

Population biology of the commercially exploited shrimp *Artemesia longinaris* (Decapoda: Penaeidae) in an upwelling region in the Western Atlantic: comparisons at different latitudes

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Abstract

This study characterized the population biology of the dendrobranchiate penaeid shrimp *Artemesia longinaris* Spence Bate, 1888, focusing on population structure, sexual maturity, reproductive period and recruitment, and comparing reproductive parameters of a different populations along western South Atlantic. Samples were collected monthly from March, 2008 to February, 2010 in Macaé, northern coast of Rio de Janeiro State, Brazil, a region influenced by the Cabo Frio upwelling. There was a significantly higher percentage of females and with larger sizes than males. Both carapace length and sexual maturity in Macaé were similar to the dimensions found in populations in the South of the continent (Argentina). Reproductive females were present in all months, with main peaks during winter and summer. Recruitment was also continuous, with peaks, usually one to two months after the appearance of reproductive females, after the reduction of the bottom temperature values of water. These data suggest that November to January would be the appropriate months for legal off-season, due to the higher intensity of spawning females and juveniles during this period. A comparação latitudinal dos parâmetros reprodutivos, não confirma o paradigma de que tamanho do corpo e a maturidade sexual das fêmeas são menores em regiões tropicais e aumentam em direção às maiores latitudes, reforçando a hipótese da influência e importância da ACAS na dinâmica reprodutiva de *A. longinaris* na região. The results of this study contribute to the understanding of the biology of *A. longinaris*, and could also be a reference to monitor this important fishery resource and consequent legal off-season. Furthermore, this population located at the northern limit of the species distribution is a source of highly relevant comparison for population studies in other areas.

Keywords: Dendrobranchiata, sex ratio, recruitment, reproductive biology, shrimp fishery.

Biologia populacional do camarão explorado comercialmente *Artemesia longinaris* (Decapoda: Penaeidae) em uma região de ressurgência do Atlântico Ocidental: comparação em diferentes latitudes

Resumo

Este estudo caracterizou a biologia populacional do camarão *Artemesia longinaris* Spence Bate, 1888, com foco na estrutura populacional, a maturidade sexual, período reprodutivo e de recrutamento, e comparação dos parâmetros reprodutivos de diferentes populações ao longo do Atlântico Sul ocidental. As amostras foram coletadas mensalmente de março de 2008 a fevereiro de 2010, em Macaé, litoral norte do Rio de Janeiro, Brasil, região influenciada pela ressurgência de Cabo Frio. Houve uma porcentagem significativamente maior de fêmeas e com tamanhos maiores do que os machos. Ambos, comprimento da carapaça e maturidade sexual, em Macaé foram similares às dimensões encontradas em populações do sul do continente (Argentina). Fêmeas reprodutivas estiveram presentes em todos os meses com os principais picos no inverno e verão. O recrutamento também foi contínuo, normalmente um a dois meses após o aparecimento de fêmeas reprodutivas, após a redução da temperatura da água de fundo. Estes dados sugerem que o período de novembro a janeiro seriam os meses apropriados para o defeso, devido à maior intensidade de fêmeas

reprodutoras e juvenis durante este período. A comparação latitudinal dos parâmetros reprodutivos, não confirma o paradigma de que tamanho do corpo e a maturidade sexual das fêmeas são menores em regiões tropicais e aumentam em direção às maiores latitudes, reforçando a hipótese da influência e importância da ACAS na dinâmica reprodutiva de *A. longinaris* na região. Os resultados deste estudo contribuem para o entendimento da biologia de *A. longinaris*, e também pode ser uma referência para monitorar esse importante recurso pesqueiro e, consequente período de defeso. Além disso, esta população situada no limite do norte da distribuição das espécies é uma fonte de comparação altamente relevante para estudos populacionais em outras áreas.

Palavras-chave: Dendrobranchiata, razão sexual, recrutamento, biologia reprodutiva, pesca de camarão.

1. Introduction

Recently, on the Brazilian Southeastern coast, two shrimp species *Pleoticus muelleri* (Spense Bate, 1888) and *Artemesia longinaris* Spense Bate, 1888 - have become part of industrial and artisanal fishery due to the excessive exploitation of the most profitable penaeid species, such as: the pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. paulensis* (Pérez Farfante, 1967), seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) and the white shrimp *Litopenaeus schmitti* (Burkenroad, 1936).

