TEN-YEAR VARIATIONS IN POPULATION STRUCTURE OF PINK-SHRIMP IN A SOUTHWESTERN ATLANTIC BAY AFFECTED BY HIGHWAY CONSTRUCTION

Felipe Freitas Jr.[1]*, Hélio A. A., Fracasso*[2]*, Joaquim O. Branco*[1] *and Martin L. Christoffersen*[3*]

[1]Centro de Ciências Tecnológicas da Terra e do Mar, CTTMar - UNIVALI
(Caixa Postal 360, 88302-202 Santa Catarina, SC, Brasil)

[2]Universidade Federal de São Carlos-UFSCar
Departamento de Hidrobiologia
(13565-905 São Carlos, SP, Brasil)

[3]Universidade Federal da Paraíba
Departamento de Sistemática e Ecologia
(58059-900 João Pessoa, PB, Brasil)

*E-mail: mlchrist@dse.ufpb.br

ABSTRACT

Objectives: Population structures of *Farfantepenaeus brasiliensis* and *F. paulensis*, consisting mainly of juveniles, were evaluated during the construction of an expressway along a mangrove area. Estuarine regions in southern Brazil function as sites for reproduction, nursery and growth of a variety of organisms, including two of the most important species of shrimp for fisheries in the southwestern Atlantic. Shrimps were collected in Saco dos Limões creek, Baía-Sul, Florianópolis, State of Santa Catarina, four times a year, by day and night, between 1997 and 2006. Fluctuations in the abundances of shrimp appear to be related to their life cycles, with largest abundances in Summer and Spring, rather than to impacts promoted by dredging activities during the expressway construction.

RESUMO

Objetivos: A estrutura populacional de *Farfantepenaeus brasiliensis* e *F. paulensis*, consistindo principalmente de juvenis, foi avaliada durante a construção de uma via expressa ao longo de uma área de manguezais. Regiões estuarinas do sul do Brasil funcionam como locais de reprodução, berçários e de crescimento de uma variedade de organismos, incluindo duas das mais importantes espécies de camarões comerciais do Atlântico Sul Ocidental. Camarões foram coletados no Saco dos Limões, Baía Sul, Florianópolis, Estado de Santa Catarina, trimestralmente, de dia e de noite, entre 1997 e 2006. Flutuações em abundâncias de camarões podem estar relacionados aos seus ciclos de vida, com as maiores abundâncias no verão e primavera, ao invés de impactos promovidos pelas atividades de dragagem durante a construção da via expressa.

Descriptors: Shrimp, *Farfantepenaeus brasiliensis*, *Farfantepenaeus paulensis*, structure of populations, environmental impacts, southern Brazil.
Descritores: Camarões, *Farfantepenaeus brasiliensis*, *Farfantepenaeus paulensis*, estrutura populacional, impactos ambientais, sul do Brasil.

INTRODUCTION

Coastal environments such as creeks, bays and estuaries are notable for their high productivity, their importance as places for reproduction, as nurseries and for the growth of a variety of organisms, and for their susceptibility to human impact (SIGNORET, 1974; BRANCO; VERANI, 1998a; ALBERTONI et al., 1999, 2003). In these ecosystems, shrimps represent one of the most important fishery resources exploited both worldwide and along the coast of Brazil (D' INCAO, 1991; VALENTINI et al., 1991; ALBERTONI et al., 2003; CASTRO et al. 2005; GUSMÃO et al., 2005; LEITE; PETRERE, 2006a, 2006b; ROBERT et al., 2007).

In southeastern Brazil, shrimp fisheries are well developed, mainly as regards the stocks of the pink shrimp (*Farfantepenaeus brasiliensis* Latreille, 1970 and *F. paulensis* Pérez-Farfante, 1967) and the Atlantic seabob shrimp (*Xiphopenaeus kroyeri* Heller, 1862) (VALENTINI et al., 1991; D' INCAO et al., 2002).

In the Conceição Lagoon, located in Florianópolis, Santa Catarina, these pink shrimps represent an important fishery resource for traditional small-scale fishing (BRANCO; VERANI, 1998a, 1998b; LUCHMANN et al., 2008).

Recent studies on captures of the pink shrimp have demonstrated that these species are over-fished (MMA, 2004). This situation results from the increasing pressure of industrial fisheries on adult stocks in the ocean, from a disregard for minimum capture size in estuarine fisheries by artisanal fishers, and from the degradation of these nursery areas (VILLELA et al., 1997; D' INCAO et al., 2002; LEITE; PETRERE, 2006a, 2006b).

The reproduction of these shrimps occurs all year round in the open sea, between depths of from 40 to 100 meters. Post-larvae enter estuaries, where growth occurs, and pre-adults migrate from these nurseries to the reproductive zones in the sea (D' INCAO, 1991; BRANCO; VERANI, 1998a, 1998b).

Baía-Sul (South Bay), with an area of 181 km^2, is an important feature of the coastal region of the State of Santa Catarina, with mangroves, an extractivist marine reserve, lagoons and a large number of islands and beaches, used for leisure, tourism, fishing, the cultivation and commercialization of mollusks, thus representing a source of food and income for a significant proportion of the local population (RESGALLA JR., 2001; SOUZA-CONCEIÇÃO et al., 2005; SCHETTINI et al., 2000). However, this ecosystem is suffering serious anthropic impact resulting from domestic effluents and dredging activities (RESGALLA JR., 2001). The government of the State of Santa Catarina extracted about $8.5x10^6$ m^3 of sand during the period from 1995 to 1997 from a bank located in the center of this creek, in order to build an embankment of 15.9 km that culminated in the construction of the southern expressway connecting Santa Catarina with the continent.

According to Von Dolah et al. (1984) and Newell et al. (2003; 2004), macrocrustaceans are usually only partially affected in areas subject to dredging, because their mobility permits them to flee the impacted areas, while the infauna composed of polychaetes, oligochaetes, mollusks and small crustaceans is usually most affected.

Considering the impact of the construction of this public expressway in Saco dos Limões creek (Baía-Sul), the aim of this paper was to analyze the population structure of *F. brasiliensis* and *F. paulensis*, to monitor the life cycles of these species, and to ascertain whether their abundance and population structures are stable over the years.

Materials and Methods

Saco dos Limões creek is located in Baía-Sul (27º36' - 27º39'S and 48º33'- 48º31'W) (Fig. 1). The bottom is composed of sand-mud mixed with biodetritic material, the creek having shallow waters of high salinity; the local hydrodynamics are controlled by the tidal regime and the prevailing southerly and northeasterly winds (RESGALLA JR., 2001; SOUZA-CONCEIÇÃO et al., 2005; SCHETTINI et al., 2000).

