# Population structure of the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) (Crustacea: Penaeoidea) in the littoral of São Paulo, Brazil*

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SUMMARY: The population structure of the penaeidean shrimp *Xyphopenaeus kroyeri* was studied in Ubatuba Bay, Ubatuba, São Paulo, Brazil. The period and site of juvenile recruitment were monitored using a monthly sampling design with eight fixed areas (transects) from September 1995 to August 1996. The population structure was assessed using size frequency distributions (based on carapace length) for each month and sampling area. Females were significantly larger than males, suggesting a differential growth between sexes. The very low occurrence of large adults in the Bay can be related to offshore migration for reproduction. Recruitment occurred throughout the year, with a peak during the summer, when the highest recruitment rates were obtained along inshore transects. The present investigation revealed valuable information on the biology of the species mainly in the study region, which is considered a nursery ground for juveniles of *X. kroyeri*. The species showed an important variation from the typical life cycle that it is assumed to hold over its entire range and *X. kroyeri* should be classified as having a life cycle different from that proposed previously in the literature, i.e. the juveniles prefer inshore areas instead of estuaries. Some suggestions for the seabob fishery management are proposed as an alternative for minimising the impact during the harvest period and adjusting the protection schedule.

*Key words*: population structure, recruitment, *Xiphopenaeus kroyeri*, Penaeoidea.

RESUMEN: ESTRUCTURA DE LA POBLACIÓN DEL CAMARÓN SEABOB *XIPHOPENAEUS KROYERI* (HELLER, 1862) (CRUSTACEA, PENAEOIDEA) EN EL LITORAL DE SÃO PAULO, BRASIL. – La estructura de una población del camarón *Xiphopenaeus kroyeri* en la Bahía de Ubatuba, Ubatuba, en Brasil, fue estudiada, con énfasis en el periodo y área de reclutamiento de juveniles. La estructura de la población fue monitoreada a través de muestreos mensuales en ocho áreas diferentes (transectos) de la Bahía, entre septiembre de 1995 y agosto de 1996. La estructura de la población fue determinada por medio de la distribución de las frecuencias de talla (basada en la longitud del cefalotórax) para cada mes y área muestreadas. Las hembras alcanzaron mayores tallas que los machos sugiriendo un crecimiento diferencial entre sexos. La ocurrencia muy baja de adultos de mayor tamaño en la bahía se puede relacionar con la migración para la reproducción mar adentro. El reclutamiento ocurrió preferentemente en los transectos costeros y en casi todos los meses, con un pico durante el verano. Los resultados muestran que la Bahía de Ubatuba puede ser considerada como una zona de cría de los juveniles de *Xiphopenaeus kroyeri*. Se propone un nuevo tipo de ciclo vital para esta especie, en el que, a diferencia de lo propuesto en trabajos anteriores, los juveniles prefieren las áreas costeras en lugar de las estuáricas. Se hacen algunas sugerencias para la actividad pesquera sobre esta especie de camarón a fin de reducir al mínimo el impacto durante el período de pesca.

*Palabras clave*: estructura de poblaciones, reclutamiento, *Xiphopenaeus kroyeri*, Penaeoidea.

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## INTRODUCTION

The shrimp *Xiphopenaeus kroyeri* (Heller, 1862) is widely distributed in the western Atlantic from Cape Hatteras, the Gulf of Mexico and the Caribbean Sea to the Rio Grande do Sul State in southern Brazil (Williams, 1984; Costa *et al.*, 2000). This species, popularly known as "camarão sete-barbas" in Brazilian waters, and as seabob around the world, is the most exploited benthic shrimp species from the coast of São Paulo State (Rodrigues *et al.,* 1993; Nakagaki and Negreiros-Fransozo, 1998), mainly because it is destined for human consumption. In coastal fisheries, this species has been subjected to intensive trawling, accounting for approximately 80% of the penaeid shrimp caught during most seasons (Mantelatto *et al.*, 1999). *Xiphopenaeus kroyeri* represents the second most important fishery resource along the São Paulo coast after pink-shrimps *Farfantepenaeus brasiliensis* (Latreille, 1817) and *Farfantepenaeus paulensis* (Pérez Farfante, 1967) (D'Incao, 1991). Furthermore, it plays an important ecological role in trophic relationships, contributing to the stability of benthic communities (Pires, 1992).