Artemesia longinaris is a species endemic to the Western South Atlantic, occurring from Atafona (21°S) (Rio de Janeiro, Brazil), to the Chubut Province (43°S) (Argentina) (Boschi, 1969a), and is commonly found in shallow waters up to 30 m (Boschi, 1997; Costa et al., 2003). Boschi (1969b) stated that this species is typical of colder regions, occurring in a temperature range from 15 to 21°C and salinity above 33. Additionally, the density of *A. longinaris* increases with latitude (Magalhães, 1944; Boschi, 1969b). This pattern has also been observed in other studies, since the species is occasionally detected in smaller amounts on the coast of Rio de Janeiro (Iwai, 1973) and São Paulo States (Iwai, 1973; Costa et al., 2005). However, from the coast of Rio Grande do Sul State to Argentina (Boschi, 1969b) the species is caught all year long. *Artemesia longinaris* lives exclusively in the marine environment throughout its life cycle, without any period linked to continental brackish waters (Boschi, 1997; Costa et al., 2005).

The coastal area of Macaé, Rio de Janeiro State, is influenced by Brazil ($T > 20^{\circ}\text{C}$, $S > 36$) and the Falklands ($T < 15^{\circ}\text{C}$, $S < 34$) oceanic currents. As a result of the confluence of both currents between the latitudes of 25°S and 45°S in the Atlantic, there is the formation of the South Atlantic Central Water (SACW; $T < 18^{\circ}\text{C}$, $S < 36$). The SACW represents part of the subtropical convergence and gives rise to the Cabo Frio upwelling, which extends between the latitudes of 23°S and 29°S (Castro Filho et al., 1987; Acha et al., 2004). Waters that are cold and nitrate rich resulting from SACW, dislocate toward the coast (Acha et al., 2004) changing the local physical conditions and also increasing water nutrient concentrations (Valentin, 1984). Consequently, the primary productivity in the Southeastern coast of Brazil is increased, especially in Cabo Frio, RJ (23° S) (De Léo and Pires-Vanin, 2006). Such physical and biological shifts resulting from the SACW might reveal particular results about reproductive dynamics of the species in that region,

since the proximate factors that act on the beginning and end of the crustacean reproduction are temperature, salinity, luminosity and food availability (Bauer and Lin, 1994).

Most of the available research about *A. longinaris* is based on populations sampled in Argentinean waters (Boschi and Mistakidis, 1966; Boschi, 1969a, b, 1997; Boschi and Scelzo, 1977; Gavio and Boschi, 2004). However, the number of studies on population biology of this species is increasing in Brazil, emphasizing the studies of Nascimento (1981) and Ruffino and Castello (1992). Recently, mainly in Rio de Janeiro, São Paulo, and Santa Catarina States, information about population, breeding dynamics (Castilho et al., 2007a, b; Semensato and Di Benedito, 2008; Costa et al., 2010), and ecological distribution (Fransozo et al., 2004; Costa et al., 2005) have been obtained and these authors state that longevity, size at onset of sexual maturity and maximum carapace length increase at higher latitudes. According to Castilho et al. (2007b) reproduction and juvenile recruitment on the coast of São Paulo (tropical = 23°S) are continuous, whereas in Mar del Plata (cool-temperate = 37°S) these events are seasonal.

The effect of latitude on the population dynamics of penaeids has been studied by several authors (Bauer, 1992; Boschi, 1997; Gavio and Boschi, 2004; Castilho et al., 2007a, b; Costa et al., 2010). Furthermore, one of the main aims of reproductive ecology studies of benthic invertebrates is to evaluate the tendencies of geographical and temporal variations on the reproductive and juvenile recruitment activity (Bauer, 1992; Costa and Fransozo, 2004). These studies are essential to implement sustainable fishery techniques, especially because reproductive patterns can differ according to distinct environmental conditions among geographical latitudes (Bauer, 1992; Castilho et al., 2007a).