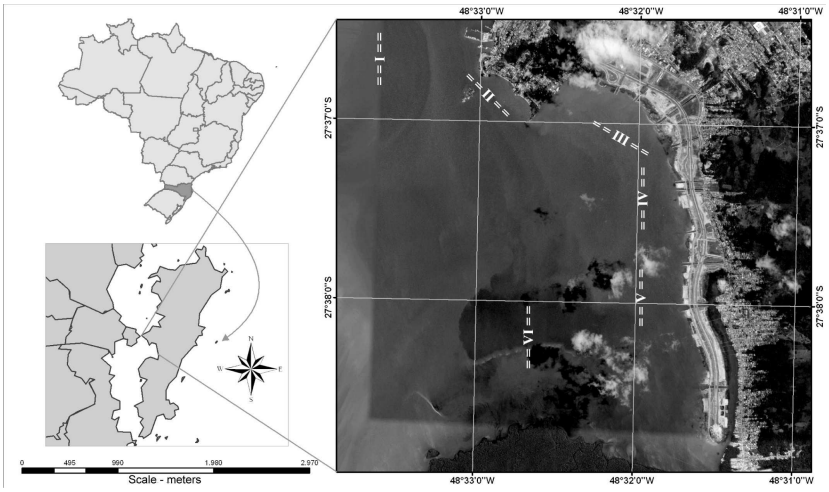

Fig. 1. Map of sampling sites. Upper left, Brazil, with the State of Santa Catarina enhanced; lower left, close-up of the municipality of Florianópolis, including the Island of Santa Catarina, which delimits two bays between the island and the continent, Baía-Norte (North Bay) and Baía-Sul (South Bay); right, close-up of upper right-hand corner of Baía-Sul (Saco dos Limões creek), showing the six collecting areas (I-VI) (Source: Geo-processing Lab - UNIVALI).

Shrimps were collected in six areas in the creek (Fig. 1). These areas were established along the creek in order to take a representative sample of the entire area in terms of depth, freshwater drainage, and dredging activities. These areas are described in Table 1. Sampling was done every three months, during the day and at night, over the period from 1997 to 2006 (excepting 1998 and 1999). Specimens were captured with two double rigged trawling nets, with 7.5 m total length and 5.5 m wide. The net mesh was 3 cm in the body of the nets and 2 cm in the collecting sac. The nets were pulled by a whaler for 10 minutes at a mean velocity of 2.0 knots. Specimens from both nets were pooled (we assumed that a single collecting device was used), providing the total number of individuals collected during 10 mins in each sub-area.

Table 1. Area descriptions of samplings during years 1997-2006, adapted from Souza-Conceição et al. (2005).

Area	Depth	Characters
# I	2 to 8 meters	In this area an increase in salinity is observed due to sea water circulation.
# II	2 to 4 meters	Presents greater exposure to weather, and has high salinity due to sea water circulation.
# III	2 meters	Area protected from the wind, with great influence of continental flow from galleries and rivers.
# IV	2 meters	The flow of surface water from small rivers and galleries has great influence on salinity and nutrient viability.
# V	2 meters	Area with greater influence of Tavares river discharge, with low salinity, high turbidity and nutrient concentration.
# VI	2 to 8 meters	Area with maritime conditions and greater depths, where the extraction of sediments for the expressway construction took place.

No subsamples were obtained. This resulted in a total of 384 samples (6 areas x twice a day x 4 times a year x 8 years). However, these data lack the randomness necessary to detect statistical differences due to specific variables f, 1984; COURTEMANCH, 1994; NORRIS, 1995). Surface water salinities and temperatures were recorded for all the samples, in order to establish seasonal fluctuations for these parameters.

The shrimp species were identified in the laboratory (PÉREZ-FARFANTE, 1978), sex and maturation stage were registered (PÉREZ-FARFANTE, 1970) and total length (Lt) in centimeters was measured from tip of rostrum to end of telson. The biometry of *F. brasiliensis* was recorded as from 2001, while the biometry of *F. paulensis* covered the period from 1997 to 2006 (except for 2000).

The c^2 test, at 5% level of significance and n-1 degrees of freedom (n= 2), was applied to verify the possible difference between the sexual proportion by class of total length (VAZZOLER, 1996). The relation weight/total length was estimated for males and females (SANTOS, 1978).

The authors opted for one-way ANOVAS because of the lack of data for several days and nights, particularly for the initial study years from 1997 to 2001. The data from these years were obtained from tables containing only the total number of individuals per station (not discriminated by area and period of the day). It was impossible, for this reason, to calculate the mean abundance of shrimp for these years. We have thus only used the total number of shrimp in some of the figures.

The abundance of specimens per station, given by the total number of organisms captured over the two nets' 10 minutes of operation, by year and sampling station, as well as water temperature and salinity, were assessed by one-way ANOVA (ZAR, 1999), being tested for homogeneity of variance (Bartlett test) and normality (Kolmogorov-Smirnov proof).

When significant differences were found, the a posteriori contrast of means (Tukey-Kramer) test was applied to indicate which of them were significantly different.

RESULTS

Environmental Parameters

The mean surface water temperature presented a uniform pattern of seasonal fluctuation, not differing significantly either over the years ($F_{4\text{-}18}$ = 0.227; p> 0.05) or by collecting area ($F_{5\text{-}18}$ = 0.058; p >0.05). The highest mean values were registered in the summer months (26.87ºC) and the lowest in winter (22.83ºC) (Fig. 2). There were significant differences among stations ($F_{3\text{-}73}$ = 30.53; p <0.05) due to the lower winter temperatures.

The mean surface water salinity showed the same tendency as temperature to vary seasonally, without there being any significant difference between years ($F_{6\text{-}18}$ = 0.657; p> 0.05) or sampling areas ($F_{5\text{-}18}$ = 0.241; p> 0.05). The highest means occurred in summer (32.43%) and the lowest in autumn (27.00%) (Fig. 2). There were significant differences among stations ($F_{3\text{-}146}$ =10.11; p <0.05), with lower salinities during winter.

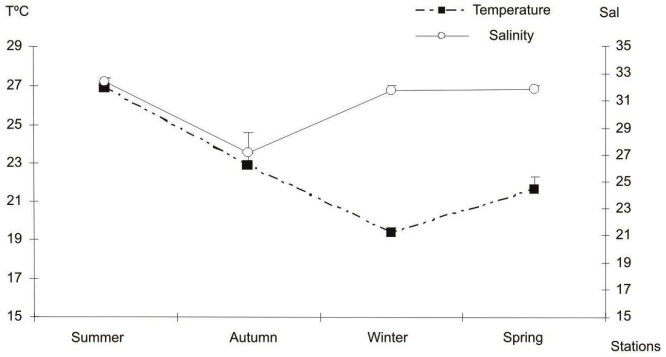

Fig. 2. Mean temporal variation of physico-chemical parameters of surface water in Saco dos Limões (South Bay) during the study period. (Vertical bar = standard error).

