January 2007

Abundance and Ecological Distribution of the "Sete-Barbas" Shrimp *Xiphopenaeus kroyeri* (Heller, 1862) (Decapoda: Penaeoidea) in Three Bays of the Ubatuba Region, Southeastern Brazil

Rogerio C. Costa
Universidade Estadual Paulista, Brazil

Adilson Fransozo
Universidade Estadual Paulista, Brazil

Fulvio A.M. Freire
Universidade Estadual Paulista, Brazil

Antonio L. Castilho
Universidade Estadual Paulista, Brazil

ABUNDANCE AND ECOLOGICAL DISTRIBUTION OF THE "SETE-BARBAS" SHRIMP *XIPHOPENAEUS KROYERI* (HELLER, 1862) (DECAPODA: PENAEOIDEA) IN THREE BAYS OF THE UBATUBA REGION, SOUTH-EASTERN BRAZIL

Rogério C. Costa[1], Adilson Fransozo[2], Fúlvio A.M. Freire[2], and Antonio L. Castilho[2]

[1,2]NEBECC (Group of Studies on Crustacean Biology, Ecology and Culture)

[1]Departamento de Ciências Biológicas, Faculdade de Ciências, Universidade Estadual Paulista, UNESP, 17033-360, Bauru, São Paulo, Brazil. E-mail rccosta@fc.unesp.br

[2]Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, 18.618.000—Botucatu, São Paulo, Brazil. Email fransozo@ibb.unesp.br

ABSTRACT The influence of environmental factors on the abundance and spatial-temporal distribution of the shrimp *Xiphopenaeus kroyeri* was investigated in southeastern Brazil over 2 years. Monthly collections were conducted in Mar Virado, Ubatuba and Ubatumirim Bays using a commercial shrimp fishing boat equipped with 2 "double-rig" nets. Each bay was divided into 6 sampling stations, all of which were less than 25 m deep. The spatial distribution of *X. kroyeri* differed among Bays. Highest abundance values were recorded in areas where silt and clay comprised more than 70% of the bottom sediment. Abundance of *X. kroyeri* followed a seasonal trend, being higher during fall and winter, when intrusions of tropical waters are frequent, causing an increase in salinity (> 35‰) and temperature (> 21° C). A clear decrease in shrimp abundance followed a decrease in bottom temperature (< 20° C) during spring and summer due to the influence of cold water currents, particularly the South Atlantic Central Water. These results suggest that sediment type, salinity, and temperature are among the most important variables affecting the spatial and seasonal distribution of this species.

INTRODUCTION

The seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862), commonly known in Brazil as "camarão sete-barbas," is widely distributed in the Western Atlantic from Cape Hatteras (North Carolina, USA) through the Caribbean region to southern Brazil (State of Rio Grande do Sul) (D'Incao 1995, Costa et al. 2000, Castro et al. 2005). This species is the second most important fishery resource in southeastern Brazil and is the most heavily exploited benthic shrimp species on the coast of the state of São Paulo (D'Incao et al. 2002, Castro et al. 2005). In addition, *X. kroyeri* plays an important ecological role in maintaining the stability of trophic relationships in benthic communities (Pires 1992, Nakagaki and Negreiros-Fransozo 1998). *Xiphopenaeus kroyeri* has been heavily exploited over the past few decades, at times accounting for 90% of all penaeoid shrimps caught in shallow waters down to 20 m (Costa 2002, Fransozo et al. 2002). During the 1980s and early 1990s, their combined biomass averaged over 10,000 t/yr but declined to less than 5,000 t/yr in the late 1990s (D'Incao et al. 2002).

Studies on *X. kroyeri* to date have focused on aspects of its geographical and bathymetric distributions (Williams 1984, D'Incao 1995, Boschi 2000), faunal surveys along the São Paulo coast (Nakagaki et al. 1995, Costa et al. 2000, 2003), or abundance and diversity patterns within the benthic community (Pires 1992). However, virtually nothing is known about the ecological distribution of *X. kroyeri* along the Brazilian coast or elsewhere in the Western Atlantic.

An important aspect of the area investigated is its hydrographic structure (Pires 1992). According to Castro-Filho et al. (1987), 3 water masses are present on the marine continental shelf, with different distribution patterns in summer and winter. Coastal Water (CW) has high temperature and low salinity (T > 20° C, S < 36 psu), Tropical Water (TW) has both high temperature and salinity (T > 20° C, S > 36 psu), and South Atlantic Central Water (SACW) has both low temperature and salinity (T < 18° C, S < 36 psu). These water masses interact to modify the temperature, salinity, and food availability during the course of the year.

We analyzed the spatial and temporal distribution patterns of *X. kroyeri* in 3 Bays in the Ubatuba region, São Paulo State, Brazil. Abundance patterns are related to variation in salinity, temperature, depth, sediment composition, and organic-matter content.

MATERIAL AND METHODS

Shrimp were collected monthly from January 1998 to December 1999 in Mar Virado (MV), Ubatuba (UBA), and Ubatumirim (UBM) Bays, located in the Ubatuba region, state of São Paulo. Each bay was classified into 6 stations, which were selected to include the full range

of environmental conditions where *X. kroyeri* is found. These conditions included: their position relative to the bay mouth, depth, and sediment type; the presence of a rocky wall or beach along the bay shore; the inflow of fresh water; and the proximity of offshore water, i.e., open areas with higher salinity. Four of the stations were located at mean depths of 5 (IV), 10 (III), 15 (II) and 20 m (I), and 2 were established adjacent to rocky shores (an exposed and a sheltered shore, stations V (9 m) and VI (6.5 m), respectively) (Figure 1). A shrimp-fishing boat equipped with 2 double-rig nets (mesh size 20 mm and 15 mm in the cod end) was used for trawling. At each station we trawled over a 30-min period, covering 18,000 m^2.