Even though Macaé is located in a tropical region, it is characterized by temperature conditions similar to the Argentinean coast (cool-temperate region) which is a result of the influence of Cabo Frio upwelling. Due to this similarity, it is expected that *A. longinaris* reproductive events along Macaé coast, such as seasonality and values of the carapace length size values, would also follow the same patterns, contradicting the latitudinal gradient theory. Thus, the aims of this study were to analyze the population biology of *A. longinaris*, focusing on sex ratio, reproductive biology and recruitment in a region under the influence of an upwelling near its northern distribution limited to the Western Atlantic Ocean (Macaé, Rio de Janeiro, Brazil), and to compare these results to studies conducted at different latitudes along the species distribution.

2. Material and Methods

Shrimps were sampled monthly from March 2008 to February 2010 in six stations divided into two areas according to the depths: inside area (5, 10 and 15 m) and outside area (25, 35 and 45 m) in Macaé, northern coast of Rio de Janeiro State (22°22'33"S, 41°46'30"W) (Figure 1). The terminologies inside area and outside area were used only to characterize less and larger depths of the stations, respectively. A shrimp fishing boat equipped with otter-trawl nets (3.5 m mouth width, mesh size 20mm and 15mm in the cod end) was used for trawling. The stations were trawled over a 15-min period in a constant speed of 2.0 nautical miles through 1 km. Salinity and temperature (°C) were measured in surface and bottom-water samples, obtained monthly in each station using a Van Dorn bottle. In the laboratory, the salinity was verified with a manual salinometer calibrated with distilled water. The water temperature was verified with a mercury thermometer immediately after sampling in a thermic isolated container in the shade.

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.

Shrimp were measured in relation to the carapace length (CL) (to nearest 0.1 mm), corresponding to the distance from the orbital angle to the posterior margin of the carapace. Length frequency distributions were

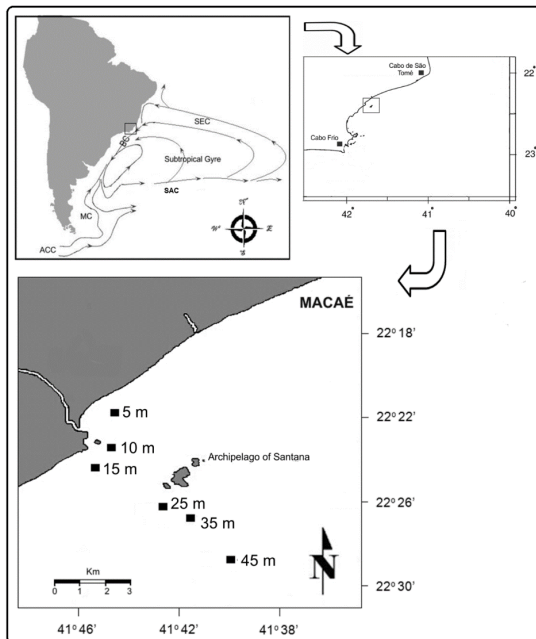


Figure 1. Location of the study area, Macaé, Rio de Janeiro, Brazil, evidencing the sampling stations (5–45m of deep) and the major ocean currents of the Southwestern Atlantic. ACC, Antarctic Circumpolar Current; MC, Malvinas Current (Falkland); SAC, South Atlantic Current; SEC, South Equatorial Current; BC, Brazil Current. (Modified from Peterson and Stramma (1991)).

constructed with 2 mm CL size classes for each sex, and the Student's T-test was used to compare the sexes. Normality of the data was examined by Shapiro–Wilk test. The null hypothesis was that size distribution between sexes did not differ significantly among sample dates or stations. 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).

The reproductive status of males was assessed by examining the shape of the petasma, which is fused in adult individuals. The reproductive status of adult females was determined by macroscopic observation of the degree of ovarian development (color and volume occupied by the gonads) according to Castilho et al. (2007b). Ovaries categorized as immature varied from thin and transparent strands to thicker strands. Ovaries of adult females were much larger and thicker, and colored white (spent), light green (developing), or green to olive green (ripe). Spawning intensity of the population was estimated as the percentage of reproductive females (developed and ripe gonad) in relation to the total of adult females in each station, month or season (e.g., summer: December to February, and so on).

The relative frequency (%) of adults in each size class was plotted, and the logistic function was fitted to the data. CL50% corresponds to the size at which 50% of the individuals are considered mature/ adults, and r is the slope of the curve. Fitting was done by the least-squares method (Aguillar et al., 1995; Vazzoler, 1996), requiring a size-range overlap of adults and young of at least two size classes. The shrimps were therefore arranged in 1.0-mm size intervals.

