POPULATION DYNAMIC AND REPRODUCTION OF *Artemesia longinaris* (DECAPODA, PENAEIDAE) IN RIO DE JANEIRO STATE, SOUTH-EASTERN BRAZIL

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ABSTRACT

During 2004, the length-frequency data of *Artemesia longinaris* (Decapoda, Penaeidae) were analyzed in Rio de Janeiro State, south-eastern Brazil, to provide information on the growth, reproduction and mortality. Monthly samples were collected from January to December 2004 during the local shrimp fishery operations. The specimens were sexed, checked for maturity and their carapace length (CL) and wet weight were measured. The size at first maturity ($CL_{50\%}$) and the breeding period was also verified. The FiSAT II program package routines were used to identify the Von Bertalanffy growth function (VBGF) ($CL_t = CL_\infty (1 - \exp - K (t - t_0)$ that best fits the size class, to estimate the mortality rates and the size at first capture ($CLC_{50\%}$), and to predict the relative yield-per-recruit (*Y'/R*). The mean *CL* of immature and mature specimens was 10 and 13 mm for males, and 14 and 17 mm for females. The carapace length-weight relationship for both sexes indicated a strong allometry, where females were greater than males. The VBGF parameters differ between sexes: CL_∞ = 18.9 mm and K = 0.69 year^{-1} (males) and CL_∞ = 28.4 mm and K = 0.58 year^{-1} (females). The $CL_{50\%}$ (12.5 mm for males and 16.4 mm for females) and the $CLC_{50\%}$ (9.6 mm for males and 10.7 mm for females) indicate that the shrimps are usually recruited to the fisheries before producing new recruits. Breeding occur year-round, but ripe females were most abundant in May (autumn) and September (late winter-early spring). The total mortality was 2.88 for males and 1.88 for females and these differences could be related to the natural mortality and distinct growth rates. The *Y'/R* analysis indicated that the actual exploration rate in the region is still lower than the predicted maximum values. The local actions, the community-based management and the educational campaigns could be more suitable to this shrimp population sustainability. They can include alternative management related to the trawl-net fishery, changes in the mesh size selection and even temporal change in the official closure of this fishery. The present results have to be considered with caution to management proposes and the continuous and long term monitoring is still require to better understand the *A. longinaris* population dynamic and its fishery scenario in the study region.

Key words: *Artemesia longinaris*, growth, reproduction, mortality, stock maintenance, South-eastern Brazil

DINÂMICA POPULACIONAL E REPRODUÇÃO DE *Artemesia longinaris* (DECAPODA, PENAEIDAE) NO ESTADO DO RIO DE JANEIRO, SUDESTE DO BRASIL

RESUMO

Durante 2004, dados referentes à distribuição de freqüência de tamanho de *Artemesia longinaris* (Decapoda, Penaeidae) foram analisados no Estado do Rio de Janeiro, sudeste do Brasil, para fornecer informações sobre crescimento, reprodução e mortalidade. Amostragens mensais foram realizadas entre Janeiro e Dezembro de 2004 durante operações de pesca locais. Os espécimes foram sexados, checados quanto à maturidade e o comprimento da carapaça (CC) e o peso úmido foram medidos. O tamanho da primeira maturação ($CC_{50\%}$) e o período reprodutivo também foram verificados. Os procedimentos do programa FiSAT II foram utilizados para identificação da função de crescimento de Von Bertalanffy (FCVB) ($CC_t = CC_\infty (1 - \exp - K (t - t_0)$ com melhor ajuste para a classe de tamanho, para estimar as taxas de mortalidade e o tamanho da primeira captura ($CCC_{50\%}$),