At each station, salinity and temperature (bottom and surface water), depth, organic matter content (%), and grain size of sediments were measured. The sampling methods and the analysis of environmental factors during the same period have been described by Bertini et al. 2001. Bottom water was sampled using a Nansen bottle. Salinity (psu) was measured with a optic refractometer Atago S/1000 and temperature (° C) using a thermometer attached to the bottle. An ecobathymeter coupled with a GPS was used to record depth (m) at sampling stations. Sediment samples were collected at each station with a Van Veen grab (0.06 m^2). In the laboratory, the sediment was oven-dried at 70° C for 72 h. For the analysis of grain size composition, two 50-g sub-samples were treated with 250 ml of a 0.2 N NaOH solution, stirred for 5 min to separate the silt and clay particles, and then rinsed on a 0.063-mm sieve.

Sediments were sieved through 2 mm (gravel); 2.0–1.01 mm (very coarse sand); 1.0–0.51 mm (coarse sand); 0.50–0.26 mm (medium sand); 0.25–0.126 mm (fine sand); and 0.125–0.063 mm (very fine sand); smaller particles were classified as silt-clay. Grain size categories followed the American standard (Wentworth 1922), and fractions were expressed on the phi (Ø) scale, thus accounting for the central tendency of sediment samples, e.g., $-1 = phi < 0$ (gravel); $0 = phi < 1$ (coarse sand); $1 = phi < 2$ (intermediate sand); $2 = phi < 3$ (fine sand); $3 = phi < 4$ (very fine sand) and $phi \geq 4$ (silt + clay) (Tucker 1988). Cumulative particle-size curves were plotted on a computer using the phi scale, with values corresponding to 16th, 50th, and 84th percentiles being used to determine the mean diameter of the sediment using the formula Md $= (\phi_{16}+\phi_{50}+\phi_{84})/3$. Finally, phi was calculated using the formula phi $= -\log_2 d$, where d = grain diameter (mm) (Tucker 1988).

The organic matter content (%) was obtained by ash-weighing: 3 aliquots of 10 g each per station were placed in porcelain crucibles and burned for 3 h at 500° C, and the samples were then weighed again (see Mantelatto and Fransozo 1999).

The abundances of shrimps were compared among years, bays, stations, and seasons (summer (January–March), autumn (April–June), winter (July–September), and spring (October–December)) of the year using an analysis of variance factorial model (ANOVA, $P < 0.05$). The homoscedasticity (Levene test) and normality assumptions
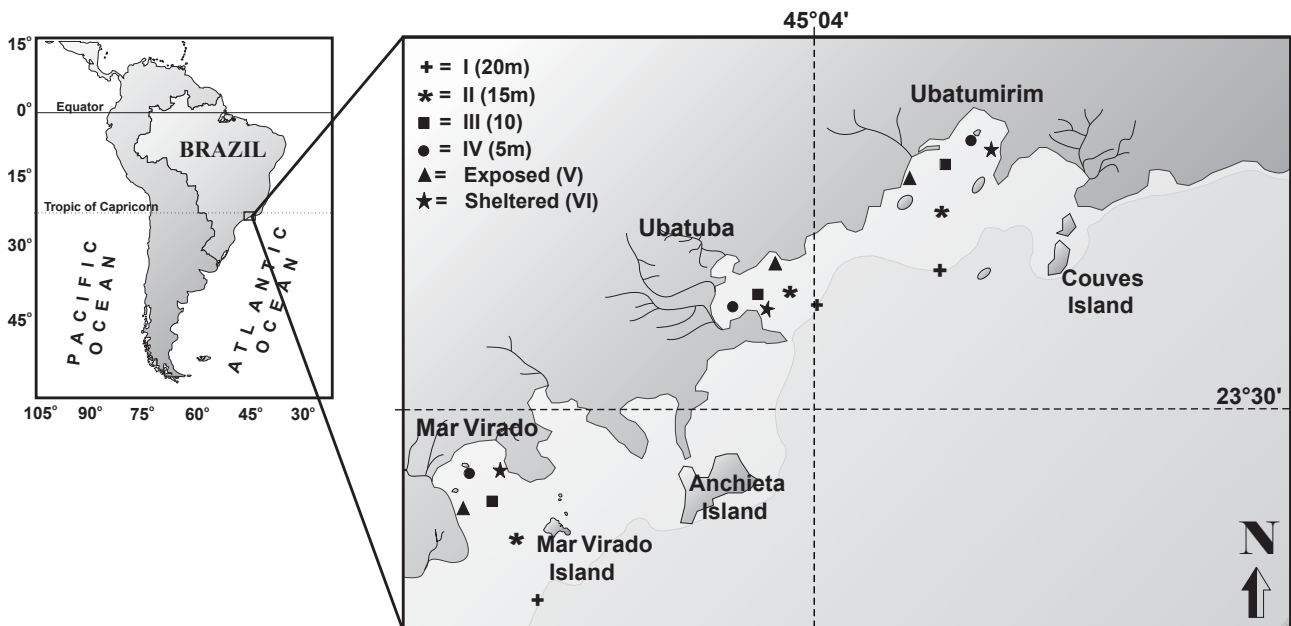