Abundance

The abundance of *F. brasiliensis* fluctuated over the years, with significantly smaller captures ($F_{3\text{-}26}$ = 3.714; p< 0.05) in 1997 (70), the highest ones occurring in 2006 (1826) (Fig. 3). In general the largest numbers occurred during the summer months, except for 2002, and the smallest ones in winter and autumn (Fig. 3). Although the largest mean abundances were found in areas VI and V during the night and in the summer and spring months, no significant differences were observed among the collecting sites whether during the day ($F_{5\text{-}18}$ = 1.479; p> 0.05) or at night ($F_{5\text{-}18}$ = 0.804; p> 0.05) (Fig. 4).

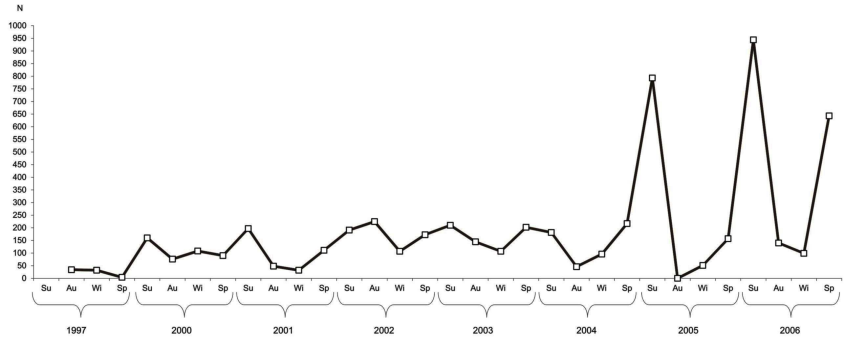

Fig. 3. Seasonal variation in abundance of *F. brasiliensis* captured in Baía-Sul (South Bay) 1997−2006.

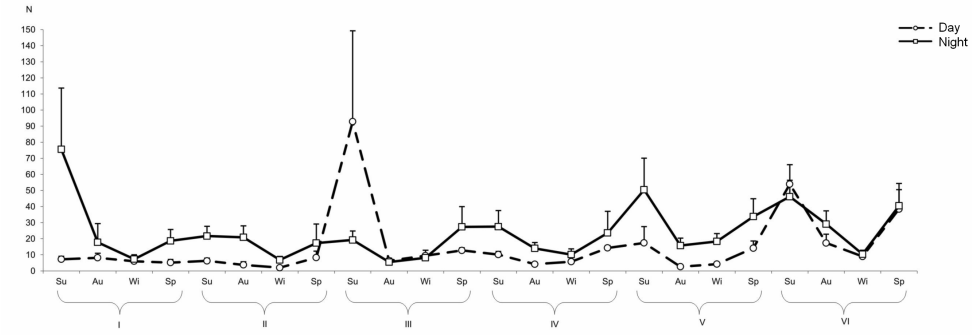

Fig. 4. Seasonal variation in abundance of *F. brasiliensis* captured in areas I, II, III, IV, V and VI, in Saco dos Limões region during the sampling period.

Only subsequently to 2001 have we been able to discriminate data per area and per period of day, these data being used to produce graphs of mean abundance per area and per period of the day. The number of *F. paulensis* oscillated over the years during the time span studied, with the highest occurrences of shrimp in 2003 and the smallest in 2001, although these values were not significantly statistically different ($F_{7\text{-}24} = 0.474$; $p > 0.05$) (Fig. 5). In general the largest captures were registered in the summer and spring months, and the smallest in winter (Fig. 5). In areas VI and V the best returns were obtained during winter-spring nights, and the smallest during the day in areas II and I; despite these variations, no significant differences were observed in the abundance of specimens captured during the day ($F_{5\text{-}18} = 2.583$; $p > 0.05$) or at night ($F_{5\text{-}18} = 2.451$; $p > 0.05$) among the collecting areas (Fig. 6).

Sexual Proportion

The distributions of relative frequencies by total length class of *F. brasiliensis* indicated that the males and females of the species had lengths, respectively, of from 4.0 to 15.0 cm and 3.0 to 16.0 cm (Fig. 7). In general, the females were significantly dominant from 3.0 to 6.0 cm and above 13.0 cm, an inversion in favor of males occurring in the class of 12.0 cm in 2004 and of 8.0 cm in 2005 (Fig. 7).

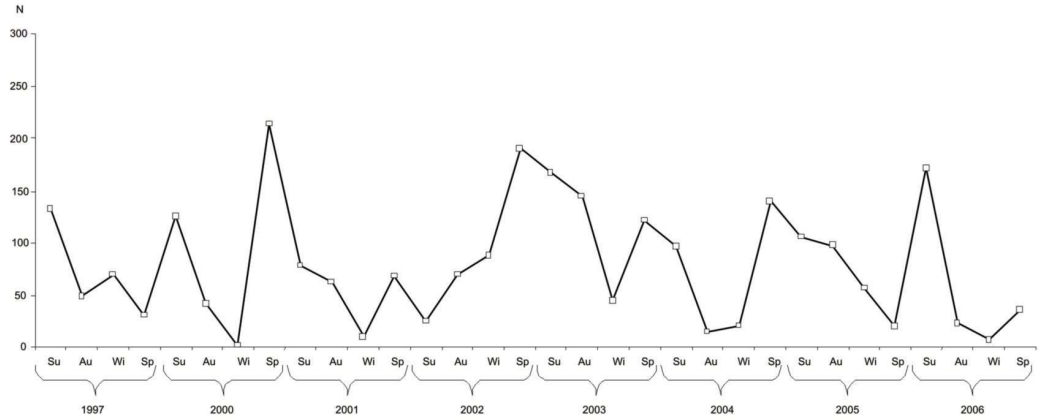

Fig. 5. Seasonal variation in the abundance of *F. paulensis* in Baía-Sul (South Bay) 1997−2006.