We tested the hypothesis that temperature and salinity are determinant in periods of reproduction and recruitment. The Spearman linear correlation ($p < 0.05$) was used to correlate these factors with the frequency of reproductive females and recruits (Zar, 1999). The recruitment was calculated by adding the number of recruits of both sexes in temporal scale.

3. Results

A total of 8,329 individuals were analyzed, with higher percentage of females compared to males. There were significant differences in sex ratios for all the months (χ^2 , $p < 0.05$), except in April 2009 (Table 1). There were also higher percentages of females across sampling locations (χ^2 , $p < 0.05$) (Table 2). The smallest reproductive female found had 10.7 mm CL, while the smallest adult male had a CL of 9.4 mm. The largest female CL was 38.3 mm, which was larger than the largest male CL (35 mm). In general, mean sizes differed significantly between females (17.01 ± 4.0 mm) and males (14.23 ± 3.17 mm) (Figure 2, Student's test, $t = 31.81$, $p = 0.001$).

The proportion of adult females in 1 mm size classes increased logistically with carapace length. The estimated CL onset of sexual maturity in Macaé was 16.3 mm ($CL_{50\%}$) for females and 13.3 mm ($CL_{50\%}$) for males. Juvenile recruitment was continuous, showing inflow peaks of lower

sizes individuals especially in March, 2008, and between September and October, 2008, March and May, 2009, and September, 2009 and January, 2010. Consequently, it was possible to identify size progressions in both sexes after the inflow of juveniles (during April to August, 2008, October, 2008 to March, 2009, April to August, 2009 and September, 2009 to February, 2010) (Figure 3).

Reproductive females were found during all months, revealing two main peaks in winter and summer (August and January of each year) (Figure 4). The inflow of recruits in the population was less evident during the first year, in autumn (April, 2008) and spring (September to October,

2008). However, during the second year, recruits inflow peaks were identified during autumn (April to May, 2009), spring (October to November 2009) and summer (January, 2010). Recruits joined the population approximately two months after the beginning of the reproductive period (Figure 4), with females and recruits groups negatively correlated (Spearman: $t = -2.38, p = 0.03$).

The outside area showed a higher number of recruits ($n = 283$) in relation to the inside area ($n = 155$). In addition, the depths of 15 and 25 m showed a greater number of recruits (119 and 150, respectively) (Table 2).

There were no significant correlations either between bottom temperature with frequency of reproductive females (Spearman, $r_s = -0.20, t = -0.96, p = 0.34$) or with recruits (Spearman, $r_s = -0.20, t = -0.97, p = 0.34$). The same was observed between bottom salinity with frequency of reproductive females (Spearman, $r_s = -0.13, t = -0.60, p = 0.55$) and with recruits (Spearman, $r_s = 0.08, t = 0.39, p = 0.70$).

However, a decrease in bottom temperature at the end of winter and more accentuated during the months of October and November of both years resulted in an increase in the frequency of reproductive females, mainly during December and January (Figures 4 and 5). Finally, regarding salinity values, no apparent synchrony of this factor occurred with the abundance of reproductive females, in contrast to a clear increase in the number of recruits with mean values of bottom salinity (Figure 5).

Table 1. Number of males (♂) and females (♀) of *Artemesia longinaris*, together with their sex ratio and chi-squared values (χ^2), from March, 2008 to February, 2010 sampled along the coast of Macaé, Rio de Janeiro, Brazil.