Figure 1. Map of the Ubatuba region with the indication of stations in each bay.
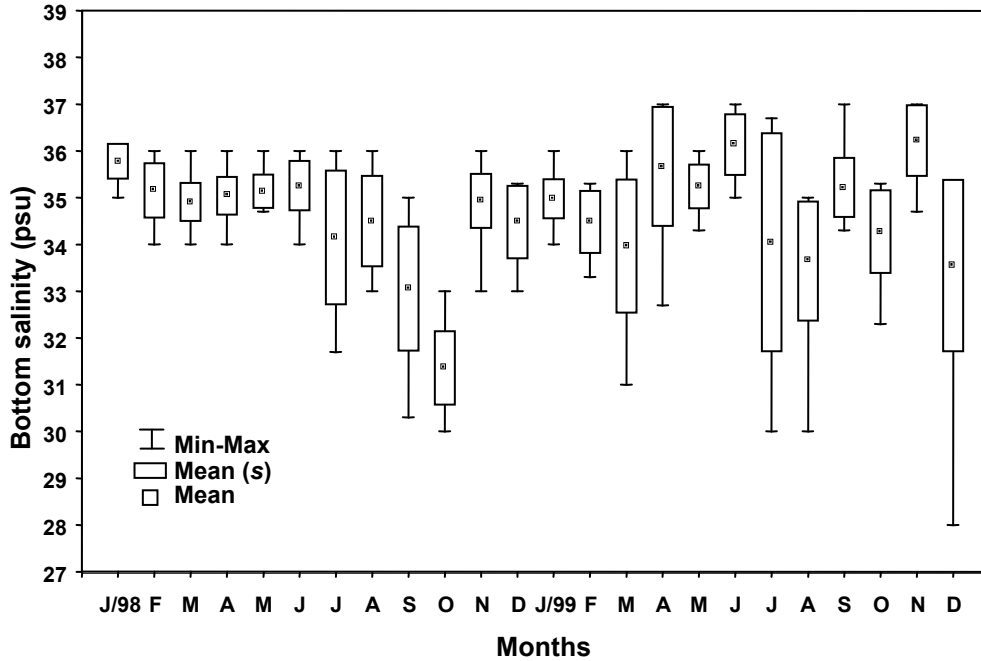
Figure 2. Boxplot showing mean (±*s*), maximum and minimum salinity values for each month during 1998 and 1999. *s* = standard deviation.

were examined and the data were $\log_{10}$-transformed prior to the analysis (Zar 1999). The influence of environmental factors on the species abundance was evaluated by multiple linear regression and also compared through analysis of variance (ANOVA, $P < 0.05$) (Zar 1999).

RESULTS

Monthly and among-station variations in mean bottom salinities are shown in Figures 2 and 3. In general, highest salinity values (>35 psu) were found during the autumn (May and June in 1998 and April–June in 1999), whereas the lowest values occurred during early spring (September and October) in the first year and during winter and spring (except November) during the second year.

Temperature within each season was significantly lower in the second year. Clear temperature differences were found among stations during spring and summer, with stations I–III being cooler than stations IV–VI (Figure 4). Mean temperature values were homogeneous among
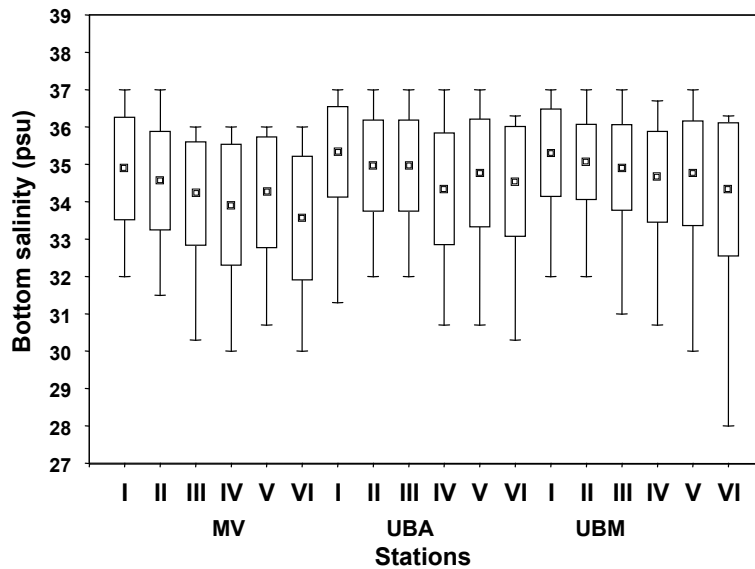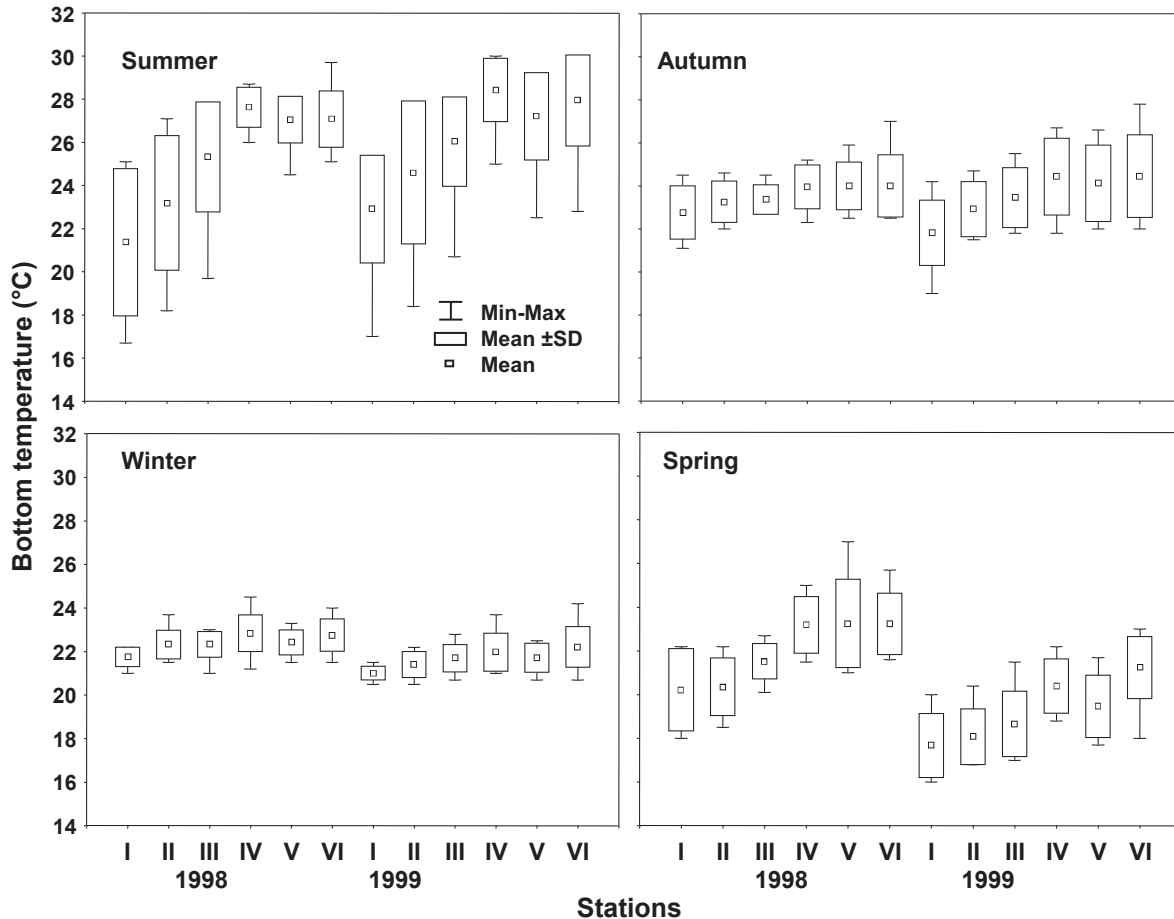