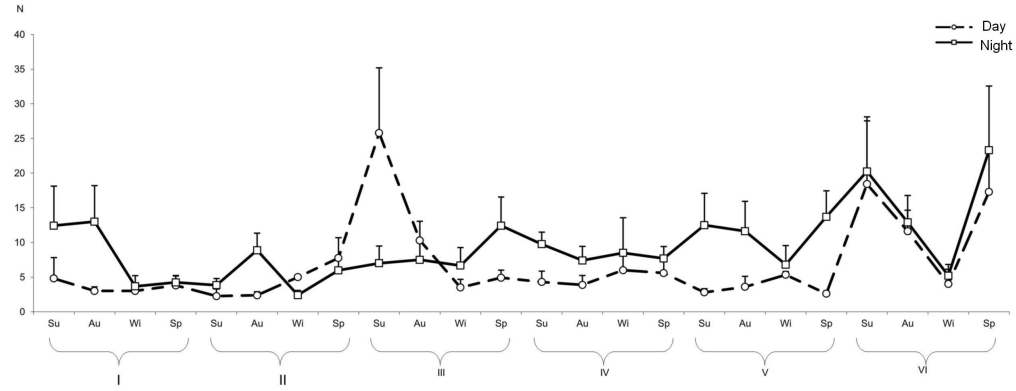

Fig. 6. Seasonal variation in abundance of *F. paulensis* captured in areas I, II, III, IV, V and VI, in Saco dos Limões region during collection period.

F. paulensis presented a length amplitude varying from 4.0 to 15.0 cm (males) and from 4.0 to 17.0 cm (females), with a dominance of these latter up to the 7.0 cm class and above 13.0 cm (except in 2001 and 2004), with an inversion in favor of males in 2001, in the 9.0, 10.0 and 13.0 cm classes (Fig. 8).

Length Structure

Figure 9 shows the distributions of annual frequencies of the length classes by sex in *F. brasiliensis*, during the period 2001 to 2006, revealing a similar distribution pattern over the years. Females in general presented total lengths superior to those of males, with increases and oscillations between 3.0 and 8.0 cm, while in males increases in abundance were registered in males between 4.0 and 8.0 cm (Fig. 9). Despite the oscillations between collecting years, most frequencies of shrimp capture occurred in the 7.0 and 8.0 cm classes (Fig. 9).

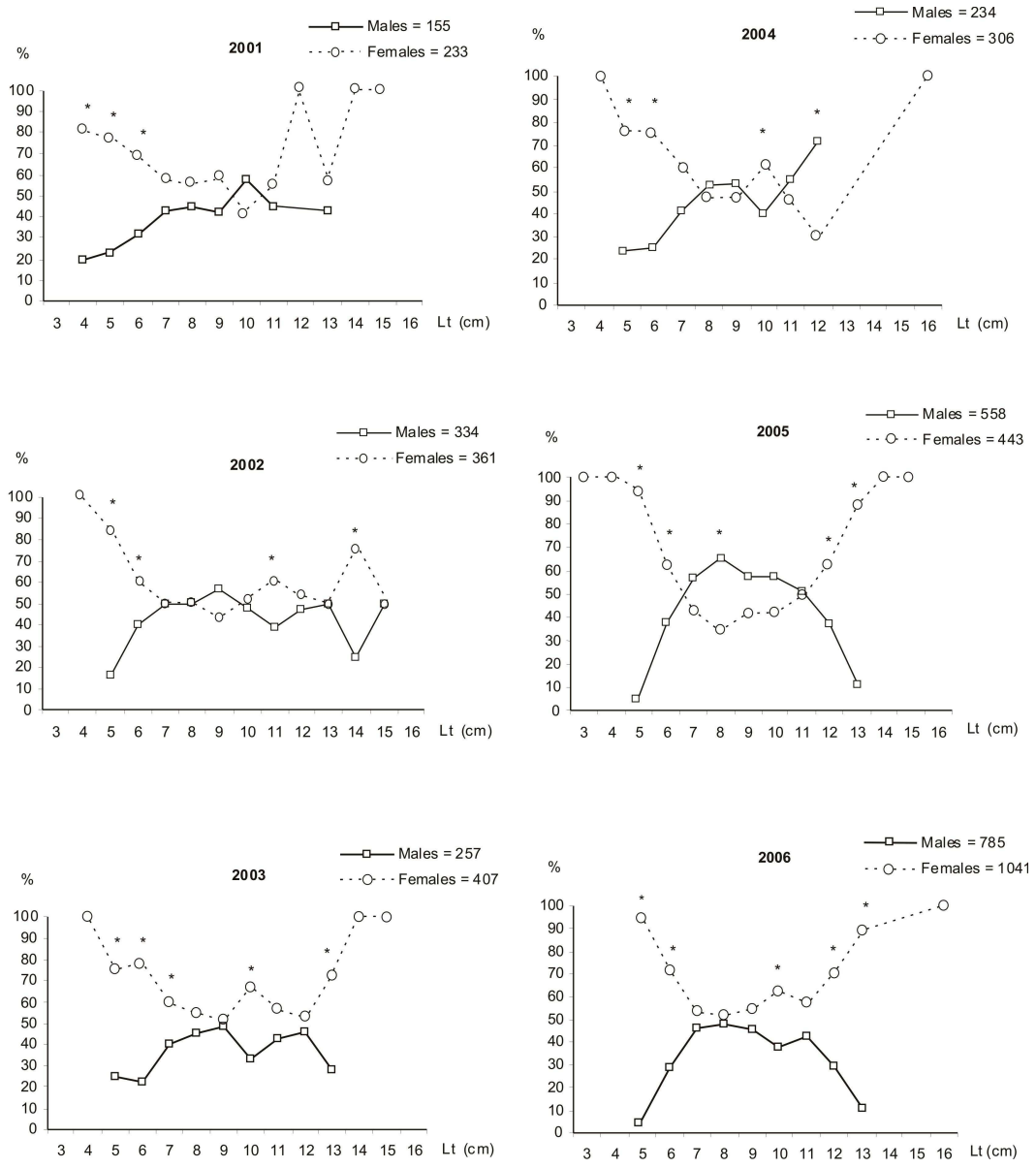

Fig. 7. Frequency of sexual occurrence (%) of *F. brasiliensis* by length class during 2001−2006. *****= significant difference of c2 test.

