Gulf and Caribbean Research

Volume 17 | Issue 1

January 2005

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Recommended Citation

Caetano da Costa, R., A. Fransozo and M. Negreiros-Fransozo. 2005. Ecology of the Rock Shrimp *Sicyonia dorsalis* Kingsley, 1878 (Crustacea: Sicyoniidae) in a Subtropical Region of Brazil. Gulf and Caribbean Research 17 (1): 49-56.
Retrieved from https://aquila.usm.edu/gcr/vol17/iss1/5
DOI: https://doi.org/10.18785/gcr.1701.05

Gulf and Caribbean Research Vol 17, 49–56, 2005 Manuscript received August 6, 2004; accepted January 14, 2005

ECOLOGY OF THE ROCK SHRIMP *SICYONIA DORSALIS* KINGSLEY, 1878 (CRUSTACEA: SICYONIIDAE) IN A SUBTROPICAL REGION OF BRAZIL

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ABSTRACT The present study analyzes the abundance and distribution of the rock shrimp *Sicyonia dorsalis*, in relation to water temperature, salinity, depth, organic matter content, and sediment texture in Mar Virado (MV), Ubatuba (UBA) and Ubatumirim (UBM), 3 distinct bays along the northern coast of São Paulo State (23°S, 45°W), Brazil. Six transects were taken in each bay, 4 being parallel to the coastline and 2 next to the rocky shores. Monthly samples were taken over a 2-year period (1998 and 1999) with a shrimp fishing boat equipped with double-rig nets. A total of 2,498 specimens was obtained with 804 from MV, 922 from UBA, and 772 from UBM. The spatial distribution of *S. dorsalis* did not differ among bays. Higher abundance values were recorded in areas where silt+clay comprised more than 60% of the sediment. Abundance also followed a seasonal trend, being highest during spring when intrusions of the cold South Atlantic Coastal Waters are most common, promoting the migration of this shrimp species to more sheltered areas. In short, sediment type and water temperature appear to be the most important environmental variables analyzed which affect the spatial and seasonal distribution of *S. dorsalis*.

INTRODUCTION

Sicyoniid shrimps are represented on the Brazilian coast by 6 species (D'Incao 1995): *Sicyonia dorsalis* Kingsley, 1878, *Sicyonia typica* (Boeck, 1864), *Sicyonia laevigata* Stimpson, 1871, *Sicyonia parri* (Burkenroad, 1934), *Sicyonia burkenroadi* Cobb, 1971 and *Sicyonia olgae* Pérez Farfante, 1980. Among these, *S. dorsalis, S. typica, S. laevigata,* and *S. parri* occur in the southeastern subtropical region of Brazil (Costa et al. 2000). *Sicyonia dorsalis* is distributed from Cape Hatteras, North Carolina (USA) including GOM to Florianópolis, Santa Catarina (Brazil) (Pérez Farfante and Kensley 1997). This species has been found from mouth of bays to 60 m deep, rarely to 420 m (Williams 1984) and, according to D'Incao (1995), the highest abundance is at 80 m. This non-commercial species along the southeastern Brazilian coast, due to its small size, constitutes the highest percentage (92%) of captured sicyoniid (Costa 2002). With respect to other Penaeoidea found in the present studied region, *S. dorsalis* is the 7th (1%) most abundant species, about 90% of the shrimps are the seabob, *Xiphopenaeus kroyeri* followed by *Farfantepenaeus brasilensis*, *F. paulensis*, *Litopenaeus schmitti*, *Artemesia longinaris*, *Rimapenaeus constrictus*, and *Pleoticus muelleri* (Costa 2002).

Most accounts of *S. dorsalis* biology are based on populations studied in the northern hemisphere. Emphasis has been given to reproductive aspects (Bauer 1992, 1996a,b) and composition, abundance and diversity patterns within the benthic community (Wenner and Boesch 1979, Wenner and Read 1982, Sánchez and Soto 1987). These latter authors also verified the influence of some abiotic factors on the distribution of penaeoidean shrimps, including *S. dorsalis*.