Figure 3. Boxplot showing mean (*s*), maximum and minimum salinity values for each station in the bays during 1998 and 1999. MV, Mar Virado; UBA, Ubatuba; and UBM, Ubatumirim. *s* = standard deviation.

Figure 4. Boxplot showing mean (±*s*), maximum and minimum temperature values for each station and season during 1998 and 1999. *s* = standard deviation.

stations in other seasons. Organic matter contents at each station of each bay are shown in Table 1. Differences in mean organic-matter content levels were found among embayments, with deeper stations located near the bay mouth (I and II) showing the lowest levels.

The amount of mud in the sediments decreased northward, i.e., from Mar Virado Bay to Ubatumirim Bay (Table 1, Figure 5). In Mar Virado Bay, the silt + clay fraction (phi > 4) was the most prevalent at the majority of stations, with values above 70% at stations II through V. A predominance of fine and very fine sand, associated with silt and clay, was observed in Ubatuba, particularly in Ubatumirim Bay (Table 1), except for stations VI in Ubatuba Bay and station I in Ubatumirim Bay.

A total of 563,636 individuals were collected during the present study; 324,861 during the first and 238,775 during the second year. In both years, the abundance of *X. kroyeri* was higher in Mar Virado Bay (248,792), compared to Ubatuba Bay (206,284) and Ubatumirim Bay (108,560). The differences among bay and year were statistically siginificant (*P* < 0.05, Table 2).

The highest shrimp abundance occurred during fall and winter in 1998 and during fall in 1999 (Figure 6), periods when shrimp abundance was significantly higher than in other seasons (*P* < 0.01). Conversely, lowest abundance occurred during summer and spring, particularly in 1999. The interaction between year and season was also significant (Table 2).

About 82% of all shrimps were caught in shallow areas, i.e., depths < 15 m (Figures 7 and 8, Table 1), except at station VI in Ubatuba Bay. Substantial differences in abundance were found among stations (*P* < 0.001) and between its interactions with bay (*P* < 0.001) and season (*P* < 0.05; see Table 2); no other interactions were observed (*P* > 0.05).

The correlation (*r* = 0.49) between abiotic factors and variation in shrimp abundance indicated that more individuals were collected in conditions of medium bottom temperature (22–24º C) and high salinity (36–38 psu). With respect to the substrate, shrimp abundance increased in areas with high organic matter content and high percentage of silt and clay (high phi values). Also, in spring and

TABLE 1

Mean values of sediment parameters (diameter = phi; mud content = % silt + clay; organic matter content = o.m.), and number of individuals (N) for each station in each sampled bay from 1998 to 1999.

STA	Mar Virado Bay				Ubatuba Bay				Ubatumirim Bay			
	phi (ϕ)	mud (%)	o.m. (%)	N	phi (ϕ)	mud (%)	o.m. (%)	N	phi (ϕ)	mud (%)	o.m. (%)	N
I	4.3	46.8	3.0	17,613	3.2	16	3.6	5,657	1.5	2.6	2.1	3,011
II	5.7	75.3	4.6	47,632	4.0	21.2	4.2	19,240	3.8	23.9	3.4	10,162
III	6.2	88.3	5.4	42,946	5.3	61.9	8.0	52,096	4.4	35.7	5.2	43,357
IV	5.9	81.2	5.6	52,944	5.7	76.3	5.7	49,074	4.9	49.6	4.2	15,607
V	5.8	79.7	4.2	50,753	4.8	47.3	7.5	79,481	4.0	22.2	2.4	16,788
VI	5.4	64.4	4.4	36,904	3.6	36.8	6.1	736	4.4	33.4	4.2	19,635
Total				248,792				206,284				108,560

summer the number of individuals decreased at stations with depths over 20 m (Figure 8). The same periods and stations had low temperatures (Figure 4). In other seasons, particularly autumn, the spatial distribution of *X. kroyeri* was more homogeneous.

There was a good fit of the multiple regression analysis using significant ($P < 0.05$) environmental variables and the abundance of *X. kroyeri* ($r = 0.49$, $P < 0.001$, $F = 69.95$, $N = 432$), which can be expressed as:

$$A = -176.447 + 18.432s + 42.347 \text{ phi}$$

where: A = abundance; s = bottom salinity (partial correlation = 0.11, $P < 0.05$); phi = phi (partial correlation = 0.49, $P < 0.05$).