According to Nakagaki *et al.* (1995), Fransozo *et al.* (2002) and Costa (2002), *X. kroyeri* is the most abundant penaeoidean in the Ubatuba region. However, little is known about the population biology of this species, in particular juvenile recruitment (Mota-Alves and Rodrigues, 1977; Rodrigues *et al.*, 1993; Branco *et al.*, 1994; Nakagaki and Negreiros-Fransozo, 1998; Fransozo *et al.*, 2000; Costa, 2002). Currently, the legal shrimp fishing protection season in the southern region of Brazil has been occurring from February to May. The law is based on data concerning the recruitment period of the pink-shrimp juveniles, i.e. *F. brasiliensis* and *F. paulensis* (D'Incao, 1991). Considering the paucity of detailed information on the population biology of *X. kroyeri* (i.e. the period and pattern of juvenile recruitment in this region), it is necessary to improve our knowledge on its population dynamics in order to contribute to a more rational and efficient fishery management and promote suitable protection periods.

As far as we know, there are only two published studies that provide information on the population dynamics of *X. kroyeri* along the northern coast of São Paulo State. The first was provided by Nakagaki and Negreiros-Fransozo (1998), who studied a population of *X. kroyeri* in Ubatuba Bay, although they only sampled in two central areas at 7.5 and 16.5 m depths, and did not propose any recruitment model. The second one is that carried out in Fortaleza Bay in the Ubatuba region by Fransozo *et al.* (2000), who found peaks of recruitment of *X. kroyeri* in areas close to the coast characterised by very fine sediment in December, January and March.

The present study examines the distribution and spatio-temporal population structure of *X. kroyeri* in Ubatuba Bay, São Paulo State, Brazil, with emphasis on juvenile recruitment.

## MATERIAL AND METHODS

Located along the northern coastline of the State of São Paulo, the Ubatuba region is an important area for crustacean research (Mantelatto and Fransozo, 2000). The region is unique when compared to other areas along the Brazilian southern coast. This coastal area is contained within a system of inlets, bays, canals, bayous, and rivers bordered by mangroves which together form estuaries rich in nutrients that are favourable for the establishment and development of the marine fauna. In addition, Ubatuba Bay is fairly pristine and used as a standard for comparison with other marine habitats that are strongly influenced by humans (Mantelatto and Fransozo, 1999). According to Castro-Filho *et al.* (1987), the region is strongly influenced by three water masses: South Atlantic Central Water

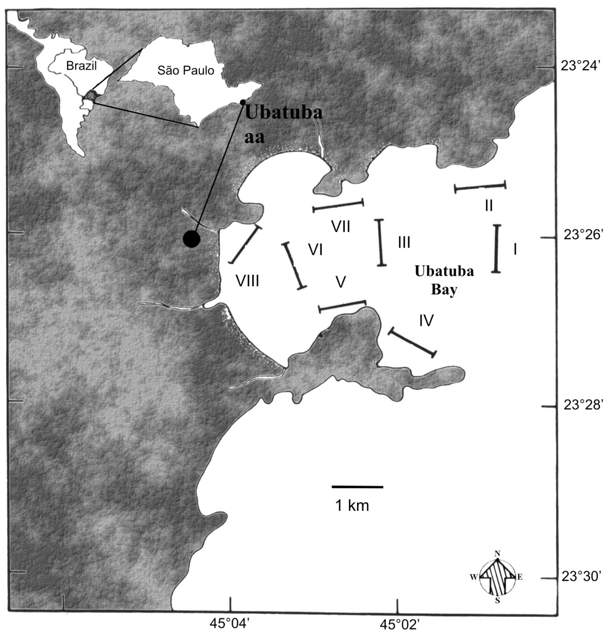


FIG. 1. – Map indicating Ubatuba Bay, Ubatuba (São Paulo State), Brazil, and the location of subareas of collection.