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e para predizer o rendimento por recruta. A média do CC de espécimes imaturos e maturos foram de 10 e 13 mm para machos e de 14 e 17 mm para fêmeas. A relação entre comprimento da carapaça-peso para ambos os sexos indicou forte alometria, onde fêmeas são maiores que machos. Os parâmetros da FCVB diferiram entre os sexos: CC_{∞} = 18,9 mm e K = 0,69 ano^{-1} (machos) e CC_{∞} = 28,4 mm e K = 0,58 ano^{-1} (fêmeas). O $CC_{50\%}$ (12,5 mm para machos e 16,4 mm para fêmeas) e da $CCC_{50\%}$ (9,6 mm para machos e 10,7 mm para fêmeas) indicam que os camarões são geralmente recrutados pela pesca antes de produzirem novos recrutas. A reprodução ocorre ao longo do ano, mas fêmeas ovadas foram abundantes principalmente em maio (outono) e setembro (final do inverno-início da primavera). A mortalidade total foi de 2,88 para machos e 1,88 para fêmeas e as diferenças podem estar relacionadas à mortalidade natural e as taxas de crescimento. A análise de rendimento por recruta indicou que a taxa de exploração na região ainda é inferior aos valores máximos preditos. As ações locais, o manejo envolvendo as comunidades e as campanhas educacionais poderiam ser mais adequadas a sustentabilidade desta população de camarão. Isso pode incluir manejo alternativo relacionado à pesca com rede de arrasto, alterações na seletividade da malha da rede e até mesmo mudança no período oficial de suspensão dessa pescaria. Os resultados apresentados devem ser considerados com cautela para fins de manejo e o monitoramento contínuo e de longo prazo ainda é requerido para melhor entendimento da dinâmica populacional de *A. longinaris* e do seu cenário de pesca na região estudada.

Palavras-chave: *Artemesia longinaris*, crescimento, reprodução, mortalidade, manutenção do estoque, Sudeste do Brasil

INTRODUCTION

Shrimp fisheries along the Brazilian coast (2°N-33°S) are typically artisanal, although the industrial fisheries have been also practiced. In the south-eastern and southern Brazil (23°S-33°S) these fisheries are largely practiced, but the landings are concentrated only in some harbours. The shrimp fisheries were mono-species, but due to the stocks decline they are becoming multi-species catches (D'INCAO *et al*., 2002). According to the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA, the average annual landing of shrimps between 2000 and 2004 was around 47,000 tons and the main target species are seabob shrimp (*Xyphopenaeus kroyeri*) (40-50%), pink shrimp (*Farfantepenaeus brasiliensis*, *F. paulensis* and *F. subtilis*) (20-30%), Argentine stiletto shrimp (*Artemesia longinaris*) (10-20%), Argentine red shrimp (*Pleoticus muelleri*) (5-10%) and southern white shrimp (*Litopenaeus schmitti*) (1-5%). These data are available at the site www.ibama.gov.br.

The penaeid *A. longinaris* is endemic to the marine coastal waters of the Western South Atlantic, from Rio de Janeiro State (Brazil) (22°S) to Puerto Rawson (Argentina) (43°S) (BOSCHI, 1997; D'INCAO, 1999). Studies have suggested that temperature, salinity and photoperiod might influence not only the *A. longinaris* distribution, but also its development (LOPÉZ and FENUCCI, 1988; PETRIELLA and BRIDI, 1992; COSTA *et al*., 2005). The species body length shows an increment towards higher latitudes. In Argentinean coast, for instance, the specimens are larger than that of Uruguayan and southern Brazilian waters (BOSCHI and MISTAKIDIS, 1966; RUFFINO and CASTELLO, 1992).

In general, the tropical shrimp species should have continuous reproduction due to the relatively stable environmental conditions, allowing year-round breeding (SARTRY, 1983). However, the females do spawn within identifiable breeding seasons and the penaeid species generally have two spawning peaks per year (PAULY *et al*., 1984; PAULY, 1987), which is also verified in *A. longinaris* (SCELZO, 1991; DUMONT and D'INCAO, 2004). Shrimps are not long lived crustaceans and the short life spans imply in high mortalities rates that could be varying between sexes (CHA *et al*., 2002).

The population dynamic and reproduction of *A. longinaris* in northern limit of its distributional range have never been studied. In this context, the aim of the present paper is to provide the first information on the growth, reproduction and mortality of this shrimp in Rio de Janeiro State, comparing with other areas along its occurrence.