Biological studies on *S. dorsalis* along the Brazilian coast are limited to a few biogeographical records and some aspects of their ecology. D'Incao (1995) presented information on taxonomy and geographic and bathymetric distributions based on specimens from scientific collections. Costa et al. (2000, 2003) also verified the presence of this species during faunistic surveys of shrimps in the Ubatuba region, State of São Paulo, Brazil. Fransozo et al. (2002) observed seasonal abundance patterns of some penaeoidean shrimps. However, the distribution in the Brazilian coast of *S. dorsalis* relative to ecological factors has not been studied to date. The aim of this study was to determine the spatial and seasonal distribution of *S. dorsalis* in the bays of Mar Virado (MV), Ubatuba (UBA), and Ubatumirim(UBM) in relation salinity, temperature, depth, sediment texture, and organic matter content in the Ubatuba region.

MATERIALS AND METHODS

Shrimps were collected monthly during day hours from January 1998 to December 1999 at MV, UBA, and UBM bays, located in the Ubatuba region, São Paulo State. Collections were made during daylight as Negreiros-Fransozo *et al*. (1999) verified that the abundance of *S. dorsalis* was not correlated with light intensity. Each bay

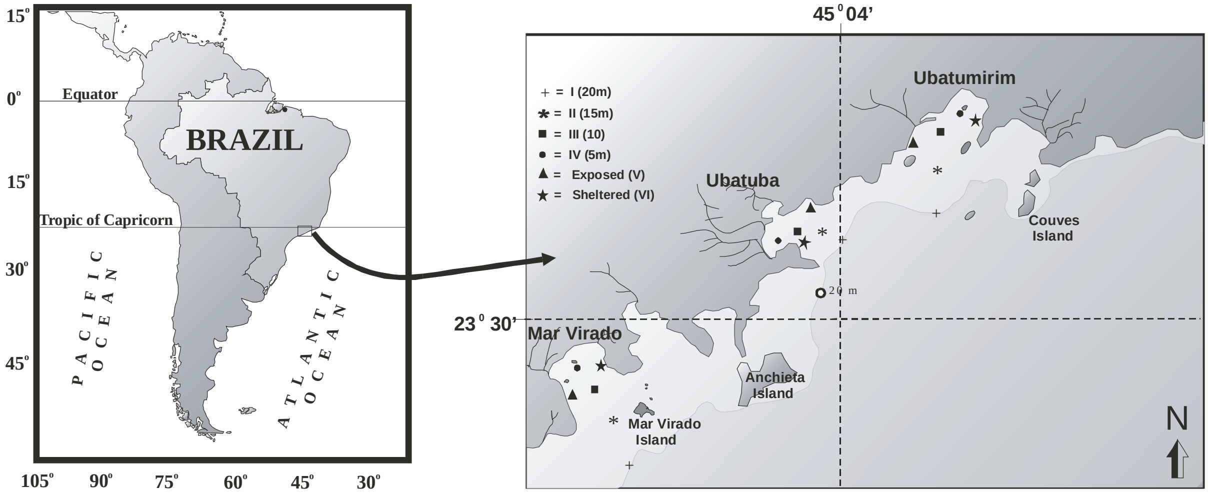

Figure 1. Study region indicating collection sites.

was divided into 6 transects (2 km each) and trawled over a 30-min period (Figure 1). Four transects were located at mean depths of 5 (IV), 10 (III), 15 (II) and 20 m (I), and the other 2 adjacent to rocky shores on exposed (V) and sheltered (VI) shore. 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. During the study period 422 trawls were conducted (144 in each bay).

Salinity (psu) and water temperature (ºC) were measured from bottom-water samples obtained each month for each transect using a Nansen bottle. An ecobathymeter coupled with a Global Position System was used to record depth at sampling sites. Sediments samples were collected in each season with a 0.06 m^2 Van Veen grab. Grain size categories followed the American standard, for which sediments were sieved at 2.0 mm (gravel), 1.0 mm (very coarse sand), 0.5 mm (coarse sand), 0.25 mm (intermediate sand), 0.125 mm (fine sand), and 0.0625 mm (very fine sand) smaller particles were classified as silt-clay. Grain size fractions were expressed in 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 = 4 (silt + clay). Cumulative particle size curves were plotted using the phi-scale, and phi values corresponding to 16th, 50th, and 84th percentiles were read from the curves to determine the mean diameter of the sediment. This was calculated according to the formula: (Ø16 + Ø50 + Ø84)/3, after that, the phi was calculated from the formula $Ø = -\log_2 d$, where d = grain diameter (mm). All procedures employed for sediment analysis followed Hakanson and Jansson (1983) and Tucker (1988).