TABLE 1. – Average values and standard deviation of the environmental factors monthly recorded in Ubatuba Bay from September 1995 to August 1996, sampled in each transect.

| Transects | Salinity | Dissolved Oxygen (g/ml) | Depth (m) | Organic Matter content (%) |
|---|---|---|---|---|
| I | 33.7 ± 1.5 | 4.9 ± 0.4 | 16.6 ± 0,9 | 5.5 ± 5.1 |
| II | 33.3 ± 1.7 | 5.2 ± 0.8 | 11.4 ± 0.6 | 5.3 ± 3.0 |
| III | 33.4 ± 1.7 | 4.6 ± 0.8 | 10.7 ± 0.7 | 13.2 ± 1.5 |
| IV | 33.2 ± 1.8 | 5.2 ± 0.4 | 9.5 ± 1.0 | 18.5 ± 9.6 |
| V | 33.1 ± 2.0 | 5.5 ± 0.5 | 7.9 ± 1.1 | 20.3 ± 6.6 |
| VI | 33.1 ± 1.8 | 5.2 ± 0.6 | 7.6 ± 0.5 | 14.5 ± 2.2 |
| VII | 32.9 ± 1.9 | 4.8 ± 0.8 | 7.3 ± 0.4 | 6.1 ± 2.4 |
| VIII | 32.4 ± 2.0 | 5.4 ± 0.6 | 3.1 ± 0.3 | 6.9 ± 1.5 |

(SACW) with low temperature and salinity (T < 20ºC, S < 36), Tropical Water (TW) with high temperature and salinity (T > 20ºC, S > 36), and Coastal Water (CW) with high temperature and low salinity (T > 20ºC, S < 36). These water masses interact to modify the temperature, salinity and nourishment condition during the seasons, especially during winter and summer. According to Pires (1992), CW and SACW interact, giving rise to a mixing zone that is variable in time and space according to the SACW penetration intensity. The SACW mass has a strong influence on near bottom sea temperature, especially on the inner shelf during the summer.

Shrimps were collected monthly from September 1995 to August 1996 at Ubatuba Bay, Ubatuba, São Paulo State (Fig. 1). In this Bay, eight 1-km transects were delimited and trawled over a 30-min period using double rig nets (3.5 m wide mouth, 12 mm mesh size in the body and 10 mm mesh size in the cod end). Due to the high number of individuals captured in each trawl, a 250g subsample was separated randomly for examination: sex and carapace length (CL, excluding the rostrum) were determined for every individual, and specimens equal to or smaller than 13.7 mm CL were considered juveniles based on the size at which half of population is physiologically mature ($CL_{50\%}$), as pointed out by Rodrigues *et al*. (1993).

The abiotic factors were obtained every month for each transect. Details of the methodology and the results obtained for the abiotic factors in the Ubatuba Bay during the same period of study can be obtained in Mantelatto and Fransozo (1999). The mean annual values of abiotic factors obtained along the transects sampled in Ubatuba Bay are presented in Table 1. The granulometric fractions in the sampled areas were predominantly fine sand and very fine sand. The seasonal mean values of bottom seawater temperature and salinity are presented in Figure 2.