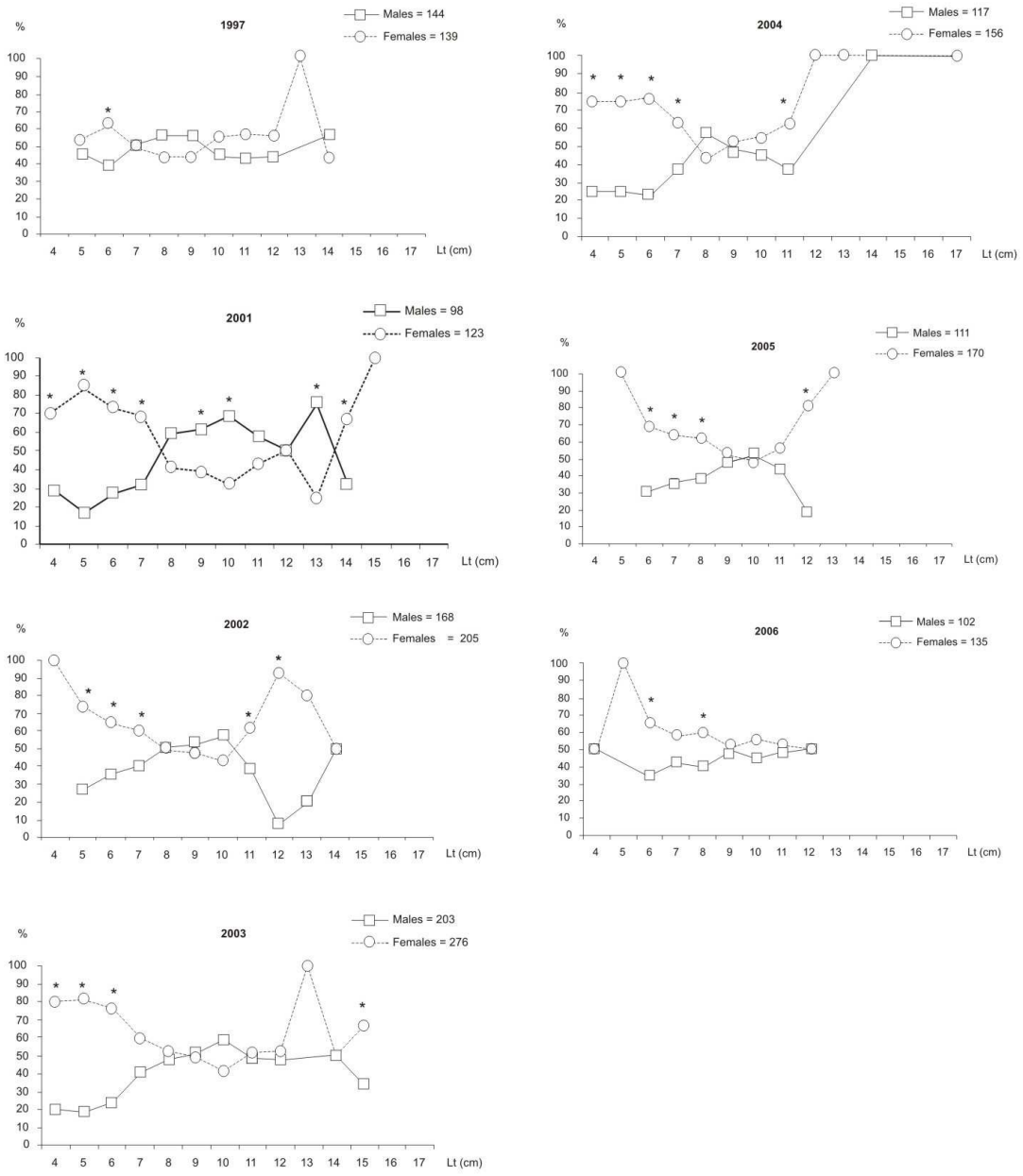

Fig. 8. Frequency of sexual occurrence (%) of *F. paulensis* by length class during 1997−2006. *****= significant difference of c2 test.

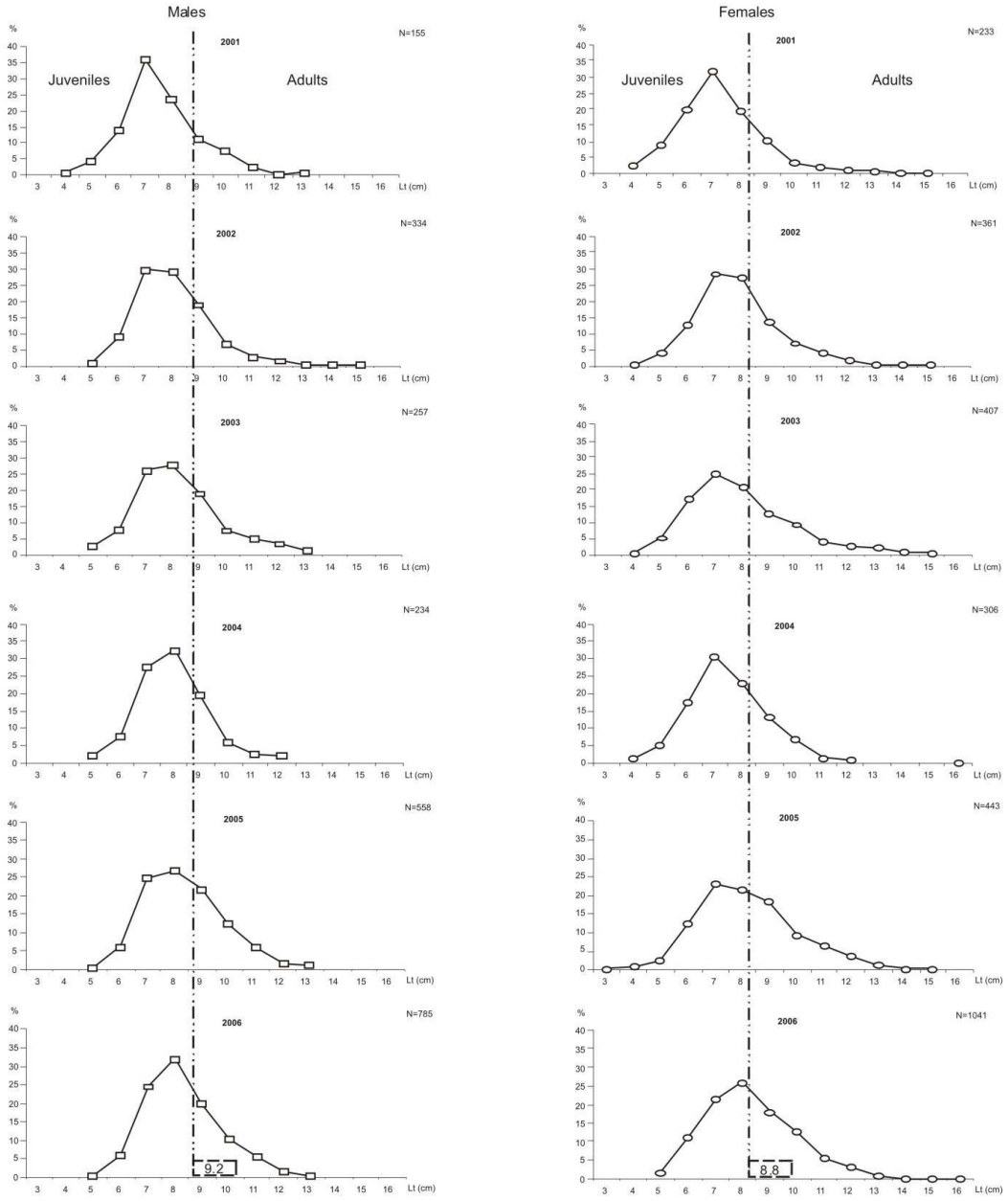

Fig. 9. Distribution of frequency by length class of *F. brasiliensis* during 2001−2006. Hatched line= L50 (BRANCO; VERANI, 1998a).