The kind of the ecological distribution of *S. dorsalis* was analyzed using the Kolmogorov-Smirnov test ($P < 0.01$). The abundance of shrimps were compared among years, bays, transects and seasons of the year using analysis of variance (ANOVA, $P < 0.05$). The influence of environmental factors on *S. dorsalis* abundance were evaluated by multiple linear regression and also compared through ANOVA ($P < 0.05$). Data were $\log_{10}$-transformed prior to the analysis to improve their normality (Zar 1999).

RESULTS

The mean depth of each transect in the bays sampled was I (22.2 ± 0.6m), II (16.5 ± 1.1m), III (11.6 ± 1.1m), IV (5.9 ± 0.4m), V (9.2 ± 1.5m) e VI (6.8 ± 2.3m). In general, mean grain size (phi) of sediments varied from intermediate sand to silt+clay. The amount of mud in the sediments decreased northward within the sampled areas from MV to UBM (Table 1).

In MV bay, the silt + clay fraction (phi > 4) dominated all transects, comprising more than 75% of the samples (Table 1). The phi values decreased in each transect of other sampled bays. In UBA, and mainly in UBM bay, a predominance of fine and very fine sand, associated with silt+clay was observed (Table 1), except at transect I in UBM (phi = 1.5). The organic matter content in the substratum was lowest in the offshore region (transect I and II) of the 3 bays, whereas I was the highest in the other transects (Figure 2).

There was a clear water temperature difference among transects during spring and summer. Water temperature at transects I through III was lower than at transects IV through VI (Figure 3). During other seasons, the mean

TABLE 1

The mean diameter of the sediment (phi), quantity of mud (% silt+clay) and mean number of *Sicyonia dorsalis* by trawl (*n*) at each transect at each bay sampled during 1998 and 1999.

	Bays								
	Mar Virado			Ubatuba			Ubatumirim		
Transects	phi (Ø)	% mud	*n*	phi (Ø)	% mud	*n*	phi (Ø)	% mud	*n*
I	4.3	46.8	4.2	3.2	16.0	0.3	1.5	2.6	0.1
II	5.7	75.3	3.5	3.99	21.2	0.8	3.8	23.9	0.6
III	6.2	88.3	6.7	5.3	61.9	8.8	4.4	35.7	17.3
IV	5.9	81.2	1.5	5.7	76.3	15.7	4.9	49.6	1.4
V	5.8	79.7	6.0	4.8	47.3	3.9	4.0	22.2	7.6
VI	5.4	64.4	11.7	3.6	36.8	9.0	4.4	33.4	5.2
Total			5.6			6.4			5.4

water temperature values were homogeneous. Variation in the mean bottom salinity within each bay is shown in Figure 4. Differences in salinities between bays is substantial with the lowest mean values recorded in MV. In general, higher salinity ranges were found at transect I, whereas lower salinities were found at transects IV and VI (Figure 4).

A total of 2,498 shrimps was obtained, 1,385 during the first year, and 1,113 during the second year. The analysis of shrimp distribution reveals they are contagiously distributed in the studied area ($P < 0.01$). For the pooled sample, the absolute abundance was highest in UBA (922), followed by MV (804) and UBM (772). The comparison of shrimp abundance among bays, years, transects and seasons is shown in Table 2. No significant difference in abundance was found between years or among bays ($P < 0.05$; Table 2).

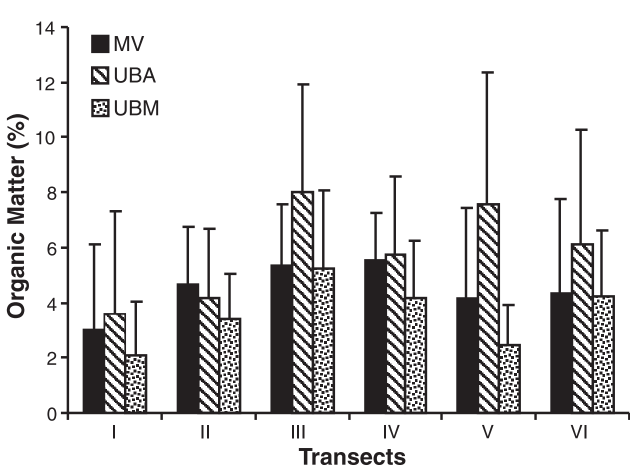

Figure 2. Mean values (±sd) of organic matter content in sediments (%) at each sampled transect in bays studied. MV = Mar Virado, UBA = Ubatuba, UBM = Ubatumirim.

