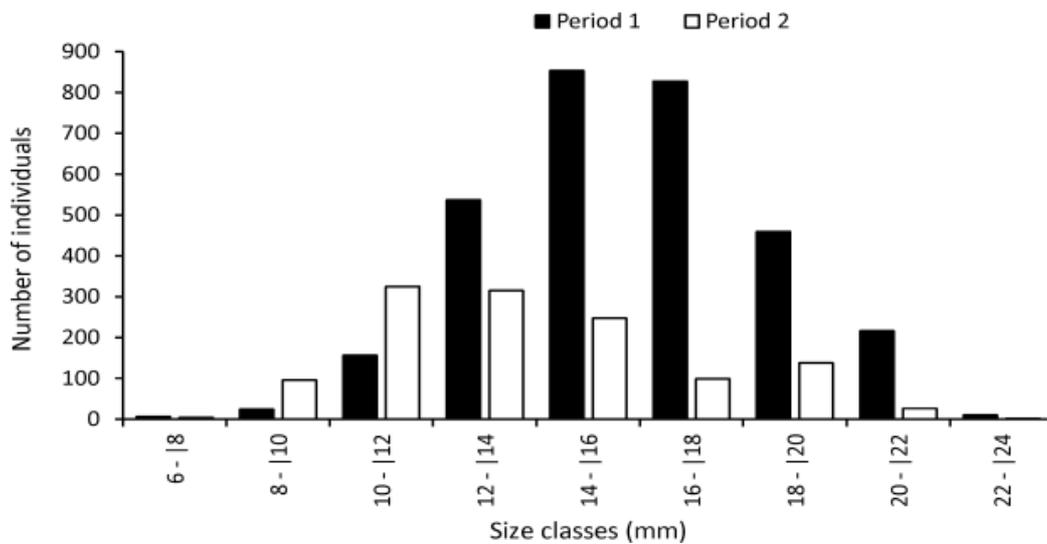
The distribution of the demographic groups of *A. longinarius* in size class by seasons of the year presented differences between the two periods. In P1, it is possible to observe a population growth; in which, in Spring and Summer, the greatest abundances of groups are found in the initial and intermediary classes and, in Autumn and Winter, in the larger classes. In P2, juveniles appear only in Spring and Summer, and adults have peaks of abundance in smaller size classes when compared to the P1 (Fig. 3).

In P1, it has occurred 676 males and 2,412 females with a sexual ratio of 1.0:3.5; in P2, 409 males and 843 females were obtained, being the sex ratio 1.0:2.1. In both periods, the sex ratio was in favor of females (Binomial test; p <0.05). There was no significant difference in the sex ratio of the size classes 6-10 mm (period 1) and 6-8 mm (period 2). In P1, there was a significant difference favoring females of classes 10-22 mm, whereas in P2, in the 8-12 mm classes, there was a difference in sex ratio in favor of males (Binomial test; p <0.05) and of classes 13-20 mm in favor of females (Binomial test; p <0.05) (Table II).