Analyzing the distributions of the lengths of males and females, together with the size of the first maturation stage, we verified that the population of *F. brasiliensis* was represented mainly by juveniles (72.2 - 87.6% of males and 68.6 -85.8% of females) (Fig. 10). Although present in all seasons of the year in the bay, the largest percentages of juveniles were registered in the spring and autumn months, with intensive individual growth continuing into the winter when the largest sizes were found (9.24 ± 1.58 cm and 9.12 ± 1.97 cm) (Fig. 10).

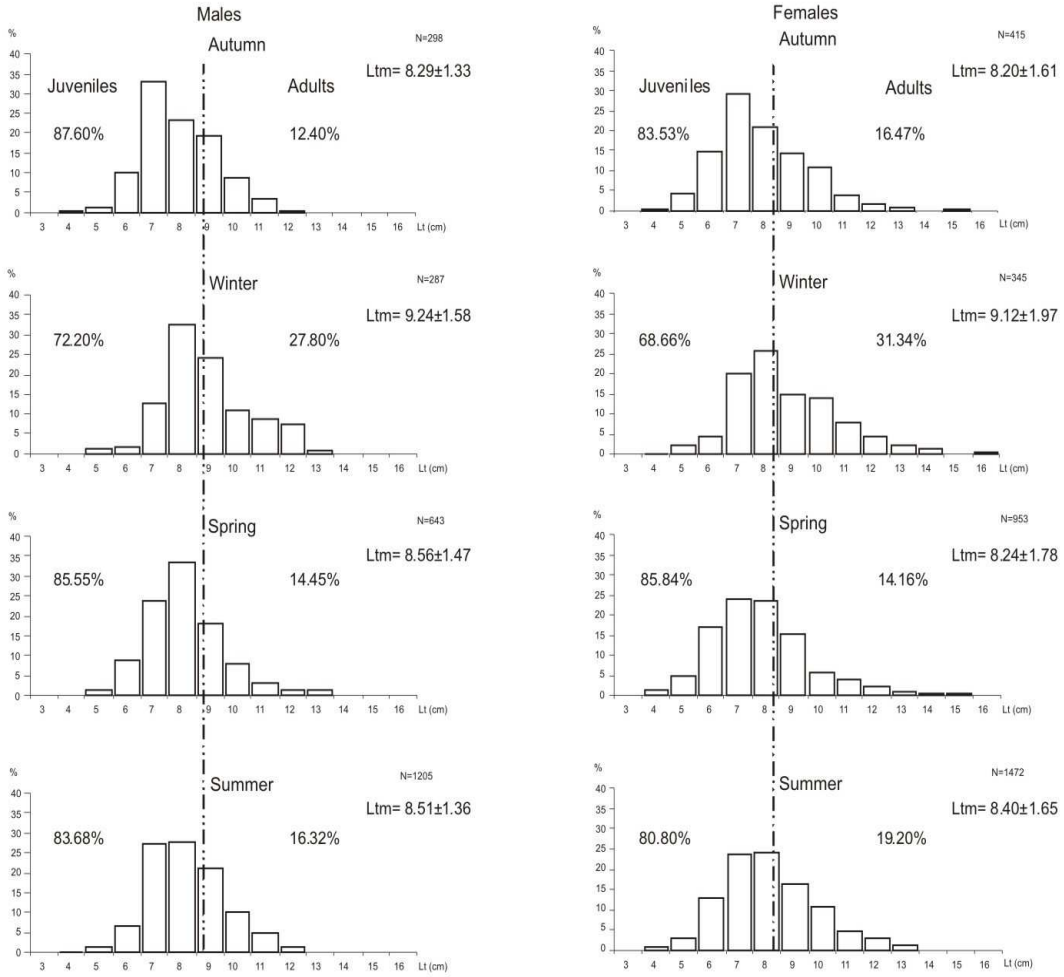

Fig. 10. Seasonal distribution of frequency by length class of *F. brasiliensis* during the years of collection in the Baía-Sul (South Bay) region. Hatched line= L50 (BRANCO; VERANI, 1998a).

The analysis of frequency distribution by length class revealed alterations in the structure and size of the population of *F. paulensis* over the years in which data were collected (Fig. 11). In 1997 the 8.0 to 10.0 cm classes contributed with the highest frequencies for both sexes, while from 2001 to 2004 the smaller specimens between 6.0 and 9.0 cm predominated in the samples. In 2005 and 2006, the largest captures were between 8.0 and 11.0 cm, with relatively smaller shrimps (Fig. 11).

Juveniles also predominated in the collections, mainly during the autumn months, while in winter the smallest occurrences and the largest mean lengths were found in the creek: 9.09 ± 1.61 cm (males) and 9.08 ± 1.80 cm (females) (Fig. 12).

Length/Weight Relationship

The equations obtained from the length/weight relationship and the determination coefficients indicate that the best associations of these variables were obtained for females, with a negative allometric growth of 2.9195 (*F. brasiliensis*) and 2.9794 (*F. paulensis*), while in males the lower r2 were observed, thus maintaining the negative allometry (Table 2).