Sicyonia dorsalis was more abundant along transects VI in MV bay and IV in UBA Bay than along other transects. In UBM, catches were highest along transect III. In general, the lowest number of specimens were collected along transects I and II, at each bay (Figure 5). Significant differences were obtained among transcripts ($P < 0.05$, Table 2).

The highest shrimp abundance occurred during spring (October to December) 1998 and early summer (January and February) and the early summer and late spring (November and December) 1999. These periods had significantly higher shrimp than other seasons ($P < 0.05$, Table 3). Conversely, lowest abundances occurred during fall and winter.

There was a good fit between *S. dorsalis* and 5 environmental variables, and this relationship is explained by Abundance = 11.78 – 1.67 (bottom temperature) – 4.63 (bottom salinity) – 0.03 (% organic matter) – 0.13 (depth) + 0.97 (phi) ($r = 0.30$, $P = 1.0001\ E^{-7}$, $n = 432$). Water temperature and salinity were negatively associated and mud content (phi) was positively associated with the number of individuals. However, no correlation was observed between organic matter content and depth in the distribution of this species ($P > 0.05$, Table 4). The analysis indicated that more individuals were collected in conditions of higher percentage of silt and clay, bottom temperature between 19 and 22 ºC and salinity between 30 and 34 psu) (Table 1, Figure 6). Also, there greater numbers of *S. dorsalis* in depths < 15m in spring and summer (Figure 7), following a decrease in bottom water temperature (Figure 3). In fall and winter, there was more homogeneity in the spatial distribution of *S. dorsalis*, however the abundance was lower than other seasons.