Months	♂	♀	Total	χ^2	Sex ratio
Mar/08	84	168	252	1.2E-07	1♂:2.00♀
Abr/08	140	292	432	2.6E-13	1♂:2.09♀
Mai/08	130	201	331	9.5E-05	1♂:1.55♀
Jun/08	225	344	569	6.1E-07	1♂:1.53♀
Jul/08	151	284	435	1.8E-10	1♂:1.88♀
Ago/08	41	167	208	2.4E-18	1♂:4.07♀
Set/08	74	151	225	2.8E-07	1♂:2.04♀
Out/08	70	143	213	5.7E-07	1♂:2.04♀
Nov/08	61	112	173	1.1E-04	1♂:1.84♀
Dez/08	16	75	91	6.2E-10	1♂:4.69♀
Jan/09	35	151	186	1.8E-17	1♂:4.31♀
Fev/09	12	149	161	3.6E-27	1♂:12.42♀
Mar/09	80	289	369	1.4E-27	1♂:3.61♀
Abr/09	114	144	258	0.06	1♂:1.26♀
Mai/09	171	317	488	3.9E-11	1♂:1.85♀
Jun/09	167	324	491	1.4E-12	1♂:1.94♀
Jul/09	170	325	495	3.2E-12	1♂:1.91♀
Ago/09	71	161	232	3.4E-09	1♂:2.27♀
Set/09	113	211	324	5.2E-08	1♂:1.87♀
Out/09	250	377	627	3.9E-07	1♂:1.51♀
Nov/09	168	363	531	2.6E-17	1♂:2.16♀
Dez/09	139	406	545	2.7E-30	1♂:2.92♀
Jan/10	157	261	418	3.6E-07	1♂:1.66♀
Fev/10	86	189	275	5.3E-10	1♂:2.20♀
Total	2725	5604	8329	2.0E-218	1♂:2.06♀

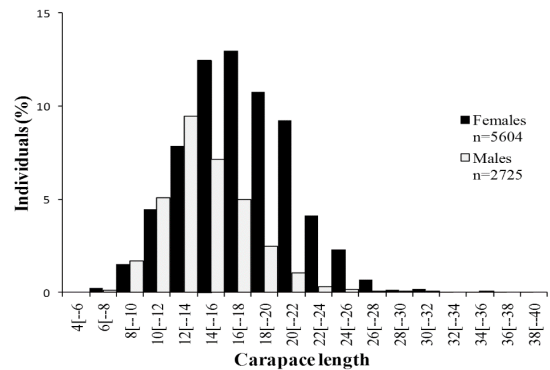


Figure 2. *Artemesia longinaris*. Percentage of male and female individuals according to size classes (mm) in Macaé, Rio de Janeiro, Brazil, sampled between March, 2008 and February, 2010.

Table 2. Number of males (♂) and females (♀) of *Artemesia longinaris*, together with their sex ratio and chi-squared values (χ^2), and the number of juveniles by area and depth, sampled along Macaé, Rio de Janeiro, Brazil.

Areas/ Stations	♂	♀	Total	χ^2	Sex ratio	Juveniles	
inside	5	178	497	675	1.8E-34	1♂:3♀	11
	10	321	969	1290	9.2E-73	1♂:3♀	25
	15	607	1509	2116	1.3E-85	1♂:2♀	119
outside	25	900	1331	2231	7.2E-20	1♂:2♀	150
	35	539	971	1510	1.0E-28	1♂:2♀	113
	45	180	327	507	6.6E-11	1♂:2♀	20
Total		2725	5604	8329	2.0E-218	1♂:2♀	438