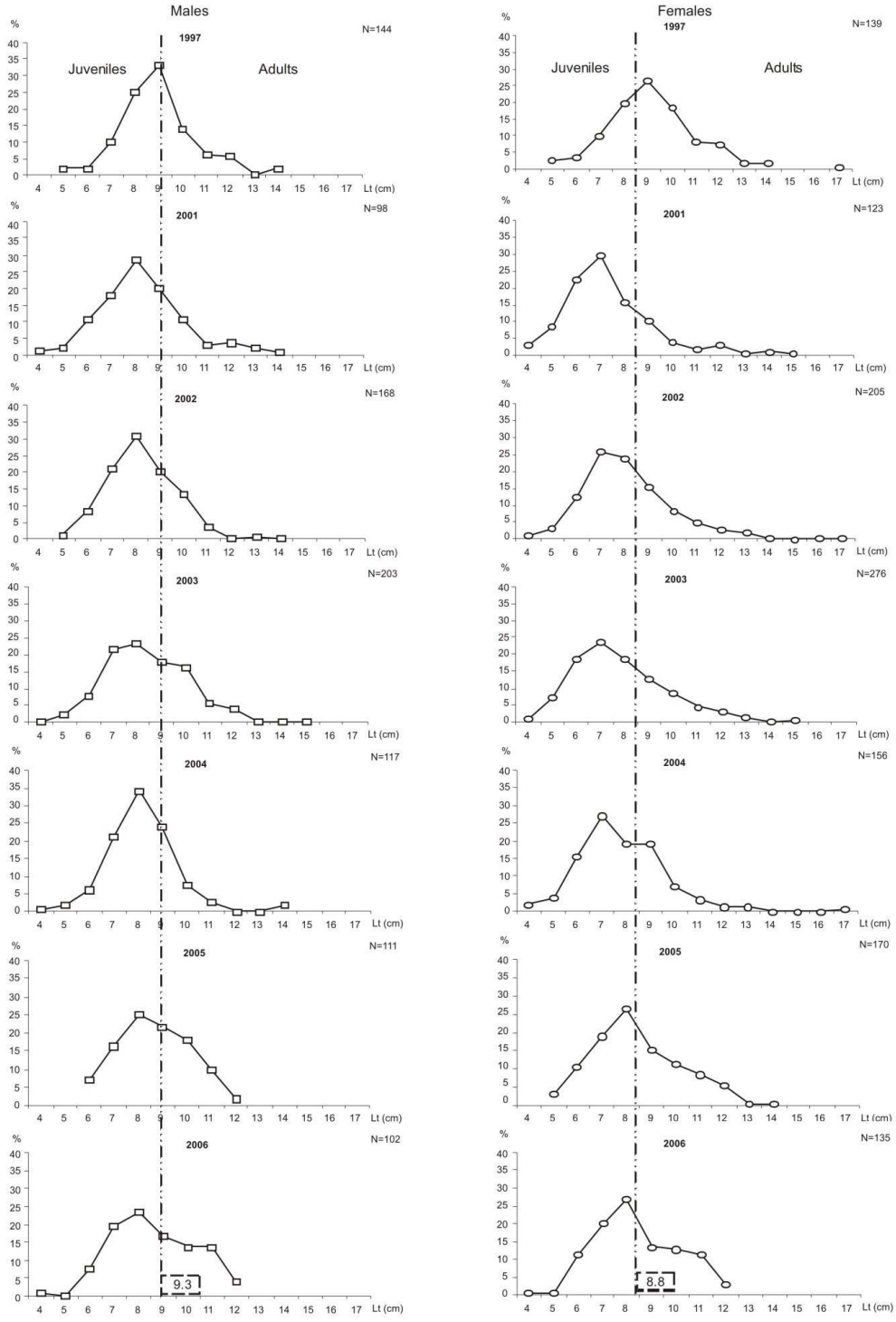

Fig. 11. Distribution of frequency by length class of *F. paulensis*, 1997−2006. Hatched line= L50 (BRANCO; VERANI, 1998b).

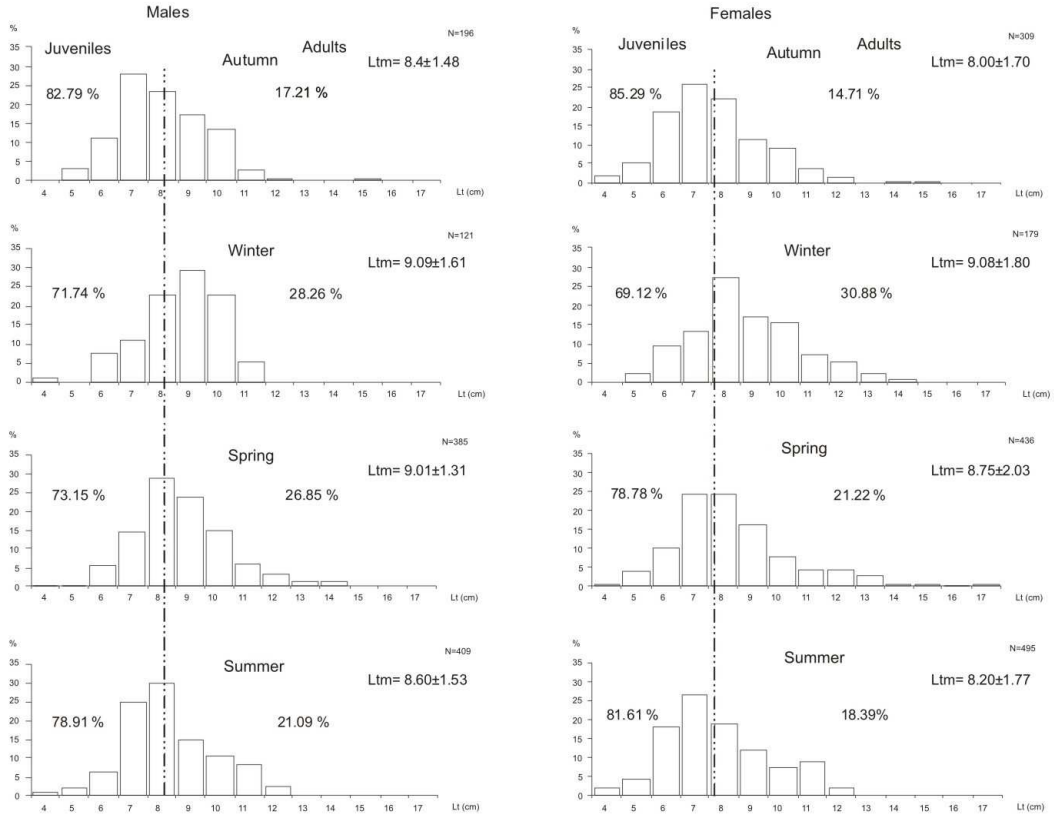

Fig. 12. Seasonal distribution of frequency by length class of *F. paulensis* during the years of collection in the Baía-Sul (South Bay) region. Hatched line= L50 (BRANCO; VERANI, 1998b).

Table 2. Length-weight relationship for males and females of *F. brasiliensis* and *F. paulensis* in Baía-Sul (South Bay) during the study period.

Species	Sex	Equation	r^2
F. brasiliensis	Males	$Wt = 0.01\ Lt^{2.8603}$	0.936
	Females	$Wt = 0.0088\ Lt^{2.9195}$	0.950
F. paulensis	Males	$Wt = 0.0088\ Lt^{2.9104}$	0.942
	Females	$Wt = 0.0077\ Lt^{2.9794}$	0.953

DISCUSSION

Seasonal fluctuations in the abundance of penaeid shrimps have been ascribed to water temperature and salinity oscillations (SIGNORET, 1974; PÉREZ-CASTAÑEDA; DEFEO, 2001; LOEBMANN; VIEIRA, 2006; LUCHMANN et al., 2008), texture of sediment (BRANFORD, 1981) and life cycle of species (MELLO, 1973; FORBES; CYRUS, 1991; NAKAGAKI et al., 1995; PÉREZ-CASTAÑEDA; DEFEO, 2005).