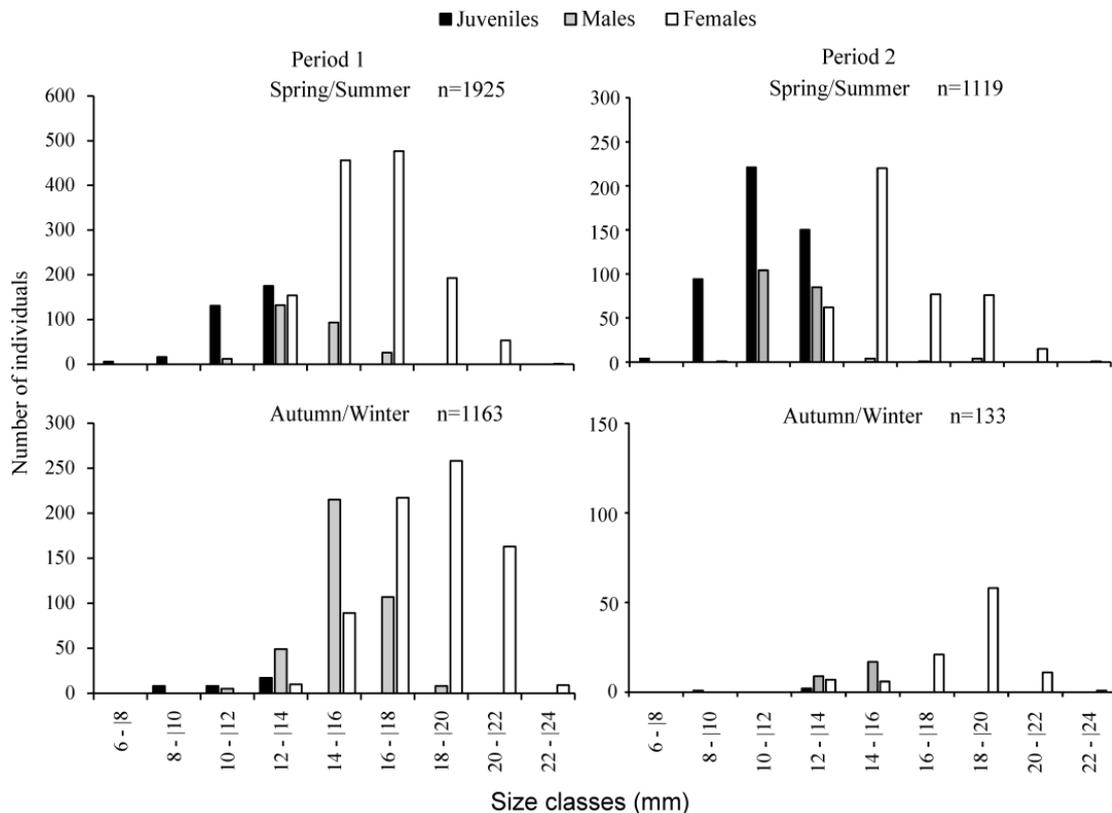
**Table I:** Size of *Artemesia longinarius* cephalothorax length (CL) of specimens collected.

Demographic groups	N		Min-Max		Mean $\pm$ SD		U
	P 1	P 2	P 1	P 2	P 1	P 2	P 1 X P 2
Juveniles	361	472	6.1 - 13.0	7.6 - 13.2	12.3 $\pm$ 1.2	10.8 $\pm$ 1.5	p=0.15
Males	647	224	11.1 - 19.2	11.1 - 19.9	14.6 $\pm$ 1.5	12.4 $\pm$ 1.3	p=0.01*
Females	2080	556	13.4 - 23.0	13.4 - 26.7	16.7 $\pm$ 2.3	16.3 $\pm$ 1.9	p=0.01*
Total	3088	1252	6.1 - 23.0	7.6 - 23.7	15.6 $\pm$ 2.5	14.3 $\pm$ 2.8	p=0.01*

N = number of individuals; Min = minimum; Max = maximum; SD = standard deviation; P 1 = November 1988 to October 1989 and P 2 = November 2008 to October 2009; U = Mann-Whitney test, \* p <0.05.



**Figure 2.** Distribution of the total abundance of *Artemesia longinaris* individuals in size classes, collected in period 1 (November/1988 to October/1989) and period 2 (November/2008 to October/2009).



**Figure 3.** Distribution of demographic groups by size classes of *Artemesia longinaris* in the seasons (Spring and Summer, Autumn and Winter) in the two periods.

The sex ratio was significantly in favor of females at all seasons of the year and in both study periods (Figure 4).