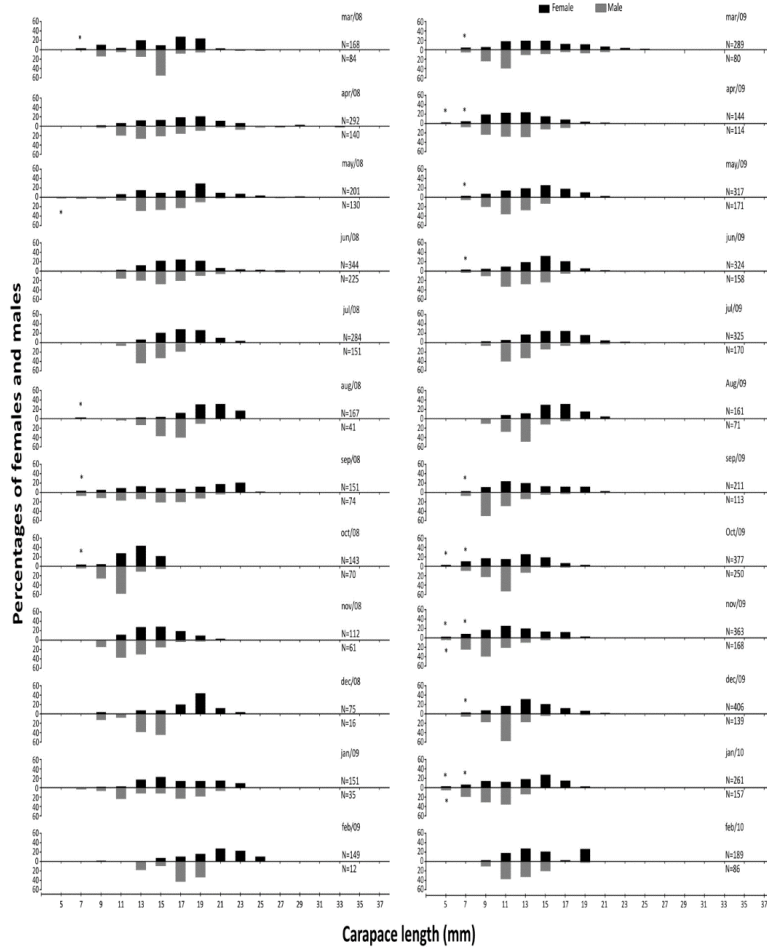


Figure 3. *Artemesia longinaris*. Percentage of male and female individuals according to size classes (mm), sampled at depths between 5 and 45 m in Macaé, Rio de Janeiro, Brazil, and the periods between March 2008 and February 2010. The range of each size class was 2 mm (*, Classes with juvenile individuals).

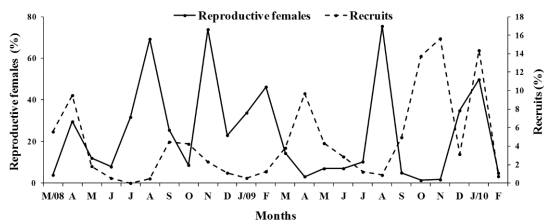


Figure 4. *Artemesia longinaris*. Percentage of juveniles and reproductive females collected between March, 2008 and February 2010 along Macaé, Rio de Janeiro, Brazil.

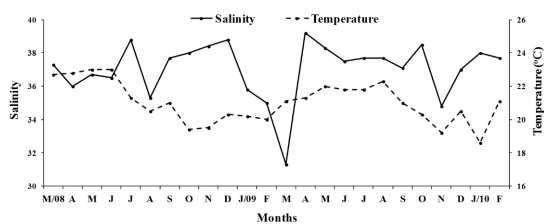


Figure 5. Monthly average values of temperature and bottom salinity, collected between March, 2008 and February, 2010 along Macaé, Rio de Janeiro, Brazil.

4. Discussion

Males and females were present during all months of study in all stations, however with higher frequency of females. Boschi (1969a) and Gavio and Boschi (2004), in Mar del Plata (Argentina) and Nascimento (1981) and Ruffino and Castello (1992), in Rio Grande do Sul (Brazil), also found a predominance of females in *A. longinaris* populations. This pattern might be due to higher mortality of the male population (Boschi, 1969a; Cha et al., 2002), easier capture of females because of their larger size (Cha et al., 2002; Costa et al., 2010), longer foraging times of females to meet the feeding needs associated with gonadal maturation (Kevrekidis and Thessalou-Legaki, 2006). In addition, Costa et al. (2010) suggested a distinct migratory pattern of *A. longinaris* between sexes during the reproductive cycle, which would be the mating taking place in deep waters with adult female subsequent migration to coastal waters for spawning. Hence, this latter hypothesis is more consistent with the results of this study.

As in other penaeid shrimps, males captured in this study reached sexual maturity with smaller carapace size

than females. Moreover, *A. longinaris* was characterized by sexual dimorphism according to size, considering that females showed larger lengths than males. According to Boschi (1969b) and Gab-Alla et al. (1990), differences in body size regarding sexes are a general rule among penaeid shrimps, because larger females may be under selective pressure to increase egg production (Costa and Fransozo, 2004; Castilho et al., 2008)

Bauer (1992) and Castilho et al. (2007a) suggest that the life style, size at sexual maturity, growth and longevity in penaeids vary according to the structuring of environmental factors in each latitudinal gradient mostly influenced by water temperature, nutrient availability, and consequently the oceanic primary productivity. The proposed pattern is that as latitude increases, reproductive periodicity tends to decrease, and size at sexual maturity and longevity tends to increase. Generally, female size values on maximum CL, mean CL, and CL at maturity were similar to the ones found by Semensato and Di Benedetto (2008) in Farol de São Tomé, a region of same latitude as the study area (22° S). The values were higher than those found by Castilho et al. (2007b), Costa et al. (2010) and Dumont and D'Incao (2008), in the latitudes of 23° S, 27° S and 32° S, respectively. However, at higher latitudes of South American (Argentina) those values become higher again, according to Castilho et al. (2007a) (37° S) and Boschi and Mistakidis (1966) (43° S) (Table 3).