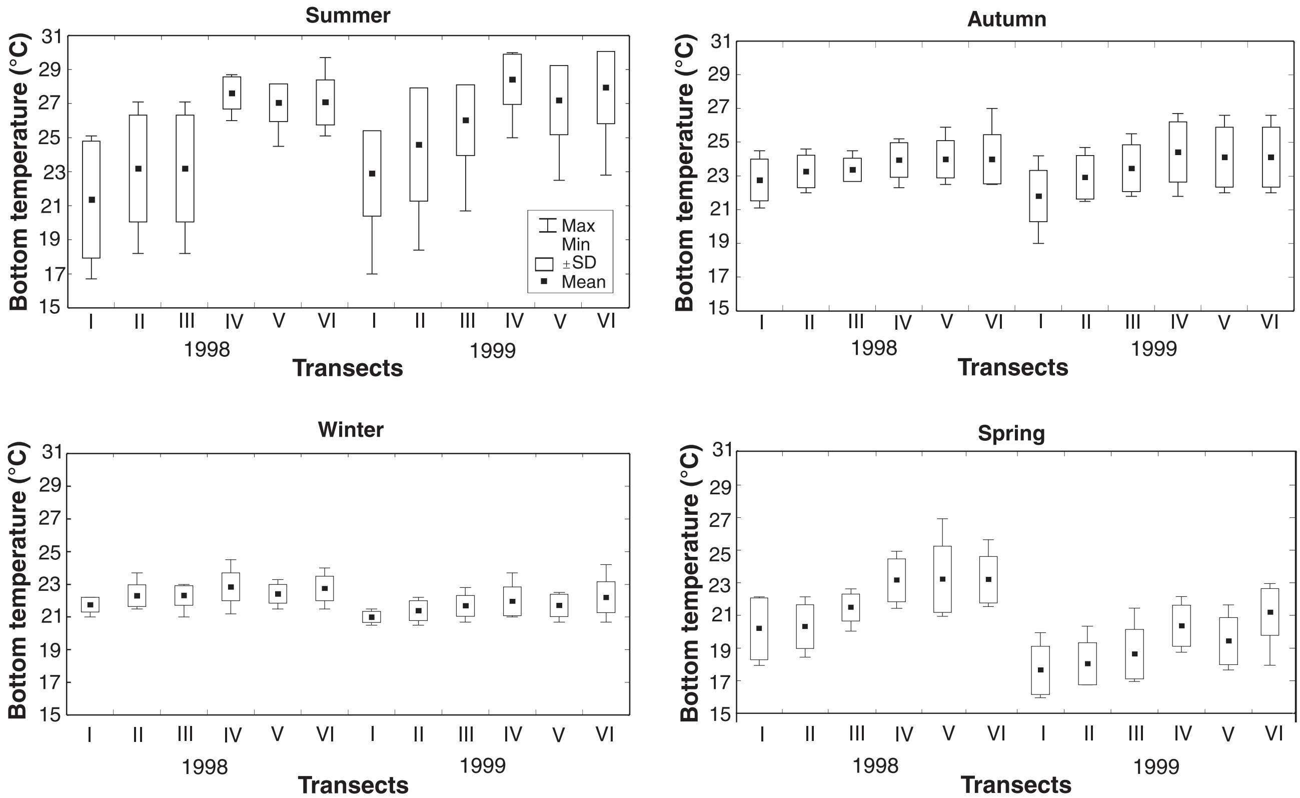

Figure 3. Boxplots showing mean, standard deviation, maximum and minimum temperature values (°C) for each transect and season in 1998 and 1999.

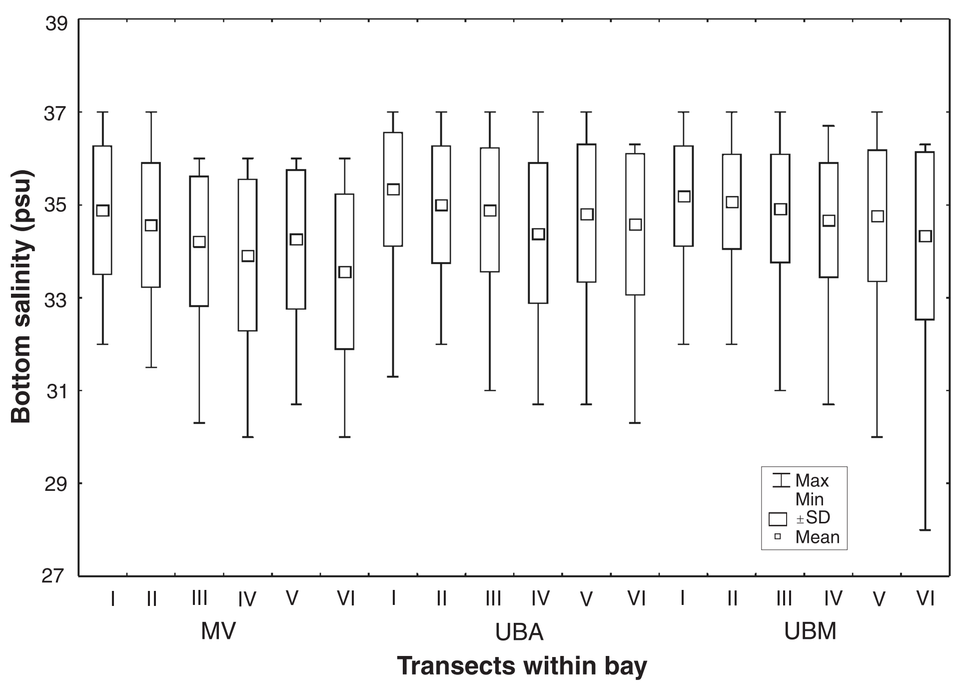

Figure 4. Boxplots showing mean, standard deviation, maximum and minimum salinity values (psu) for each transect within each bay in 1998 and 1999. MV = Mar Virado, UBA = Ubatuba, UBM = Ubatumirim.

TABLE 2

Results of the analysis of variance of the mean catch (data $\log_{10}$-transformed) of *Sicyonia dorsalis* by year, bay, transect or season.