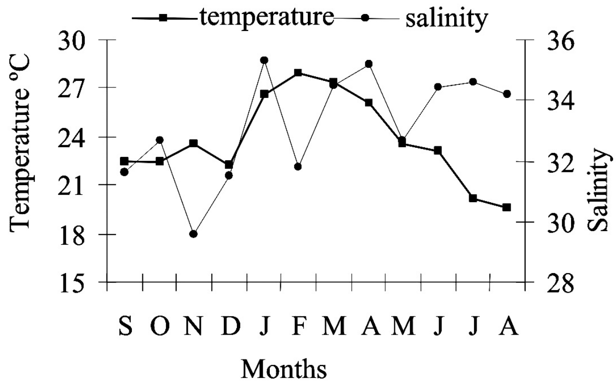


FIG. 2. – Mean values of temperature (ºC) and salinity of bottom water recorded monthly from September 1995 to August 1996 in Ubatuba Bay.

Proportions of juveniles and adults during the months and transects were compared statistically using Goodman's test (Curi and Moraes, 1981), complemented by Tukey's test ($p < 0.05$). Spearman's correlation was calculated to test whether a correlation between the absolute abundance of the juveniles and mean values of depth, organic matter content of substrate, temperature and salinity existed. The mean size of individuals of both sexes was compared by Student's t-test. All used tests are in accordance with the methods described by Zar (1996).

## RESULTS

A total of 19065 specimens were analysed, 8833 (46.33%) being males, 10232 (53.37%) females,

TABLE 2. – Absolute and relative size frequency distribution of *X. kroyeri* collected in Ubatuba Bay, during September 1995 and August 1996.

| Number Classes | Size Classes mm CL | Total | | | |
|---|---|---|---|---|---|
| | | Juvenile | | Adult | |
| | | N | % | N | % |
| 1 | 3.8 - 6.0 | 17 | 0.09 | – | – |
| 2 | 6.0 - 8.2 | 292 | 1.54 | – | – |
| 3 | 8.2 - 10.4 | 1242 | 6.51 | – | – |
| 4 | 10.4 - 12.6 | 2532 | 13.28 | – | – |
| 5 | 12.6 - 14.8 | 1862 | 9.76 | 1900 | 9.96 |
| 6 | 14.8 - 17.0 | – | – | 4289 | 22.50 |
| 7 | 17.0 - 19.2 | – | – | 3784 | 19.85 |
| 8 | 19.2 - 21.4 | – | – | 1881 | 9.86 |
| 9 | 21.4 - 23.6 | – | – | 843 | 4.42 |
| 10 | 23.6 - 25.8 | – | – | 317 | 1.66 |
| 11 | 25.8 - 28.0 | – | – | 77 | 0.41 |
| 12 | 28.0 - 30.2 | – | – | 22 | 0.12 |
| 13 | 30.2 - 32.4 | – | – | 7 | 0.04 |
| 14 | 32.4 - 34.6 | – | – | – | – |
| 15 | 34.6 - 36.8 | – | – | 1 | 0.01 |
| Total | | 5945 | 31.18 | 13120 | 68.52 |