The abiotic factors such as sediment (phi) and salinity were positively correlated with the number of collected individuals. No significant relationship was observed between bottom temperature or water depth and abundance ($P > 0.05$).

DISCUSSION

The most important variables affecting the spatial and seasonal distribution of *X. kroyeri* in this study were sediment type, salinity, and temperature. This was exemplified by the high abundance of the species in areas characterized by muddy substrates, and high salinity and temperature.

The northern coast of São Paulo state is strongly influenced by 2 water masses: CW and TW. The effects of these water masses are felt most during autumn and winter, when temperature and salinity levels increase to over 21° C

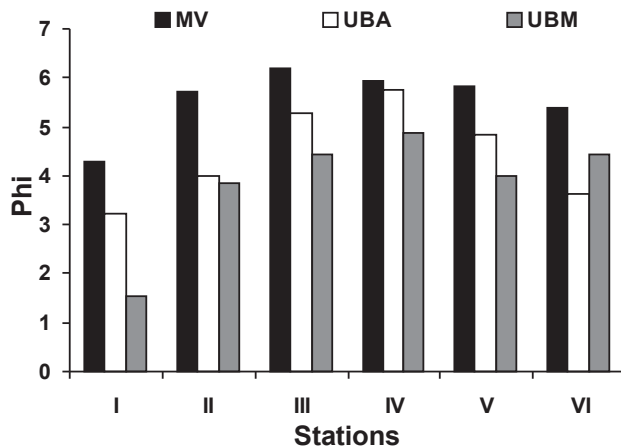**Figure 5. Mean diameter of sediment grains (phi) at each sampled station in the bays studied. MV, Mar Virado; UBA, Ubatuba; UBM, Ubatumirim.**

TABLE 2

Results of the analysis of variance (factorial ANOVA) of the number of individuals collected ($\log_{10}$-transformed) of *Xiphopenaeus kroyeri* by year, bay, or season and station.

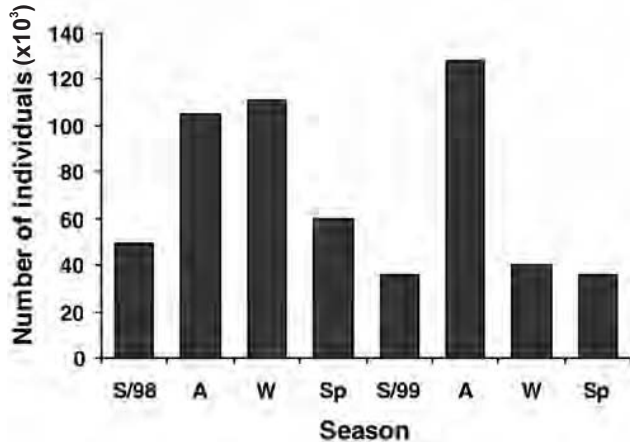| Source	df	MS	F	P
Year	1	2.48	4.66	0.03
Bay	2	16.36	30.73	0.00
Station	5	31.15	58.51	0.00
Bay x Station	10	5.71	10.73	0.00
Season	3	16.31	30.63	0.00
Season x Year	3	1.47	2.76	0.04
Season x Station	15	0.93	1.75	0.04

Figure 6. Number of individuals of *X. kroyeri* obtained by season in the sampled Bays during the 2-yr period.

and 35 psu, respectively. Another water mass, the SACW, intrudes throughout late spring and summer causing decreases in temperature (< 20° C) and bottom salinity (< 5 psu). The incursion of the TW into the uppermost water layers and the dislocation of the CW toward the ocean during the fall and winter causes vertical mixing and thus eliminates the existing seasonal thermocline causing the SACW to recede towards the offshore region (Castro-Filho et al. 1987, Castilho et al. in press).

In addition to corroborating the scenario described above, our results indicate that fluctuations in the seasonal and bathymetric distribution of *X. kroyeri* were influenced by variation in temperature (summer) and salinity levels caused by these water masses. Therefore, the influence of the SACW in the spring and summer most likely led to a decrease in the number of collected individuals. The retreat of this water mass and the incursion of TW during

autumn and winter considerably increased the abundance of *X. kroyeri*. Similar results were found by Fransozo et al. (2002) for *X. kroyeri* in Fortaleza Bay, by Costa and Fransozo (2004) for *Rimapenaeus constrictus* (Stimpson, 1874), and by Costa et al. (2005a) for *Sicyonia dorsalis* Kingsley, 1878, all in the Ubatuba region. In addition, the number of captured individuals in these studies was smaller in these periods when compared with autumn and winter. Several authors (Rodrigues et al. 1993, Nakagaki and Negreiros-Fransozo 1998, Castro et al. 2005) have hypothesized that individuals of *X. kroyeri* migrate to deeper regions to spawn, given that their main reproductive period occurs during spring and summer. However, even after 3 yr of sampling stations up to 40 m deep in Ubatuba Bay, Costa (2002) and Pinheiro (2004) did not find a single individual of *X. kroyeri* deeper than 25 m. Therefore, one can infer that these shrimp migrate to the northernmost region of southeastern Brazil upon the arrival of the cold water currents. According to Castro-Filho et al. (1987), the SACW reaches its northern limit off the state of Rio de Janeiro, north of which temperatures are markedly higher than off southern Brazil.

There was a marked increase in abundance during winter, even though bottom temperature dropped considerably. This inverse oscillation in abundance caused by variation in temperature during summer and winter may have masked the association between temperature and shrimp abundance, minimizing its impact on the analysis. Nevertheless, our results suggest that temperatures below 21° C may be limiting for this species.