MATERIAL AND METHODS

The present study was conducted in the Farol de São Thomé harbour (22°05`S), where *A. longinaris* is the main target species, followed by *X. kroyeri*. In general, the annual catch ratio between these

species is 3:1, respectively, but monthly variation can occur. This harbour encloses 240 trawlers measuring 10-12 m in length and having load capacity of approximately 4-5 tons. Throughout the entire fishing ground (22°00'S-22°21'S) the trawlers operations are conducted from less than one to six nautical miles from shore and from 10 to 30 m of depth (Figure 1).

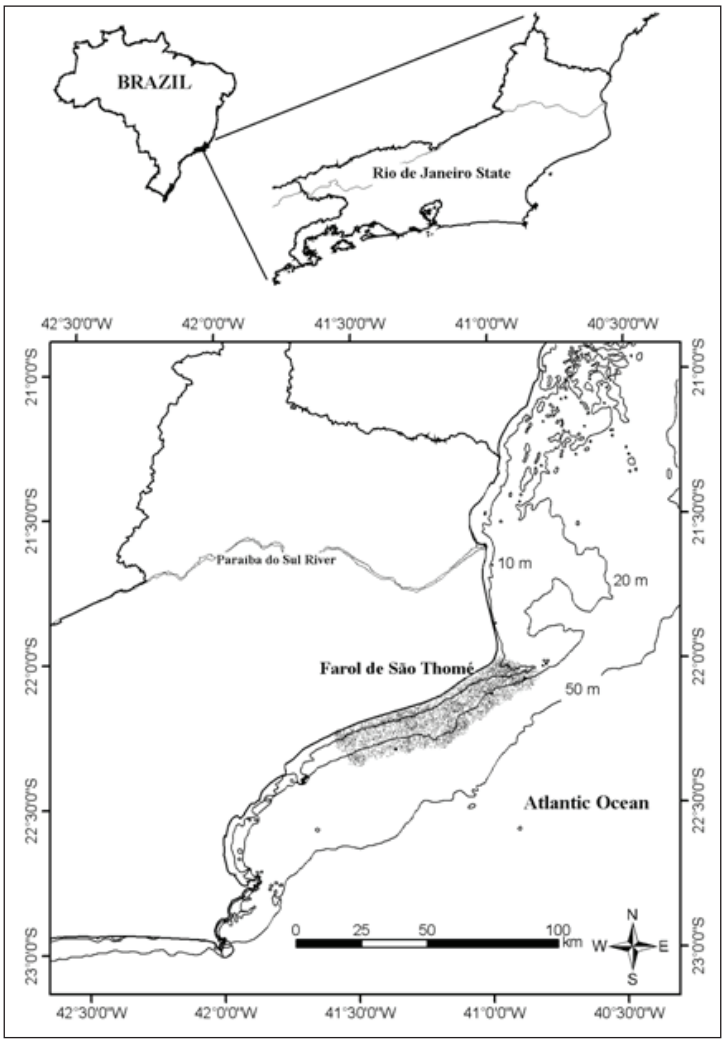

Figure 1. Map of northern Rio de Janeiro State indicating the Farol de São Thomé fishing harbour and the fishing ground where shrimps were collected

Monthly samples of *A. longinaris* were collected from January to December 2004 during the local fishing operations. The net measured about 10 m in length with a horizontal opening of about 6 m and a cod-end mesh size of 15 mm from knot to knot.

Fresh specimens of *A. longinaris* were sexed and males and females were checked for maturity by the petasma fusion level and the gonadal maturation state, respectively. Males without fusioned pestasma were considered as "immature", and with fusioned petasma as "mature". The maturity stages of the ovaries were recorded macroscopically, according to the chromatic scale proposed by DUMONT and D'INCAO (2004). Females at stages I (immature - white/translucent gonads) and II (developing - neutral green gonads) were considered as "immature", while those at stages III (mature - dark green gonads) and IV (spawning - white/translucent gonads, but with the larger body length) as "mature".