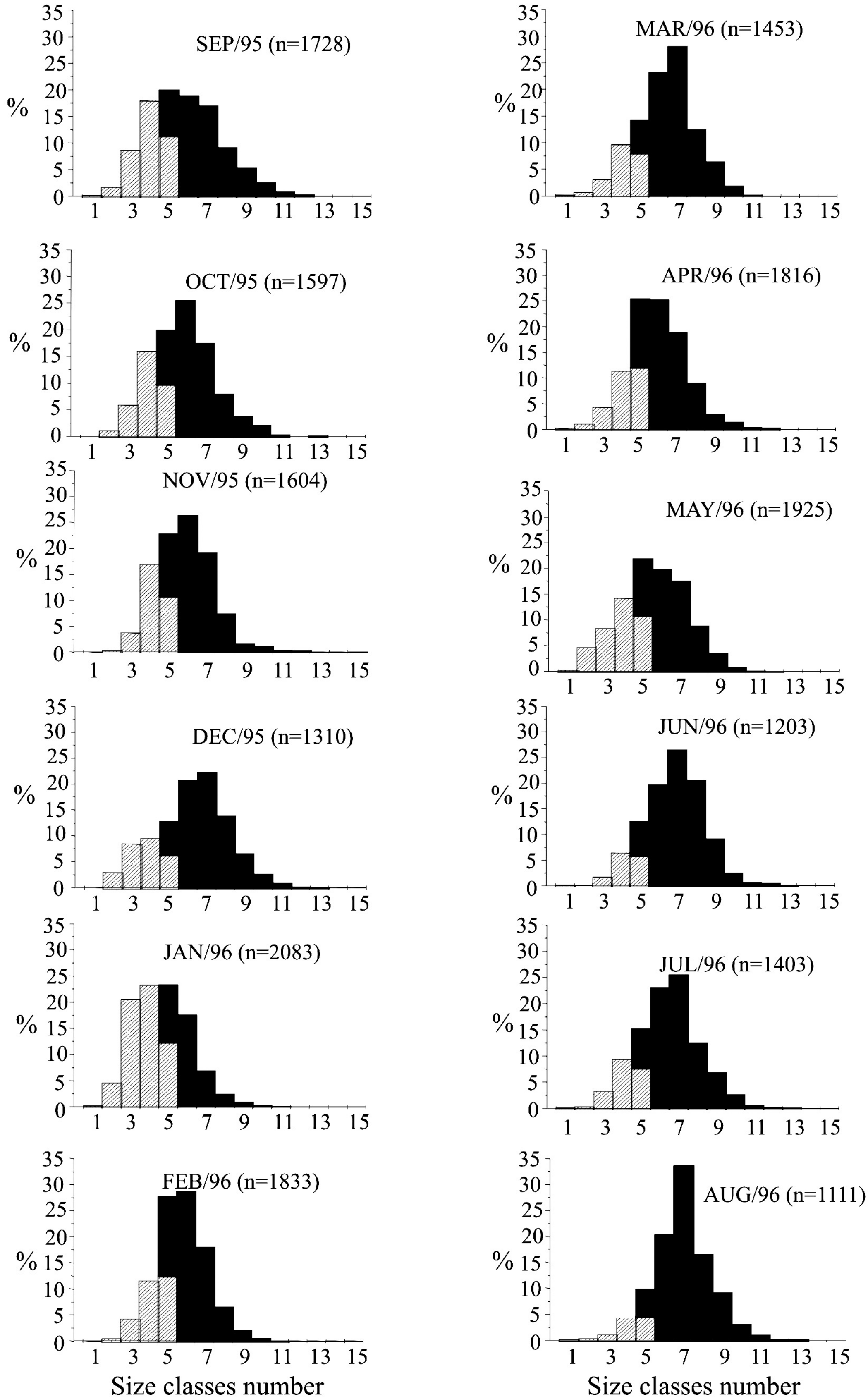


FIG. 3. – Monthly size frequency distribution (carapace length) of juveniles (hatched bars) and adults (solid bars) collected in Ubatuba Bay from September 1995 to August 1996.