High abundance of *X. kroyeri* were almost invariably associated with high salinity. This finding is similar to that of Castro et al. (2005), who investigated the population structure of this species in Ubatuba Bay, concluding
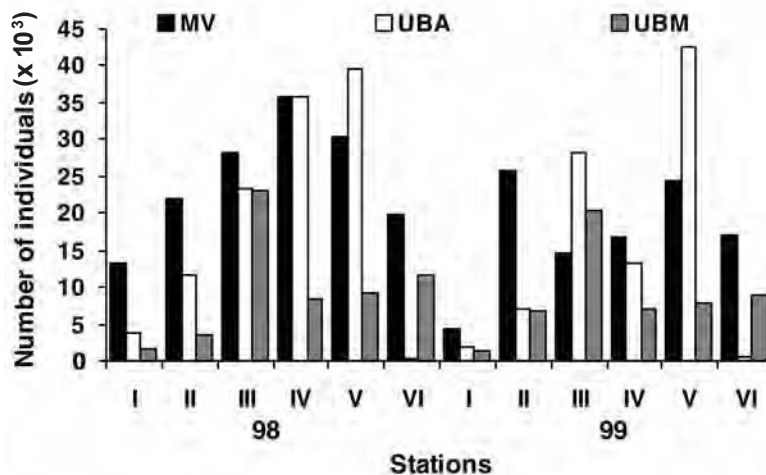

Figure 7. Number of individuals of *X. kroyeri* obtained by station in the sampled bays during the 2-yr period. MV, Mar Virado; UBA, Ubatuba; UBM, Ubatumirim.
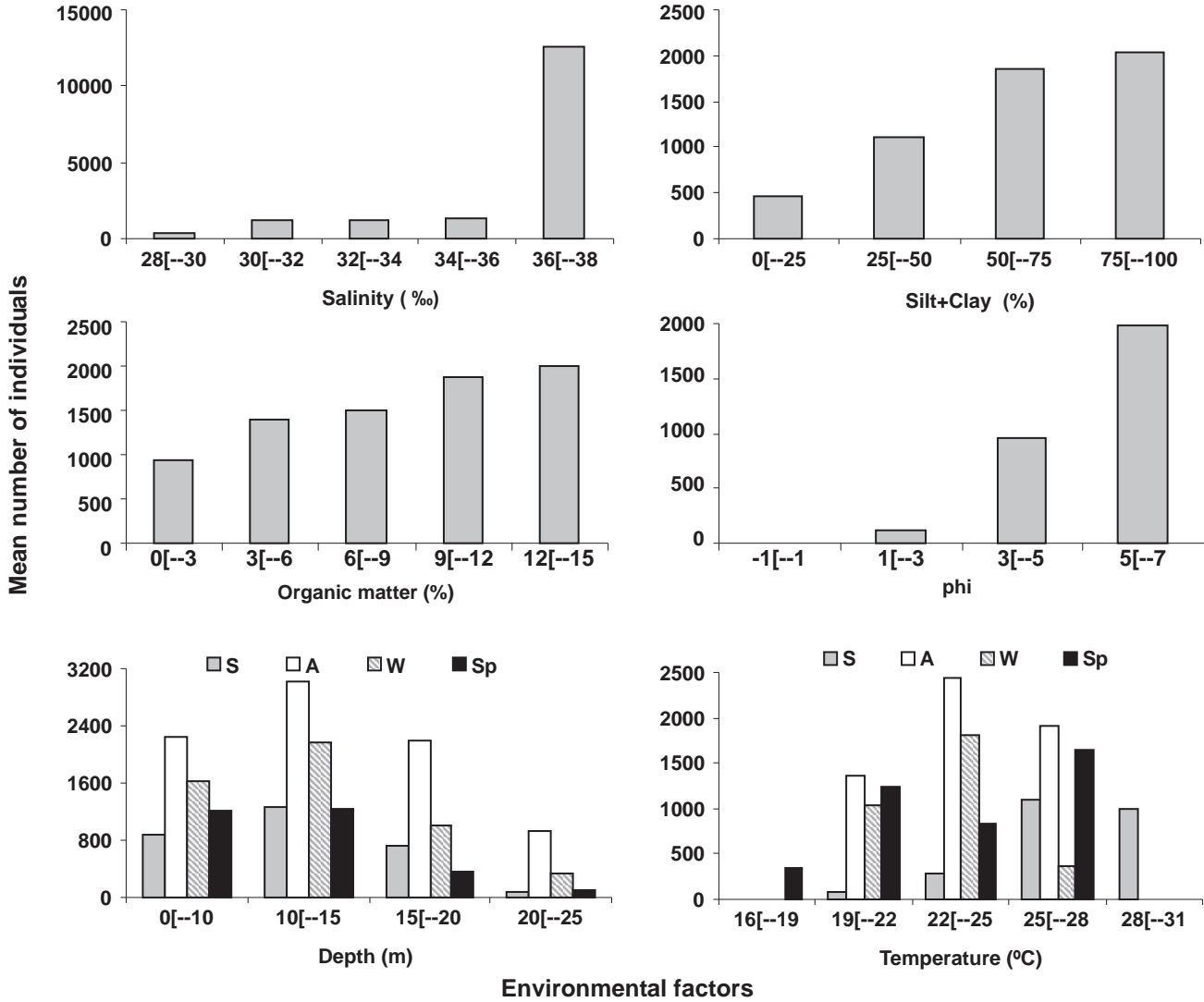
Figure 8. Distribution of the mean number of individuals of *X. kroyeri* in relation to the environmental factors (botton salinity, silt+clay, organic matter, granulometric classes, depth and bottom temperature). S, summer; A, autumn; W, winter; Sp, spring.

that juveniles are not dependent on estuarine regions and complete their life-cycles in salinities above 30 psu. In contrast, our results contradict other studies that suggest that *X. kroyeri* is euryhaline but only tolerates salinities between 21.2 psu and 36 psu in many parts of its geographical range, such as the coast of Texas, USA (Gunter et al.1964), the Laguna de Términos, Mexico (Signoret 1974), and the Caribbean coast of Colombia (Cortés and Newmark 1992). These contradictory observations may result from the presence of only small estuaries in the Ubatuba region (Costa and Fransozo 1999).