Carapace length was measured to the nearest 1 mm, from the posterior rim of the eye socket to the posterior lateral edge of the carapace. The wet weight of each specimen was measured to the nearest 0.01 g. The carapace length-weight relationships were described by the equation: $W = aCL^b$, where W is the

weight (g), *CL* the carapace length (mm) and *a*, *b* the constants for each sex separately.

Size class distributions of males and females (1 mm intervals) were recorded for each month. In December, however, only four specimens of *A. longinaris* were collected (one male and three females) and the data were not considered in the present study.

The electronic length-frequency analysis (ELEFAN I) of the FiSAT II program package (GAYANILO *et al*., 2005) was used to identify the Von Bertalanffy growth function (VBGF) that best fits the size class: $CL_t = CL_\infty (1 - \exp - K (t - t_0))$, where CL_∞ is the asymptotic carapace length, CL_t the carapace length at time *t*, *K* the growth coefficient (year^{-1}) and t_0 the theoretical age at zero length (with no biological significance). The R_n value (ranging from 0 to 1) calculated by the ELEFAN I is the index of goodness of fit, indicating the fitting of the data to the growth model. The estimates of CL_∞ and *K* were used for comparison of growth performance index (φ′) (PAULY and MUNRO, 1984) between sexes using the equation: $\varphi' = \log_{10}K + \log_{10}CL_\infty$.

In the present study, the t_0 value for males and females was not considered in the FiSAT II routines. This value is not necessary to estimate total mortality (*Z*) from steady-state sample through the length-converted catch curve for cases where growth does not exhibit annual oscillations (GAYANILO *et al*., 2005), as expected in a tropical area. Moreover, the *A. longinaris* carapace length at hatching, which could be applied to calculate the t_0 value using the relation described by LOPES VEIGA (1979), is not available in the literature to the study area or even to the surrounding regions. In this way, the authors preferred do not use the available data from colder areas, as southern Brazil (DUMONT, 2003) and Argentina (BOSCHI, 1969a).

The proportions of mature shrimps at each size class were adjusted to a logistic model to estimate the size at first maturity ($CL_{50\%}$) for both sexes: $PM = a/1 + b\exp(-cCL)$, where *PM* is the percentage of mature shrimps and *a*, *b*, *c* the constants for each sex separately. Monthly relative frequency of mature (stage III) and spawning (stage IV) females were also calculated in order to infer about the breeding period.

Total mortality (*Z*) was estimated by the length-converted catch curve method (PAULY, 1980), separately for males and females. As an extension of this method in the FiSAT II routines, the instantaneous natural mortality (*M*) was computed using the empirical model of PAULY (1980): $\log M = -0.006 - 0.27\log CL_\infty + 0.654\log K + 0.463\log T$, where *T* is the mean water temperature in degree centigrade (in the study area around 20°C); the fishery mortality (*F*) was calculated as: $F = Z - M$; and the exploration rate (*E*) as: $E = F/Z$.

The probability of capture of each size class was obtained from length-converted catch curve, by backward extrapolation of the catch curve and comparison of the numbers actually sampled with those that were expected to have been sampled. By plotting the cumulative probability of capture against the class interval, it was obtained a logistic curve from which the size at first capture ($CLC_{50\%}$) was taken.

The relative yield-per-recruit (*Y′/R*) using the Beverton and Holt model modified by PAULY and SORIANO (1986) was applied to predict the exploration rate at which the *Y′/R* is highest (E_{max}).

RESULTS

A total number of 5,033 specimens of *A. longinaris* was analysed between January and November 2004. The mean *CL* of immature and mature males was 10 mm (±2 S.D.) and 13 mm (±2 S.D.), respectively. Females were significantly greater than males (t = -29.6, $p < 0.001$), and the mean *CL* was 14 mm (±2 S.D.) for the immature specimens and 17 mm (±2 S.D.) for the mature ones. The minimum and maximum CL and the corresponding wet weight recorded were 6 mm/0.20 g and 24 mm/3.81 g for males, and 7 mm/0.39 g and 27 mm/10.42 g for females.

The size-frequency distribution of males and females from January to November is illustrated in Figure 2 and the differences between sexes size-structure can be noted.