Source	df	MS	F	p
Bay	2	2.21	2.47	0.0855
Transect (bay)	15	6.42	7.20	0.0001
Year	1	1.24	1.38	0.2403
Season	3	37.71	42.27	0.0001
Season x Year	3	9.23	10.34	0.0001

DISCUSSION

Castro-Filho et al. (1987) showed that the study region is strongly influenced by 2 types of water currents: coastal waters (CW) and tropical waters (TW). These currents occur during fall and winter, causing an increase in water temperature and salinity to over 21 ºC and 35 psu, respectively. Also, another current occurs throughout late spring and summer, the South Atlantic Central Water (SACW), causing decreases in water temperature (< 20 ºC) and bottom salinity (< 35). The incursion of the TW into the uppermost water layers and the dislocation of the CW towards the ocean during the fall and winter cause vertical mixing and thus eliminate the existing seasonal thermocline, causing the SACW to recede towards the offshore region.

The intrusion of SACW was detected in this study during spring and summer at 10 and 15 m isobaths. Our results indicate that fluctuations in the seasonal and bathymetric distribution of *S. dorsalis* were influenced by variation in water temperature caused by these currents. When intruding into the bays, SACW causes a decrease in water temperature and confinement of the shrimp in shallower areas (< 15m). Similar results were also reported for the shrimp *Xiphopenaeus kroyeri* (Heller, 1862) by Nakagaki and Negreiros-Fransozo (1998), *Rimapenaeus constrictus* (Stimpson, 1874) by Costa and Fransozo (2004), and the "argentinean" shrimp *Pleoticus muelleri* Bate, 1888 by Costa et al. (2004), all in Ubatuba bay. In contrast, during late summer and autumn, when bottom-water temperature increased, a few specimens were captured in shallower areas. It may be inferred that the elevation of water temperature during these periods caused the migration of shrimp to the outer areas of the bays

In spite of the association found between the abundance of *S. dorsalis* and low salinity conditions, there is no evidence of a direct influence of salinity in the distribution of this species. Past biological studies on *S. dorsalis* were restricted to bathymetric distribution, and occurrences on sediment type (Williams 1984, Sanchez and Soto 1985, D'Incao 1995). Only Gunter (1950) and Fransozo et al. (2002) have focused on the influence of salinity and stated that *S. dorsalis* were captured in areas where salinity was > 33.5 psu. However, Gunter (1950) found only 10 individuals 8.05 km offshore in the Gulf of Mexico in Texas, and Fransozo et al. (2002) found 35 individuals in Fortaleza bay, Ubatuba, São Paulo. According to our results and the bathymetric distribution mentioned for this species, we suggest that it prefers areas with values above 30 psu. Pérez Farfante (1985) also pointed out that other congeneric species such as *S. brevirostris* Stimpson 1871 and *S. ingentis* (Burkenroad, 1938) occur in waters of high salinity (33 to 35 psu) and that these shrimps do not depend upon estuarine waters for their life cycle.

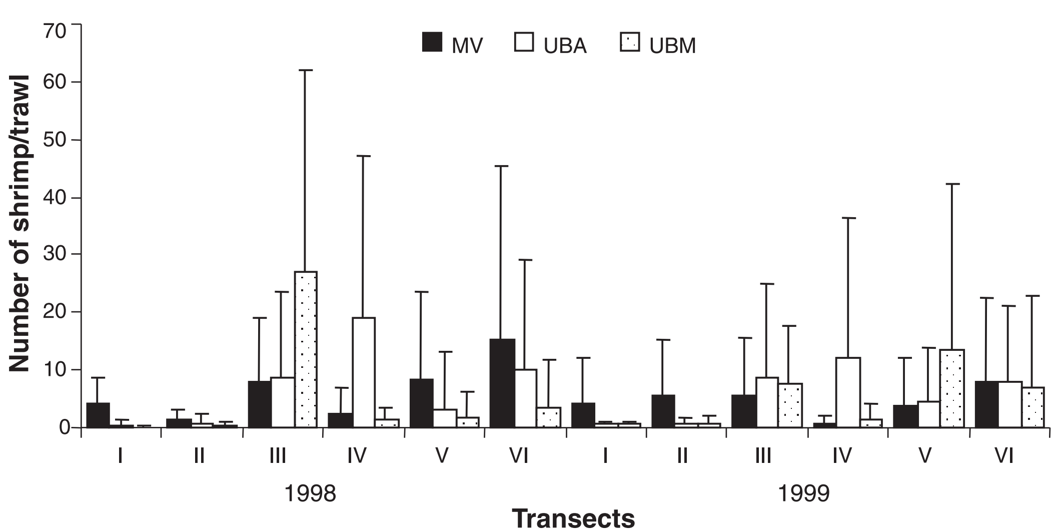

Figure 5. Mean number of shrimp by bay and transect during 1998 and 1999. MV = Mar Virado, UBA = Ubatuba, UBM = Ubatumirim.