Based on the results found in this study and on the comparison with the studies mentioned above, the hypothesis proposed by Bauer (1992) and corroborated by Castilho et al. (2007a) cannot be confirmed. These authors state that the body size and sexual maturity of females are smaller in tropical regions and increase toward higher latitudes (temperate regions). Such hypothesis should take into account parameters of the local environment, like water temperature and food availability for larval stages, as in the study area.

The similarity of values of female CL and maturity between the regions of Macaé and Farol de São Tomé (northern limit of distribution) strengthens the hypothesis of the influence and importance of the SACW in the reproductive dynamics of *A. longinaris* in the study area. The region of Macaé is located near an upwelling area, which reduces the average annual temperature to values lower than those found by Castilho et al. (2007a, b, 2008) in tropical and subtropical regions like São Paulo State coast. Such parameter is probably the reason why the recorded CL values in this study were higher than the ones found in São Paulo State coast, and similar to the ones from the Argentinean coast.

The Cabo Frio upwelling is seasonal (stronger during summer) with predominant North and Northeast winds (Silveira et al., 2000). According to Castro and Miranda (1998), the SACW intrusion is associated with meanders and eddies from the Brazil Current. The intrusion of SACW events during spring and summer results in a water nutrients increase and, as a consequence, the phytoplankton biomass increases as well (De Léo and Pires-Vanin, 2006). However, the upwelling might occur at any time of the year, since it can be activated by favorable Northeast winds (Matsuura, 1986). According to De Léo and Pires-Vanin (2006), the wind change is capable of causing primary productivity peaks during winter. Sumida et al. (2005) proposed that chlorophyll *a* level changes in the Cabo Frio external shelf may be attributed to the induced upwelling from meanders and eddies even during winter. Furthermore, according to Sumida et al. (2005), the opposite of these conditions are responsible for a higher particle flow toward bottom sediments.

The results of this study showed that regions under environmental conditions distinct from processes usually found in the tropical region, as is the one studied, might therefore be the example of exceptions to the life pattern of *Peneoidea* that is proposed according to latitude. The

Table 3. Reproductive parameters of different populations of *Artemesia longinaris* along Western South Atlantic.

References	Coordinates (Lat)	Region (State/Country)	Size at sexual maturity (CL50%) (mm)	Mean \pm SD of CL (mm)	Maximum size of carapace (mm)
Semensato and Di Benedetto (2008)	22° S	RJ/BR	16.4	17.0 \pm 2.0	27.0
Present study	22° S	RJ/BR	16.3	19.0 \pm 3.4	38.3
Castilho et al. (2007b)	23° S	SP/BR	13.4	14.4 \pm 3.0	27.3
Costa et al. (2010)	27° S	SC/BR	13.4	12.8	21.3
Dumont and D'Incao (2008)	32° S	RS/BR	---	15.1 \pm 3.6	30.0
Castilho et al. (2007a)	37° S	MP/ARG	22.1	23.7 \pm 1.8*	30.0
Boschi and Mistakidis (1966)	43° S	CHU/ARG	---	---	37.0

Lat: latitude; CL: carapace length; BR: Brazil; RJ: Rio de Janeiro; SP: São Paulo; SC: Santa Catarina; RS: Rio Grande do Sul; P: Mar Del Plata; CHU: Chubut; ARG: Argentina. *A.L. Castilho, unpublished data.

lower water temperature mean values and the increase of nutrient concentration throughout the year might offer similar conditions to the ones found in the South of the continent, where the species is commonly found. Therefore, the study area that is under influence of Cabo Frio upwelling provides a suitable location for the establishment of the species.