The carapace length-weight relationship is represented by: $W = 0.0016CL^{2.677}$ ($r^2 = 0.84$; n = 2,493) (males) and $W = 0.0015CL^{2.685}$ ($r^2 = 0.91$; n = 2,540) (females). The regressions were highly significant ($p < 0.001$) and the slope (*b*) indicated a strong allometric growth for both sexes. The parameters (CL_∞, *K*) of the VBGF estimated by ELEFAN I for each sex are given in Table 1. The analysis of modal progression showed that males had lower CL_∞ and higher *K* than females, reaching the adult stage earlier. However, the difference of the growth performance index of both sexes was not great (2.392 for males and 2.669 for females).

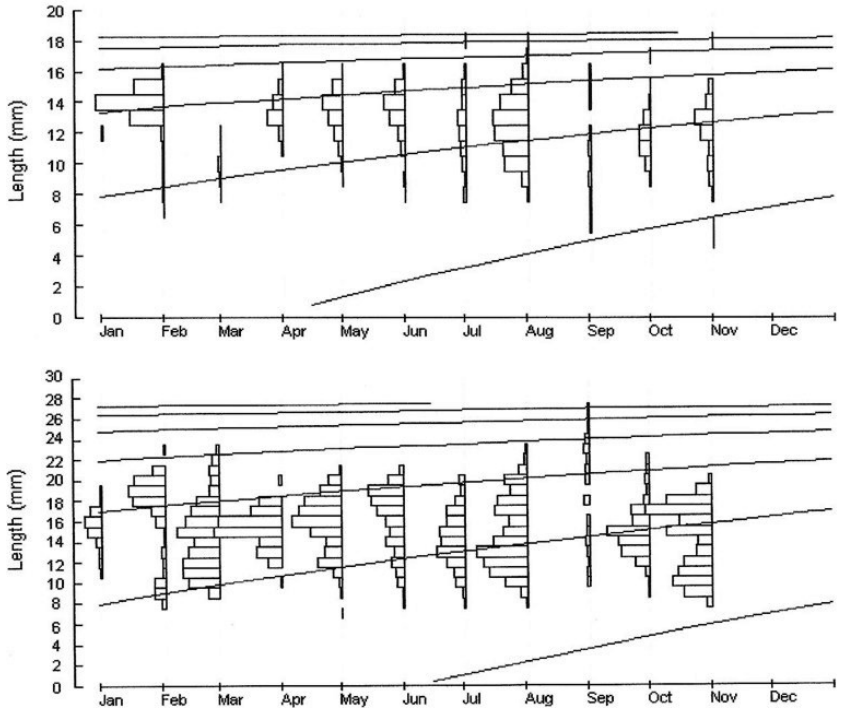

Figure 2. Size-frequency distribution of males (above) and females (below) of *Artemesia longinaris* in northern Rio de Janeiro State, south-eastern Brazil, during 2004

Table 1. Growth, maturity and mortality estimatives for *Artemesia longinaris* in northern Rio de Janeiro State, southeastern Brazil

Parameters	Males	Females
CL_{∞}	18.9	28.4
K	0.69	0.58
R_n	0.283	0.266
φ'	2.392	2.669
$CL_{50\%}$	12.5	16.4
Z	2.88	1.88
M	1.36	1.09
F	1.52	0.79
E	0.53	0.42
$CLC_{50\%}$	9.6	10.7
E_{max}	0.81	0.61

CL_{∞}: asymptotic carapace length (mm); K: growth coefficient (year^{-1}); R_n: index of goodness of fit of the 'best' growth curve; φ': growth performance index; $CL_{50\%}$: size at first maturity (mm); Z: total mortality; M: instantaneous natural mortality (at 20°C); F: fishery mortality; E: exploration rate; $CLC_{50\%}$: size at first capture (mm); E_{max}: exploration rate at which yield-per-recruit is highest.

The $CL_{50\%}$ was estimated as 12.5 mm for males and 16.4 mm for females and the difference is reflecting the sexes' growth rates (Figure 3). The mature females (stages III and IV) were observed year-round, but the higher values were recorded in May (74.1%) and September (68.9%) (Figure 4).