In the region of Saco dos Limões, *F. brasiliensis* and *F. paulensis* presented the same tendency to seasonal variation, with higher abundances during the summer months. This pattern appears to be associated with high water temperature, availability of food, in the form of particulate organic matter (BRANCO; MORITZ JR., 2001; PÉREZ-CASTAÑEDA; DEFEO, 2001), besides the contribution of external larvae in this period (RESGALLA JR., 2001). However, for Branco and Verani (1998b) and Luchmann et al. (2008), the autumn was responsible for the largest abundances of *F. paulensis* in the neighborhood of Lagoa da Conceição, indicating a strategy of temporal separation between the two species in these environments.

Females of *F. brasiliensis* and *F. paulensis* occurred in higher abundances and sizes than males, corroborating what had previously been registered for the southern and southeastern littoral (D' INCAO; CALAZANS, 1978; VILLELA et al., 1997; BRANCO; VERANI, 1998a, 1998b; LEITE; PETRERE, 2006a; ROBERT et al., 2007). These disparities between the sexes may be attributed to growth indices, mortality, longevity, differential migration of sexes and selectivity in fishery activities (D' INCAO, 1990; LINS-OLIVEIRA, 1996; ALBERTONI et al., 2003; PÉREZ-CASTAÑEDA; DEFEO, 2005; LEITE; PETRERE, 2006a, 2006b).

The length/weight relationship rate has been used to facilitate the estimation of the weight of a specimen, inferred from the knowledge of its length, and to determine the type of growth of the species, being regularly used in studies of population dynamics and evaluation of stocks (BRANCO et al., 2002), in which penaeids have a tendency to present differential allometric growth between the sexes (BRANCO, 2005). This pattern was found in populations of *F. brasiliensis* landed in the port of Santos (São Paulo) by Mello (1973) and Leite and Petrere (2006a) and in Lagoa da Conceição (BRANCO; VERANI, 1998a). However, for *F. paulensis* in Lagoa dos Patos it was positive (D' INCAO; CALAZANS, 1978) and in Lagoa da Conceição negative for both sexes (BRANCO; VERANI, 1998b). In the present study both species maintained the negative growth pattern, with a more intensive increment in size than in weight.

From the distribution of frequency by length class, it was possible to ascertain that the populations of *F. brasiliensis* and *F. paulensis* were represented, predominantly, by juveniles, reinforcing the importance of the area as a nursery and repository of pre-adults for the fisheries stock of areas in the open sea (CHAGAS-SOARES et al., 1995; BRANCO; VERANI, 1998a, 1998b). Yet some specimens may remain in the bay until they attain the age of 10 months (D' INCAO, 1991). Environmental alterations of the areas of growth may affect the size of adults (ALBERTONI et al., 2003). Thus, the biometric monitoring of shrimps is fundamental to determine possible changes in the structure of populations submitted to a significant impact (MOURA et al. 2003) such as the dredging undertaken in Saco dos Limões.

In the present study, a relatively stable length pattern was observed in the population of *F. brasiliensis* and alterations were observed in the structure of *F. paulensis*, with a reduction in the size of individuals. In 2005 and 2006, relatively smaller shrimps were captured (Fig. 1), correlating with the reduced occurrence of zoeae and organic matter.

The abundance of *F. brasiliensis* was significantly different as between the years of collection, with the lowest capture indices at the beginning of the sampling period. This fluctuation should possibly be associated with the instability due to the mechanical action of the collecting gear, either by blocking the gills with material in suspension, which occasions high mortality rates (BEMVENUTI et al., 2005), or by the reduced occurrence of zoeae and organic matter, limiting the primary productivity of the environment (RESGALLA JR., 2001), or even by the reduction of sessile prey of low locomotive potential, which are especially vulnerable to the collecting equipment (VON DOLAH et al., 1984; NEWELL et al., 2003, 2004). Despite this initial reduction, the abundance of *F. brasiliensis* recovered in the following years, the capture indices increasing from 2004 onwards.

The proximity of areas V and VI to the mangrove swamps on the Rio Tavares, as well as to the mouth of the Defuntos river, may have contributed to the input of food supplies under sheltered conditions. This may have provided a favorable environment for juvenile growth, reflecting the greater abundance recorded. Moreover, the higher rate of flow in area I (MOLLERI; BONETTI, 2005) was possibly related to the entry and exit of individuals from the Baía-Sul. A similar pattern was found by Branco and Verani (1998a) and Branco and Masunari (2000) for the crab and shrimp populations of the Lagoa da Conceição.

The extraction of sand has apparently had but slight impact on the biology of these two shrimps, but it is difficult to be categorical about this because there are no data prior to 1995 that could serve as control. Due to the high environmental variability in estuarine regions and bays, the fluctuations observed in this study may just as well be a result of the life cycle of these species (FORBES; CYRUS, 1991; BEMVENUTI et al., 2005; PÉREZ-CASTAÑEDA; DEFEO, 2005). The population dynamics in the post-impact period are stable in the long term (despite the natural short term variability) and pink-shrimp stocks do not seem to be declining. The implications for fisheries management are that even extensive bottom dredging operations may not significantly affect fishery stocks of commercial shrimp so long as the normal hydrodynamics of the estuaries concerned are not affected.

CONCLUSIONS

F. brasiliensis population abundance was significantly smaller in 1997 due to environment instability caused by the end of dredging activity. However, the same trend in captures was observed from 1998 to 2003, showing increases in abundance only after 2004. *F. paulensis* showed abrupt variations over the years studied, but without any significant

statistical differences among them. Regarding length, *F. brasiliensis* showed little change over the years. On the other hand, *F. paulensis* became smaller over the sampling period.

The expressway construction has not apparently affected either the hydrodynamics of Saco dos Limões creek or, as a result, the free exchange between open sea adult and estuarine juvenile populations. Neither has the dredging or the highway construction significantly affected the population structure of the two commercial species of pink shrimp monitored during the decade in which the expressway was being constructed, at least not in the long run. The seasonal changes in stock sizes do not apparently exceed the normal fluctuations observed in estuarine regions.

Apparently physical disturbances of estuarine environments promote less damage to shrimp stocks than do other potential anthropic influences, such as overfishing pressure on adults and juveniles and excessive discharges of domestic effluents. Excessive fishing and intensive chemical and organic pollution may have more catastrophic consequences for the conservation of commercial shrimp than the temporary dredging and localized damming resulting from the coastal expressway construction which occurred at the beginning of the period of this study.

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