The result of Pearson correlation analysis between bottom temperature and CL revealed that there was a significant correlation between them. Seasonally, in P1, the lowest temperatures were

recorded in December, January, and July (22.4°C, 22.2°C and 21.0°C, respectively). In P2, the lowest temperatures occurred in December (19.7 ± 1.6°C) and July (21.0°C). From February until April, temperature means were higher than 26°C in both periods. In P1, the mean bottom temperature was 23.5°C ± 2.5 and in P2, 23.5 ± 2.1°C (Mann-Whitney

test; d. f. = 1; U= 3,273.0; p = 0.42) (Fig. 5). Larger shrimp were sampled at lower temperatures (Pearson's correlation; r = -0.80; p <0.05).

**Discussion**

The results obtained in this study showed that shrimps with smaller CL sizes of all demographic groups were sampled in P2. According to Bauer (1992), variations of some environmental factors, such as, temperature and nutrient availability may influence the growth of the individuals. Thus, it is assumed that the higher temperatures in the tropical regions can induce an increase of the metabolism, and consequently, there is a decrease in the length of the carapace growth. According to Bergmann (1947), body size is directly related to temperature, thus animals from colder regions have larger sizes than animals from warmer regions.

There is a clear increase in the size of individuals of *A. longinaris* in locations, where

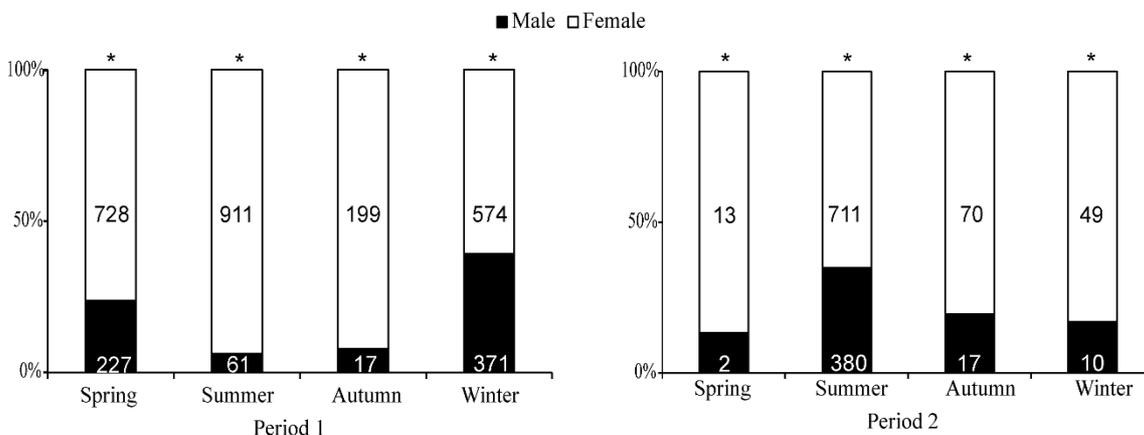
water temperature is colder than other locations that are warmer. Our results showed a relationship between temperature and CL that was shown by Pearson's correlation. In the studies accomplished by Castilho *et al.* (2007b) at Ubatuba-SP (23° S) and Sancinetti *et al.* (2015) at Macaé-RJ (22° S), more favorable environmental conditions, such as lower temperatures and greater food availability, registered larger individuals of *A. longinaris* in Macaé with a mean size of 19.0 mm CL than those collected in Ubatuba (14.4 mm CL).

Considering that temperature influences the growth of *A. longinaris* and that it presents larger sizes in places with colder temperatures, as found by Boschi (1997) and Castilho *et al.* (2007b), it is evident that the alteration of this environmental factor, caused by changes in latitudes or by water masses can promote changes in the size of these species.