The Z value was 2.88 ($2.01 < Z < 3.75$) for males and 1.88 ($1.58 < Z < 2.19$) for females (Table 1). The values of M, F and E are also presented in Table 1 and all of them were highest for males. The Figure 5 showed the mortality estimation through the length-converted catch curve. The probability of capture indicated that the $CLC_{50\%}$ was similar between the sexes: 9.6 and 10.7 mm for males and females, respectively. According to the Y'/R analysis, the E value for both sexes in the study area is still lower than the predicted maximum values of E_{max} (Table 1).

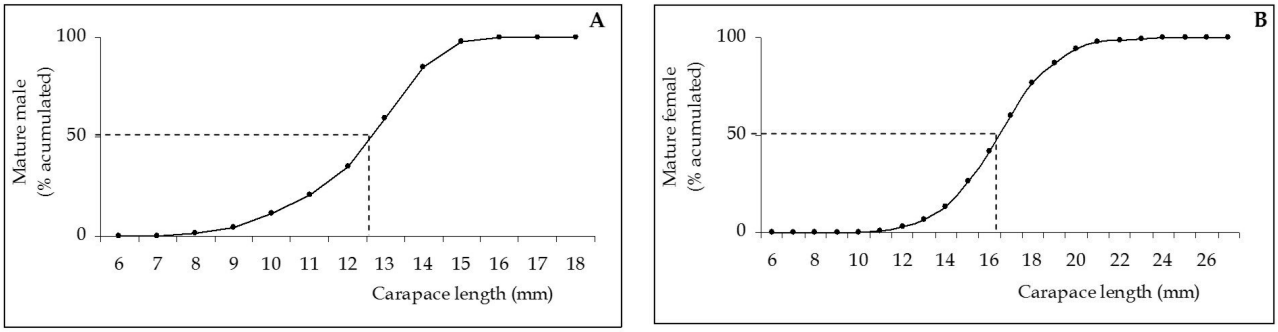

Figure 3. Size of first mature ($CL_{50\%}$) for males (A) and females (B) of *Artemesia longinaris* along northern Rio de Janeiro State coast, south-eastern Brazil

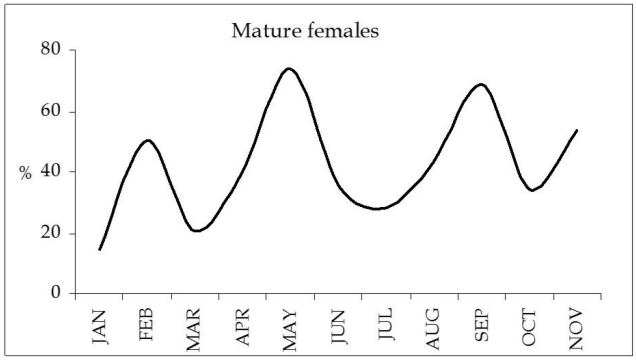

Figure 4. Relative frequency of mature females (III and IV stages) of *Artemesia longinaris* along northern Rio de Janeiro State coast, south-eastern Brazil, during 2004