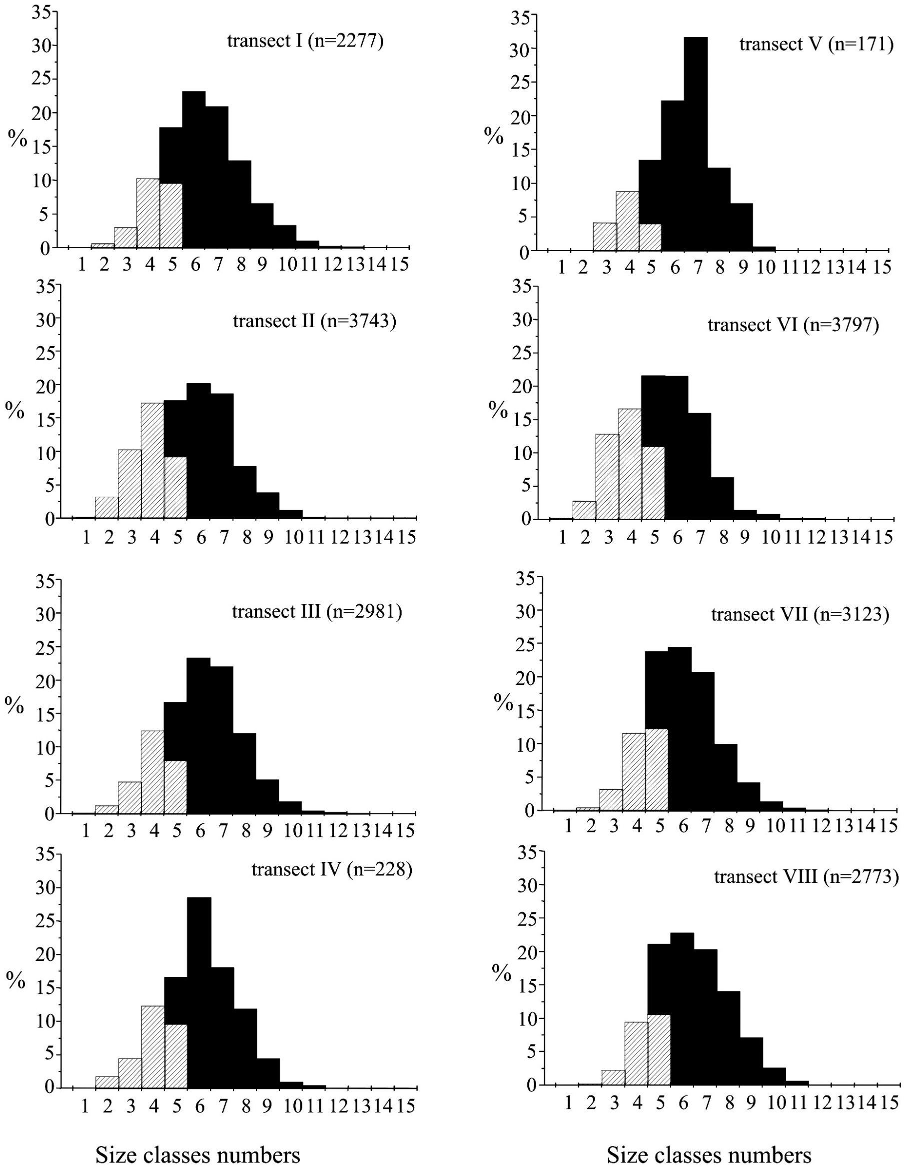


FIG. 4. – Spatial size frequency distribution (carapace length) of juveniles (hatched bars) and adults (solid bars) collected in the subareas of Ubatuba Bay from September 1995 to August 1996.

and 5945 (31.18%) juveniles. The mean size for males was 15.2 ± 3.0 mm CL, ranging from 6.3 to 28.7 mm; for females 16.1 ± 4.3 mm CL, ranging from 4.6 to 35.1 mm; and for juveniles 11.6 ± 1.8 mm CL, ranging from 4.6 to 13.7 mm. The mean size of females was significantly larger than the mean size of males ($p < 0.05$).

Seasonal and spatial size frequency distributions for *X. kroyeri* are presented in Table 2 and Figures 3 and 4. The highest percentage of juveniles in relation to adults occurred in early summer (61% in January), with significant differences (Goodman test, $p < 0.05$) in relation to other months. Secondary peaks of juveniles (i.e. values between 30 and 40%) were recorded in spring (September and November) and autumn (May). The lowest numbers of juveniles were significantly registered in winter (from June to August) (Table 3), with some of the lowest bottom temperatures (Fig. 2). There was no positive correlation between number of juveniles and temperature ($C_s = 0.51$; $p > 0.05$), salinity ($C_s = -0.18$; $p > 0.05$), depth ($C_s = 0.07$; $p > 0.05$), and sediment organic matter content ($C_s = -0.19$; $p > 0.05$).