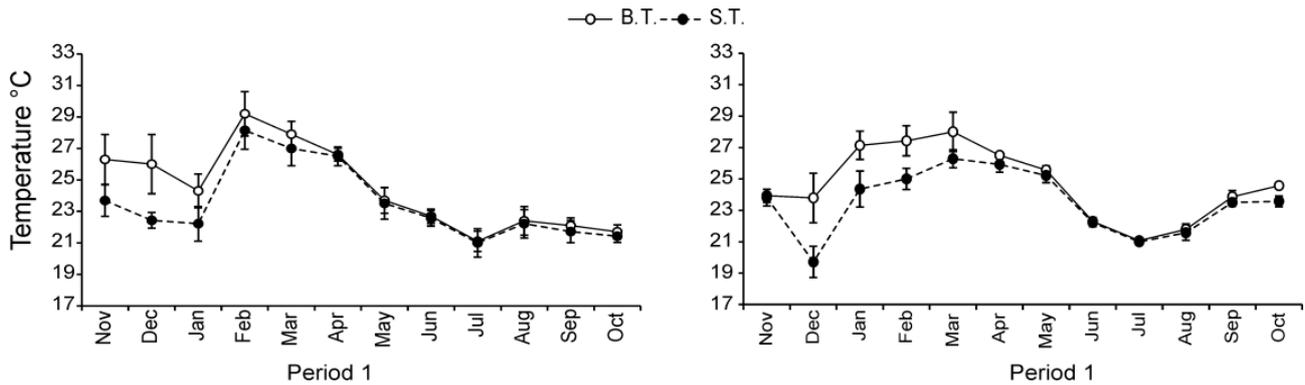
**Table II.** Sex ratio by size class of individuals of *Artemesia longinaris* collected in the Fortaleza bay in Period 1 and Period 2.

Size Classes	Period 1				Period 2			
	Male	Female	M:F	Binomial	Male	Female	M:F	Binomial
6 -  8	3	3	1.0:1.0	p>0.05	4	0	1.0:0.0	p>0.05
8 -  10	12	12	1.0:1.0	p>0.05	72	24	1.0:0.3	p<0.05*
10 -  12	31	125	1.0:4.0	p<0.05*	213	112	1.0:0.5	p<0.05*
12 -  14	181	356	1.0:2.0	p<0.05*	94	221	1.0:2.4	p<0.05*
14 -  16	308	545	1.0:1.8	p<0.05*	21	226	1.0:10.8	p<0.05*
16 -  18	133	694	1.0:5.2	p<0.05*	1	98	1.0:98.0	p<0.05*
18 -  20	8	451	1.0:56.4	p<0.05*	4	134	1.0:33.5	p<0.05*
20 -  22	0	216	0.0:1.0	p<0.05*	0	26	0.0:1.0	p<0.05*
22 -  24	0	10	0.0:1.0	p<0.05*	0	2	0.0:1.0	p>0.05
<b>Total</b>	<b>676</b>	<b>2,412</b>	<b>1.0:3.6</b>	<b>p&lt;0.05*</b>	<b>409</b>	<b>843</b>	<b>1.0:2.1</b>	<b>p&lt;0.05*</b>

\* Statistically significant values (Binomial test; p<0.05).



**Figure 4.** Percentage and number of males and females of *Artemesia longinaris* for different seasons of periods 1 and 2. (Binomial test; \*p<0.05).



**Figure 5.** Mean and standard deviation of bottom and surface water temperature sampled in the two periods of Fortaleza bay. Period 1 (November/1988 to October/1989) and period 2 (November/2008 to October/2009).

In addition, Davanzo *et al.* (2017) suggest that local variations may also exert a strong influence on shrimps size. These authors compared the size of *Xiphopenaeus kroyeri* (demographic groups) in two regions (Macaé, Rio de Janeiro State and Ubatuba, São Paulo State) and obtained larger individuals for all groups in Macaé, where the region is influenced by the resurgence phenomenon, which characterizes the region with colder waters throughout the year (Valentin 1984).

In the P1, the thermocline caused by South Atlantic Central Water (SACW) was observed in November and December of 1988 to January of 1989, whereas in P2, it can be perceived only in December of 2008. In P2, the effects produced by SACW in the Fortaleza bay were lower. The lower effects produced by SACW may have been a cause of smaller sized individuals and lower abundance in the second period, because according to Castilho *et al.* (2007a), *A. longinaris* migrate to coastal regions with SACW. As it is known, the SACW causes changes in the water conditions in the Ubatuba region, such as the increase in primary productivity and the decrease in the bottom temperature Pires (1992).