Dumont et al. (2009) tested the mtDNA control region as a molecular marker for a population study with *A. longinaris* from distinct areas (Mar del Plata – Argentina, Rio Grande do Sul and Macaé - Brazil), and suggested that populations inhabiting the northern boundary of distribution (Macaé) are less closely related with the other regions studied. Analyzing the results about size structure of the individuals captured for this study with the results of Dumont et al. (2009), it may be inferred that Cabo Frio and Macaé populations are distinct from those found in the South. Thus, management strategies for the preservation of the species, like the closed season, must take into account the biological aspects of each region.

As the evolutionary history of *A. longinaris* is related to sub-Antarctic regions (Boschi, 2000), one can infer that the species might have dispersed over evolutionary time to Brazilian coast by migration through larval drift. Furthermore, the environmental differences found along Brazilian coast did not prevent migrant inflow, since it is possible to find the species from latitude 21° to 43°. One can hypothesize that, under the same migratory pattern, *A. longinaris* started to inhabit the southeastern coast of Brazil using SACW currents to travel long distances. Moreover, favorable environmental conditions, especially the temperature found in the Cabo Frio/RJ region and adjacent areas, allow the establishment of this species. Additionally, the lower temperatures found all year long in this upwelling region, favors individuals to remain in the same area without the necessity of neither returning to their place of origin nor shifting to more favorable locations at higher latitudes when the temperature increases.

According to Semensato and Di Benedetto (2008) in the same studied region, females with developed gonads were found in different periods (autumn and late spring), however with seasonal peaks. However, the seasonal variation in the frequency of females with mature ovaries was similar to the one reported for *Rimapenaeus constrictus* (Stimpson 1874) and *X. kroyeri* (Costa and Fransozo, 2004; Nakagaki and Negreiros-Fransozo, 1998, respectively), and more common during winter and summer.

The occurrence of breeding peaks followed by recruitment peaks indicates fitness in the population (Crocós, 1987). Crocós and van der Velde (1995) proposed the term “effective spawning” when the reproductive activity of a given population contributes to the following recruitment within that same population. Thus, *A. longinaris* showed an effective spawning in Macaé region.

Several authors have suggested that temperature has an important influence on regulating spawning periods in penaeids (Bauer and Lin, 1994; Nascimento, 1981; Castilho et al., 2007b). Probably, the environmental scenery of the studied region that is similar to thermic

pattern of colder areas might have enabled the maintenance or both reproductive females and recruits. However, Castilho et al. (2007b, 2008) did not record effective spawning for *A. longinaris* and *P. muelleri* in the northern coast of São Paulo State.

Recruitment may be affected by variation in environmental factors (e.g., food availability, predation, currents), which have an effect on growth, survival, or dispersal of larval and post-larval stages. Although *A. longinaris* showed effective spawning, species abundance may also be under the influence of such factors. Part of the population might migrate to other areas because recruitment represented only 5.3% (438 juveniles) of the total captured shrimps.

During upwelling periods a greater concentration of chlorophyll *a* (phytoplankton production) occurs with a consequent organic enrichment of sediment in Cabo Frio region (Sumida et al., 2005). This primary production sustains a greater biomass of herbivorous zooplankton, creating favorable conditions to the survival of benthic animals (Pires-Vanin and Matsuura, 1993). Thorson (1950) and Bauer (1992) affirm that periods of higher food availability for larvae are considered suitable for reproductive events. Even though there is not a numerical correlation with low summer temperature, the greater reproductive intensity occurred mainly in this period, probably due to the assumptions of the authors that associated upwelling events with the increasing of primary productivity and biological enrichment, thus higher food availability for larval stages.

According to the current law regulating the shrimp protection period (IBAMA, CEPESUL), to the southeast and south shrimp fishery is not allowed between March and May. However, the obtained results in this study suggest that the imposed restriction period is not consistent with the biology of the species, which is probably due to different oceanographic conditions in the region. Based on the data of spawning and recruitment, the suitable period to restrict *A. longinaris* fishery in the study area would be between November and January, given that it is during this time of the year that reproductive females and recruits are most abundant. The results of this study already provide an important contribution to the knowledge of the biology of *A. longinaris* and may be used as reference to its monitoring, thus assisting the preservation of this fishery resource.

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