The abundance of *X. kroyeri* was strongly associated with the mud content of the substrate in each bay, which increased southward from Ubatumirim Bay to Mar Virado Bay. Therefore, the high abundance of *X. kroyeri* in Mar

Virado Bay is probably a result of the high silt and clay content. The increasingly mixed sediments in other embayments, such as at station VI in Ubatuba Bay and station I in Ubatumirim Bay, seem to be avoided by this species.

Given that penaeoid shrimps usually prefer substrates with higher mud and silt content, probably to facilitate their burrowing behavior, this characteristic may affect their distribution (Dall et al. 1990). However, a preference for a given kind of sediment seems to be species specific. In another study at the same site, Costa et al. (2004) found the same spatial distribution in the shrimp *Pleoticus muelleri* (Bate, 1888), and *Artemesia longinaris* Bate, 1888 was found at sites with higher percentages of fine and very fine sands (Fransozo et al. 2004, Costa et al. 2005b). On the other hand, the shrimp *R. constrictus*

showed a stronger preference for much coarser substrates (Costa and Fransozo 2004). According to Penn (1984), preference for a given substrate in the case of penaeoids is associated with their capacity to perform gas exchange when burrowed.

Several authors have suggested that the distribution of penaeoid shrimps is strongly modulated by the texture and organic content of the substrate (Rulifson 1981, Somers 1987, Stoner 1988, Dall et al. 1990, Sanchez 1997). In the present study, the distinctive characteristics of each bay determined to a large extent the differences in the abundance of *X. kroyeri*. However, no correlation was detected between shrimp abundance and the organic content of the substrate.

Even though water depth was not identified as a significant predictor of the abundance of *X. kroyeri* in multiple regression analyses in our study, this result should be interpreted with caution, given that this abiotic factor is usually co-linear with bottom temperature and the type of sediment. Pires (1992) studied the decapod community in the Caraguatatuba region, the southernmost part of the north shore of the state of São Paulo and encountered specimens of *X. kroyeri* in depths between 50 and 60 m. High mud contents were found at these depths compared to other sites farther north. When viewed in the light of our study, these results suggest that the sediment with higher mud content allowed an expansion of their bathymetric distribution and thus might represent an essential factor for the establishment of this species.

ACKNOWLEDGEMENTS

LITERATURE CITED

Bertini, G., A. Fransozo, and R.C. Costa. 2001. Ecological distribution of three species of *Persephona* (Brachyura: Leucosiidae) in the Ubatuba region, São Paulo, Brazil. Nauplius 9:31–42.

Boschi, E.E. 2000. Species of decapod crustaceans and their distribution in the marine zoogeographic provinces. Revista de Investigación y Desarrollo Pesquero 13:7–136.

Castilho, A.L., R.C. Costa, A. Fransozo, and E.E. Boschi. in press. Reproductive pattern of the South American endemic shrimp *Artemesia longinaris* (Decapoda, Penaeidae), off the coast of São Paulo state, Brazil. Revista de Biología Tropical.

Castro, R.H., R.C. Costa, A. Fransozo, and F.L.M. Mantelatto. 2005. Population structure of the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) (Crustacea, Penaeoidea) in the littoral of São Paulo, Brazil. Scientia Marina 69:105–112.

Castro-Filho, B.M., L.B. Miranda, and S.Y. Myao. 1987. Condições hidrográficas na plataforma continental ao largo de Ubatuba: Variações sazonais e em média escala. Boletim do Instituto Oceanográfico 35:13–51.

Cortés, M.L. and E. Newmark. 1992. Distribución y abundancia del camarón titi *Xiphopenaeus kroyeri* en Costa Verde (Cienaga) Caribe colombiano. Boletin Ecotropica 25:15–27.

Costa, R.C. 2002. Biologia e Distribuição Ecológica das Espécies de Camarões Dendrobranchiata (Crustacea: Decapoda) na Região de Ubatuba (SP). Ph.D. Thesis. Universidade Estadual Paulista, Botucatu, São Paulo, BR, 186 p.

Costa, R.C. and A. Fransozo. 1999. A nursery ground for two tropical pink-shrimp *Penaeus* species: Ubatuba Bay, northern coast of São Paulo, Brazil. Nauplius 7:73–81.

Costa, R.C. and A. Fransozo. 2004. Abundance and ecologic distribution of the shrimp *Rimapenaeus constrictus* (Crustacea: Penaeidae) in the northern coast of São Paulo State, Brazil. Journal of Natural History 38:901–912.

Costa, R.C., A. Fransozo, F.L.M. Mantelatto, and R.H. Castro. 2000. Occurrence of shrimp species (Natantia: Penaeidea: Caridea) in Ubatuba Bay, Ubatuba, SP, Brazil. Proceedings of the Biological Society of Washington 113:776–781.

Costa, R.C., A. Fransozo, G.A.S. Melo, and F.A.M. Freire. 2003. An illustrated key for Dendrobranchiata shrimps from the northern coast of São Paulo state, Brazil. Biota Neotrópica 3:1–12.

Costa, R.C., A. Fransozo, and A.P. Pinheiro. 2004. Ecological distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) (Decapoda: Penaeoidea) of Southeastern Brazil. Hydrobiologia 529:195–203.