There was a continuous recruitment of juveniles during the study period, with peaks during all summer months (36%), and with a lower percentage of occurrence during winter (9.6%). The frequency of juveniles ranged between 28 and 26% during spring and autumn respectively. Recruitment occurred in all transects sampled, with a higher and most signif-

TABLE 3. – Comparative analysis of the percentages of juveniles and adults monthly sampled between September 1995 and August 1996 in the Ubatuba Bay (values with at least one same letter did not differ significantly; lower case letters correspond to comparison of juveniles and adults over all months sampled; upper case letters correspond to the comparison between juveniles and adults during the same month sampled).

| Month | Juvenile | Adult |
|---|---|---|
| September | 0.37 f<br>A | 0.63 b<br>B |
| October | 0.32 e<br>A | 0.68 c<br>B |
| November | 0.32 e<br>A | 0.68 c<br>B |
| December | 0.26 cd<br>A | 0.74 de<br>B |
| January | 0.61 g<br>B | 0.39 a<br>A |
| February | 0.29 de<br>A | 0.71 cd<br>B |
| March | 0.21 bc<br>A | 0.79 ef<br>B |
| April | 0.28 de<br>A | 0.72 cd<br>B |
| May | 0.38 f<br>A | 0.62 b<br>B |
| June | 0.14 a<br>A | 0.86 g<br>B |
| July | 0.20 b<br>A | 0.80 f<br>B |
| August | 0.10 a<br>A | 0.90 g<br>B |

icant incidence in transects II and VI (Table 4). The abiotic conditions of these transects are as follows:

Transect II - this site is exposed to the open sea and it has high wave action; it is lined by a rocky coast that acts as a barrier to the waves, inducing strong breakers; the mean depth is 11.4 ± 0.62 m, and the organic matter content 5.4 ± 2.91%; the predominant granulometric fraction is very fine sand (71.6 ± 9.14%).

Transect VI - this site has calm water because it is located in a sheltered area in the middle of the Bay, directed towards the mouth in front of small rivers; there is a littoral plain with a large number of residential developments producing domestic sewage; the mean depth is 7.6 ± 0.52 m, and the organic matter content is 14.6 ± 2.11%; the predominant granulometric fractions are very fine sand (23.3 ± 6.45%) and silt/clay (31.3 ± 8.64%).

## DISCUSSION

The seabob shrimp *X. kroyeri* is sexually dimorphic in relation to size, with females reaching larger carapace widths than males, suggesting a higher growth rate or a longer growth period for females.

TABLE 4. – Comparative analysis of the percentages of juveniles and adults sampled along the eight transects between September 1995 and August 1996 in the Ubatuba Bay (values with at least one same letter did not differ significantly, $p < 0.05$; lower case letters correspond to comparison of juveniles and adults over all transects; upper case letters correspond to the comparison between juveniles and adults between the same transect).

| Transects | Juvenile | Adult |
|---|---|---|
| I | 0.22 a<br>A | 0.78 b<br>B |
| II | 0.39 b<br>A | 0.61 a<br>B |
| III | 0.26 a<br>A | 0.74 b<br>B |
| IV | 0.28 a<br>A | 0.72 b<br>B |
| V | 0.17 a<br>A | 0.83 b<br>B |
| VI | 0.42 b<br>A | 0.58 a<br>B |
| VII | 0.27 a<br>A | 0.73 b<br>B |
| VIII | 0.22 a<br>A | 0.78 b<br>B |

The results obtained here followed the pattern obtained by Rodrigues *et al*. (1993) and Nakagaki and Negreiros-Fransozo (1998) in São Paulo State areas. Gab-Alla *et al*. (1990) reported slower growth rates in males and suggested that reproductive processes are related to this difference.