In addition, another possible cause to justify the lower size individuals sampled in the P2 in this bay is the intense activity of shrimp fishing that exists in the region of Ubatuba. According to Kaiser *et al.* (2002), among the impacts caused by trawling in the ecosystem are the reduction of body size of organisms and early attainment of the sexual maturity.

Although Fortaleza bay is not a direct target for artisanal and commercial fishing, regions nearby are often exploited, which may have led to indirect consequences for the individuals in the bay. According to Vazzoler (1996) and Keunecke *et al.* (2012), many populations under intense fishing

pressure may have reduced sizes. For the demographic group of *A. longinaris*, adult males and adult females presented significant reduction of size between periods. These smaller individuals found in P2 (mainly females), may already be causing damages to the abundances of these species. According to Costa & Fransozo (2004), individuals with smaller sizes present a reduction of egg production, and this long time may have contributed to a reduction in the abundance of these species.

Two other important aspects analyzed after 20 years were sexual dimorphism and sexual ratio. According to Boschi (1969b) and Branco *et al.* (1999), the differences in body size between the sexes, with larger females than males, are a general rule among Penaeoideans. According to Gab-Alla *et al.* (1990), Costa & Fransozo (2004), and Castilho *et al.* (2008), the sexual dimorphism in shrimps probably occurs due to an adaptation to the increase in egg production. Regarding sexual dimorphism, in both periods, females of *A. longinaris* had cephalothorax length greater than males. Other examples of shrimps following this pattern of size sexual dimorphism are *Xiphopenaeus kroyeri* (Heller, 1862) in the studies by Severino-Rodrigues *et al.* (1993), Nakagaki & Negreiros-Fransozo (1998) and Castro *et al.* (2005), *Rimapenaeus constrictus* (Stimpson, 1874) in study by Costa & Fransozo (2004) and *Sicyonia dorsalis* (Kingsley, 1878) by Castilho *et al.* (2008). This result was found for *A. longinaris* also by Castilho *et al.* (2007b), Costa *et al.* (2010) and Sancinetti *et al.* (2015).

Due to their larger size, females are more vulnerable to be captured by trawl nets. After 20 years under this impact, this species could have triggered changes in the sex ratio. However, we did not observe changes in the sex ratio with the predominance of females maintained. According to

Wenner (1972), among marine crustaceans, the ratio of 1:1 is considered an exception rather than a rule. In the first size classes, tended to balance, this corroborates with what was suggested by Leigh (1970) that the sexual ratio between males and females tend to be close to 1:1 at birth. After birth, factors such as migration and differential mortality, longevity, sex change, and differential growth rate may affect this relationship (Wenner 1972). Several hypotheses can be cited as possible explanations for the sexual reason of *A. longinarius* being favored by females in both period in the Fortaleza bay. Some authors suggested that there is a differential migration between the sexes during the reproductive cycle, with copulation occurring in deeper areas (where the ratio would be closer to 1:1) and migration only of adult females to coastal areas to spawn, justifying the sex ratio found in this study (Costa *et al.* 2010, Castilho *et al.* 2012). Another hypothesis according to Pianka (1983) is that a single male could copulate several females. Otherwise, Kevrekidis & Thessalou-Legaki (2011) suggested that the greatest capture of females of *Melicertus kerathurus* (Forskål, 1775) is due to the longer foraging time for ovarian maturation. In addition, the high capture of females could be because larger females are more susceptible to be captured by the network mesh.

Considering the target species of this study is an endemic shrimp of the Western South Atlantic, these results serve as a warning for the monitoring and sustainable use of these stocks. The present results showed that after 20 years, among the analyzed aspects of the population biology of *A. longinarius*, the shrimp size, in each demographic group, was the only one showing change. In P2, smaller individuals were sampled, which may have been caused by natural phenomena or anthropic activity. Aspects related to sexual dimorphism (females greater than males) and sex ratio (greater number of females) did not show changes after 20 years.

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