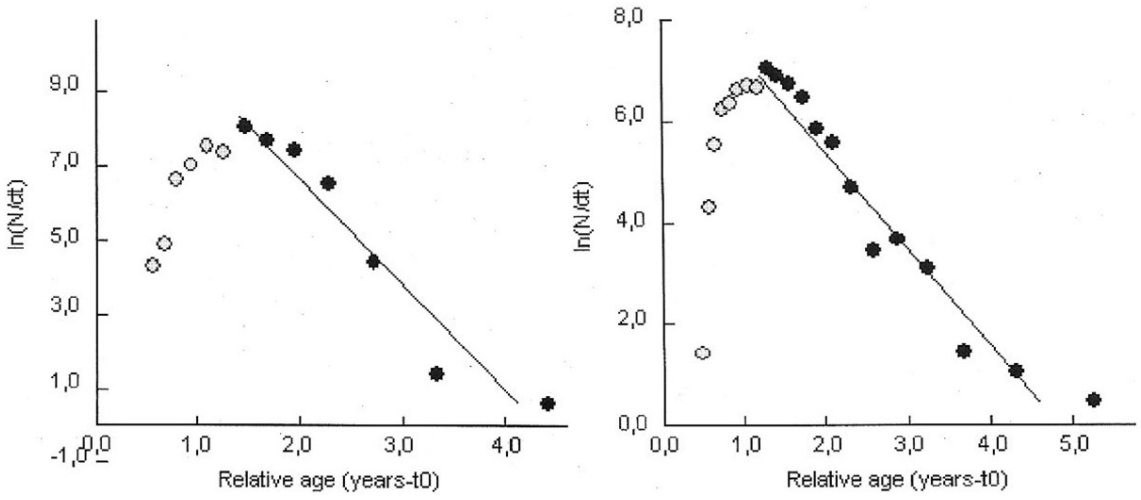

Figure 5. Length-converted catch curve for males (left) and females (right) of *Artemesia longinaris* along northern Rio de Janeiro State coast, south-eastern Brazil

DISCUSSION

The *A. longinaris* body length shows an increment towards higher latitudes. In Argentinean coast, the specimens are larger than that of Uruguayan and southern Brazilian waters (BOSCHI and MISTAKIDIS, 1966; RUFFINO and CASTELLO, 1992). As expected, the shrimps from northern distribution limit presented the species' lowest size. Penaeids shrimps show a size dimorphism, where females are greater than males (HARTNOLL, 1982). In the present study, the carapace length-weight relationship indicated a strong allometry in both sexes where females were larger and heavier than males. *A. longinaris* specimens from Argentina and

southern Brazil presented the same characteristics (BOSCHI, 1969b; DUMONT, 2003).

The analysis of length-frequency data is a reliable way of obtaining shrimp population and fisheries parameters (PAULY, 1987). The results showed that estimates of growth parameters for *A. longinaris* are in agreement with the short longevity of the penaeid species (PAULY *et al*., 1984; CHA *et al*., 2002; DUMONT, 2003), but some differences are recorded along its distribution. DUMONT (2003) analyzed this species in southern Rio Grande do Sul State, southern Brazil, and the CL_{∞} for males is greater than in northern Rio de Janeiro State (21.0 mm vs. 18.9 mm), while for females it can be considered rather similar (28.8 mm vs. 28.4 mm). However, the *K* value is lower (0.37 and 0.29 for males and females, respectively) when compared to the present investigation (0.69 and 0.58 for males and females, respectively). In Argentina, BOSCHI (1969a) also recorded greater values for the body length and lower values for the growth rate, in comparison with the Rio de Janeiro State coast.

Studies have suggested that temperature and salinity might play important role in determining the ecological distribution of *A. longinaris* (COSTA *et al*., 2005), as well as in its development (LOPÉZ and FENUCCI, 1988; HARÁN *et al*., 1992; PETRIELLA and BRIDI, 1992). Moulting frequency varies with temperature changes and in high temperatures (around 20°C) the inter-moulting period is shorter and the growth is faster, whereas opposite pattern is verified in low temperatures (bellow 14°C) (PETRIELLA and BRIDI, 1992). HARÁN *et al*. (1992) verified that in low salinities (bellow 16) the shrimp *A. longinaris* reduces its growth rate and in waters above 25 better rates were recorded. DALLEY (1980) and CHAMBERLAIN and LAWRENCE (1981) also verified that the photoperiod is directly related to the moult cycle and growth in shrimps.

The northern Rio de Janeiro State is situated in a tropical region, where the photoperiod extends over 10-12 hours and there is little seasonal variation. The water temperature can varies from 15 to 28°C, according to year season and hydrological influences (rivers' discharges and water mass), but values around 20°C or higher are normally found. The salinity usually varies from 33 to 37 and lower values can be recorded only around river mouths (PETROBRAS, 1993; MUEHE and VALENTINI, 1998). These characteristics could be favouring a faster growth of *A. longinaris* in the study area, when comparing to southern populations (Argentina and southern Brazil) where temperatures are lower and photoperiod is shorter, especially in autumn-winter months.