Few large specimens (> 25.8 mm CL) were collected in the studied population. There are two hypotheses that could explain the absence of larger specimens in this Bay. The great fishing effort in Ubatuba Bay probably affects the size species composition, which targets the larger specimens during continuous harvesting, especially when other shrimp species are scarce or absent. According to Rothlisberg *et al*. (1985) and Somers *et al*. (1987), the effect of the fishery increases the mortality rate of adult shrimps. Secondly, according to Dall *et al*. (1990), the adults of *X. kroyeri* generally move to open waters offshore to spawn. For this reason the larger specimens were not captured since sampling was localised and did not cover extensive areas offshore deeper than 17 m. Juneau (1977) considered that this species found along the Louisiana coast, Gulf of Mexico either spawned and matured offshore in deeper water or migrated from other Gulf States.

The unimodality obtained in the size frequency distribution evidenced a continuous recruitment of juveniles in all sampled months and transects. The highest occurrence of juveniles in January 1996 (summer) may be the result of a previous spawning period from October to December (spring to early summer) (see Castro, 1997). A peak of mature females in Ubatuba Bay occurred during March and April, and the presence of juvenile shrimp was observed during May (autumn). In view of this evidence, we assumed that *X. kroyeri* exhibits a tropical/subtropical model of reproduction following the designation of Dall *et al.* (1990), in which there is a main reproductive period in the spring to early summer and a secondary one in the autumn. The present results are corroborated by previous observations (Motta-Alves and Rodrigues, 1977; Cortés, 1991; Nakagaki and Negreiros-Fransozo, 1998).

Considering the wide variability in life-history types and the range of habitats occupied by different developmental stages, it is not surprising that penaeid shrimps exhibit rather complex seasonal/spatial life-history patterns (Dall *et al.*, 1990). These authors pointed out that juveniles of the genus *Xiphopenaeus* are distributed along the inlets in estuarine zones. However, Ubatuba region has only small estuaries that are limited in relation to the number of juveniles that are protected in these nursery grounds. For this reason, and based on personal observations on capture of postlarval, juvenile and adult speciemens in these estuaries, it seems valid to infer that the initial phases of the life cycle of *X. kroyeri* would not be settling in this area. Thus, *X. kroyeri* should be classified as having a life cycle type III rather than type II as reported by Dall *et al.* (1990). This pattern is also supported by the assertion of Kutkuhn (1966), who reported that seabobs rarely, if ever, penetrate the estuaries, either in juvenile or adult form.

The absence of estuaries with large extensions can reduce the dependence that postlarval and juvenile penaeid shrimps show for this type of habitat (Stoner, 1988). This hypothesis can explain the presence of *X. kroyeri* in the Ubatuba Bay throughout the year, with juveniles inhabiting shallow waters to depths of 10 m. A similar preference was noted for *X. kroyeri* by Rodrigues *et al.* (1993). This pattern was also observed for *Farfantepenaeus brasiliensis* and *F. paulensis* by Costa and Fransozo (1999).

The presence of a high number of juveniles in transects II and VI could be related to substrates with fine sediments and the presence of fragments of algae and plants that are utilised as substrata for settlement (Mantelatto and Fransozo, 1999). Preferences for a particular substratum and vegetation appear to be dominant factors that govern settlement in postlarval and juvenile penaeids (Dall *et al.*, 1990; Sánchez, 1997; Pérez-Castañeda and Defeo, 2001).

According to the present results and those obtained by Fransozo *et al.* (2000) in Fortaleza Bay, a close and similar area to Ubatuba Bay, we suggest that the protection period for *X. kroyeri* in the southern region must extend from September to January, since the juveniles are growing in shallow water during this period. Alternative management practices considering this suggestion may be included to allow trawling only within a certain distance from the Bay mouth (offshore area), combined with a periodical monitoring of shallow waters to adjust the protection schedule and fishery activities.

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