Costa, R.C., A. Fransozo, and M.L. Negreiros-Fransozo. 2005a. Ecology of rock shrimp *Sicyonia dorsalis* Kingsley, 1878 (Crustacea: Sicyoniidae) in a Subtropical region of Brazil. Gulf and Caribbean Research 17:49–56.

Costa, R.C., A. Fransozo, A.L. Castilho, and F.A.M. Freire. 2005b. Annual, seasonal and spatial variation of abundance of *Artemesia longinaris* (Decapoda, Penaeoidea) in a southeastern region of Brazil. Journal of the Marine Biological Association of the United Kingdom 85:107–112.

Dall, W., B.J. Hill, P.C. Rothlisberg, and D.J. Sharples. 1990. The biology of the Penaeidae. In: J.H.S. Blaxter and A.J. Southward, eds. Advances in Marine Biology. San Diego: Academic Press, San Diego, CA, USA, 27:1-489.

D'Incao, F. 1995. Taxonomia, padrões distribucionais e ecológicos dos Dendrobranchiata (Crustacea: Decapoda) do litoral brasileiro. PhD Thesis, Universidade Federal do Paraná, Curitiba, Paraná, BR, 365 p.

D'Incao, F., H. Valentini, and L.F. Rodrigues. 2002. Avaliação da pesca de camarões nas regiões Sudeste e Sul do Brasil. Atlântica 24:103–116.

Fransozo, A., R.C. Costa, A.L. Castilho, and F.L.M. Mantelatto. 2004. Ecological distribution of the shrimp "barba-ruça" *Artemesia longinaris* (Decapoda: Penaeidae) in Fortaleza Bay, Ubatuba, Brazil. Revista de Investigación y Desarrollo Pesquero 16:45–53.

Fransozo, A., R.C. Costa, F.L.M. Mantelatto, M.A.A. Pinheiro, and S. Santos. 2002. Composition and abundance of shrimp species (Penaeidea and Caridea) in Fortaleza Bay, Ubatuba, São Paulo, Brazil. In: E.E. Briones and F. Alvarez, eds. Modern Approaches to the Study of Crustacea, New York, NY, USA, p. 117–125.

Gunter, G., J.Y. Christmas, and R. Killebrew. 1964. Some relations of salinity to population distributions of motile estuarine organism, with special reference to penaeid shrimp. Ecology 45:181–185.

Mantelatto, F.L.M. and A. Fransozo. 1999. Characterization of the physical and chemical parameters of Ubatuba Bay, northern coast of São Paulo state, Brazil. Revista Brasileira de Biologia 59:23–31.

Nakagaki, J.M. and M.L. Negreiros-Fransozo. 1998. Population biology of *Xiphopenaeus kroyeri* (Heller, 1862) (Decapoda: Penaeidae) from Ubatuba Bay, São Paulo, Brazil. Journal of Shellfish Research 17:93–935.

Nakagaki, J.M., M.L. Negreiros-Fransozo, and A. Fransozo. 1995. Composição e abundância de camarões marinhos (Crustacea: Decapoda: Penaeidae) na Enseada de Ubatuba, Ubatuba, Brazil. Arquivos de Biologia e Tecnologia 38:583–591.

Penn, J.W. 1984. The behavior and catchability of some commercially exploited penaeids and their relationship to stock and recruitment. In: J.A. Gulland and B.J. Rothschild, eds. Penaeid Shrimps—Their Biology and Management. Fishing News Books, Farnham, UK, p. 173–186.

Pinheiro, A.P. 2004. Biodiversidade de Penaeoidea (Crustácea: Decapoda) do Litoral Norte do Estado de São Paulo. Master's Thesis, Universidade Estadual Paulista, Botucatu, São Paulo, BR, 89 p.

Pires, A.M.S. 1992. Structure and dynamics of benthic megafauna on the continental shelf offshore of Ubatuba, southeastern, Brazil. Marine Ecology Progress Series 86:63–76.

Rodrigues, E.S., J.B. Pita, R. Graça-Lopes, J.A. Coelho, and A. Puzzi. 1993. Aspectos biológicos e pesqueiros do camarão sete-barbas (*Xiphopenaeus kroyeri*) capturados pela pesca artesanal no litoral do estado de São Paulo. Boletim do Instituto de Pesca 19:67–81.

Rulifson, R.A. 1981. Substrate preference of juvenile penaeid shrimp in estuarine habitats. Contributions of Marine Science 24:33–52.

Sanchez, A.J. 1997. Habitat preference of *Penaeus duorarum* Burkenroad (Crustacea: Decapoda) in a tropical coastal lagoon, southwest Gulf of Mexico. Journal of Experimental Marine Biology and Ecology 217:107–117.

Signoret, M. 1974. Abundancia, tamaño y distribución de camarones (Crustacea, Penaeidae) de la laguna de Términos Campeche y su relación con algunos factores hidrológicos. Anales del Instituto de Biología, Universidad Nacional Autónoma de México. Serie Zoológica 45:119–140.

Somers, I.F. 1987. Sediment type as a factor in the distribution of commercial prawn species in the Western Gulf, Australia. Australian Journal of Marine and Freshwater Research 38:133–149.

Stoner, A.W. 1988. A nursery ground for four tropical *Penaeus* species: Laguna Joyuda, Puerto Rico. Marine Ecology Progress Series 42: 133-141.

Tucker, M. 1988. Techniques in Sedimentology. Blackwell Scientific Publications, Boston, MA, USA, 394 p.

Wentworth, C.K. 1922. A scale of grade and tems for cladistic sediments. Journal of Geology 30:377–392.

Williams, A.B. 1984. Shrimps, lobsters and crabs of the Atlantic coast of the eastern United States, Maine to Florida. Smithsonian Institution Press, Washington, DC, USA, 550 p.

Zar, J.H. 1999. Biostatistical Analysis. Prentice-Hall, NJ, USA, 663 p.