The $CL_{50\%}$ estimated in this study was 12.5 mm for males and 16.4 mm for females, while the $CLC_{50\%}$ was 9.6 and 10.7 mm. In northern Rio de Janeiro State, most part of *A. longinaris* shrimps is being recruited by fisheries before reaching the sexual maturity and, consequently, before producing new recruits. Thus, it could be considered as a potential risk to the local resource sustainability.

Generally, tropical shrimp species should have continuous reproduction because the relatively stable and elevated water temperatures in this region allow year-round breeding (SARTRY, 1983). However, the bulk of the females do spawn within identifiable breeding seasons, even in tropics, and penaeid shrimps generally have two spawning peaks per year (PAULY *et al*., 1984; PAULY, 1987). The species *A. longinaris* has multiple spawning during the inter-moulting period, resulting from a unique insemination event (SCELZO, 1991; PETRIELLA and BRIDI, 1992; DUMONT and D'INCAO, 2004). The same pattern was verified to other penaeid species, as *Penaeus kerathurus* and *P. latisulcatus* (PENN, 1980; RODRIGUEZ, 1981). Although breeding occur year-round in the study area, ripe females were most abundant in May (autumn) and September (late winter-early spring). So, we can infer that in 2004 the autumn spawning was the most important to the local stock maintenance. In Argentina and southern Brazil, the most representative cohort is resulting from the spring spawning (PETRIELLA and BRIDI, 1992; DUMONT, 2003). These differences could be related to environmental conditions, as already described above.

Shrimps are not long lived crustaceans and the short life spans imply high mortalities rates. Natural mortality could be varying between sexes (CHA *et al*., 2002) and the faster growth resulting in higher mesh size selection. Thus, this could explain the differences in *Z* values between males (2.88) and females (1.88). RUFFINO (1991), investigating the *A. longinaris* population dynamic in southern Brazil, presented the same *Z* values recorded in the present study for males and females. Meanwhile, DUMONT (2003), which also worked in southern Brazil, recorded higher values (Z = 6.48 and 6.36 and M = 3.48 and

4.47 for males and females, respectively). These differences can be related to temporal variations between the authors' studies, but differences in the methodological procedures can not be discharged.

Since the beginning of 2006, no specific management measures have been adopted for *A. longinaris* in Brazil. As the Brazilian shrimp fisheries have became a multi-species practice, *A. longinaris* is now indirectly protected by management measures for *X. kroyeri* and *Farfantepenaeus* species along their sympatric areas. Nowadays, the shrimp catches in south-eastern and southern Brazil are closed from March to May in areas where *Farfantepenaeus* species are largely present and from October to December in areas where *X. kroyeri* is dominant. In northern Rio de Janeiro State (21°18'S-22°30'S), the official closure of the shrimp fishery is based on *X. kroyeri*.

As the current management measure to the *A. longinaris* population maintenance along the Brazilian coast is indirect and, probably, ineffective, the local actions involving the community-based management, as well as educational campaigns, could be more suitable. These actions can include the alternative management related to the trawl-net fishery, as a better utilization of the shrimp fishery by-catch or even the shrimp exosqueleton, improving the fishermen profit and favouring the fishing effort reducing. Changes in the mesh size selection, especially in the net cod-end, could be another suggestion, but in this case a financial subsidy to the fishery community will be necessary. Finally, in order to propose a regional temporal change in the official closure of this shrimp fishery, a long time series study is needful.

CONCLUSIONS

In the study region, *A. longinaris* is the main fishery resource for the community located at Farol de São Thomé harbour. Although the actual fishery pressure is lower than the exploitation level which maximizes the relative yield-per-recruit, the middle-long term stock sustainability would warrants concern. As the present results include only one-year monthly samples, they have to be considered as preliminary and treated with caution to management proposes. A continuous and long term monitoring is require to confirm the present findings and to better understand the *A. longinaris* population dynamic and its fishery scenario in northern Rio de Janeiro State.

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