TABLE 3

Monthly catch of *Sicyonia dorsalis* with each bay in 1998, 1999, and total catch for each season. Results of the ANOVA are shown for each season. Abundance followed by the same letter in the column (Season) do not differ statistically (*P* > 0.05). MV = Mar Virado; UBA = Ubatuba; UBM = Ubatumirim.

	Bays								
Month	**MV**		**UBA**		**UBM**		**Total**		**Season**
Year	**98**	**99**	**98**	**99**	**98**	**99**	**98**	**99**	**Total**
January	1	112	20	61	8	35	29	208	Summer/98 = 58 a
February	9	64	10	80	2	28	21	172	Summer/99 = 394 b
March	3	8	5	3	0	3	8	14	
April	1	0	2	2	2	32	5	34	Fall/98 = 38 a
May	2	4	1	4	5	2	8	10	Fall/99 = 45 a
June	2	0	11	0	12	1	25	1	
July	8	4	21	6	25	3	54	13	Winter/98 = 251 b
August	44	4	34	26	23	1	101	31	Winter/99 = 66 a
September	32	4	34	12	30	6	96	22	
October	40	19	44	31	21	7	105	57	Spring/98 = 1038 c
November	85	50	31	26	81	98	197	174	Spring/99 = 608 bc
December	240	68	296	162	200	147	736	377	
Total	467	337	509	413	409	363	1385	1113	2498

The abundance of *S. dorsalis* in the bays does not differ statistically, although it was higher in UBA bay, followed by MV bay. This probably results from the higher content of silt and clay in those areas. The more sorted sediments in the other sites, as for transect III in UBM and transect VI in UBA, are apparently preferred by this species, and appear to favor establishment of populations. Similar results were obtained by Sánchez and Soto (1987) for a population of *S. dorsalis* in the Gulf of Mexico and Pérez Farfante (1985) for the geminate species, *S. disdorsalis* (Burkenroad, 1934), in the eastern Pacific where shrimps were found associated with muddy sediments.

In transects where the number of shrimps was highest, besides the prevalence of silt + clay, we observed that these sites are located in a more sheltered area of each bay. Because of the particular hydrodynamics acting on these areas, water currents are weak at transects VI in MV bay, at transects III and V in BM and transects III, VI, and mainly IV, in UBA bay. This favors the deposition of fine sediments, and consequently allowing settlement of *S. dorsalis*.

TABLE 4

Results of a multiple linear regression among environmental factors and the number of *Sicyonia dorsalis*.

Environmental factors	t	*P*
bottom temperature (°C)	–2.951	0.0033
bottom salinity (psu)	–2.918	0.0037
depth (m)	–0.808	0.4200
organic matter	–0.338	0.7360
phi (f)	3.585	0.0004

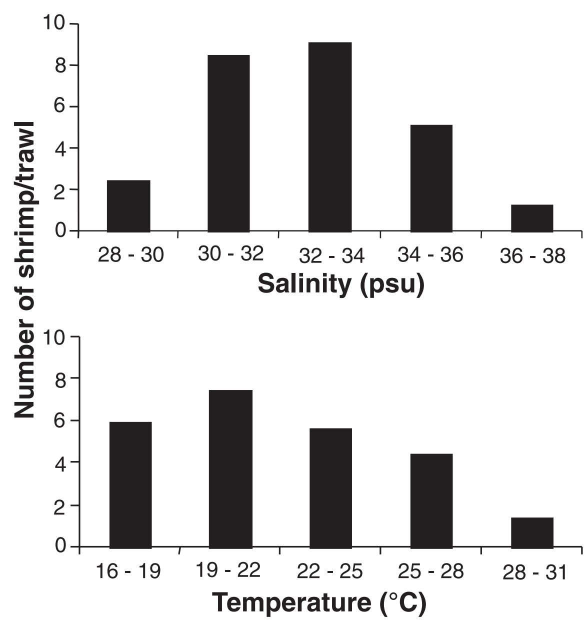

Figure 6. Plot of the mean number of shrimp in each salinity and water temperature class per trawl.

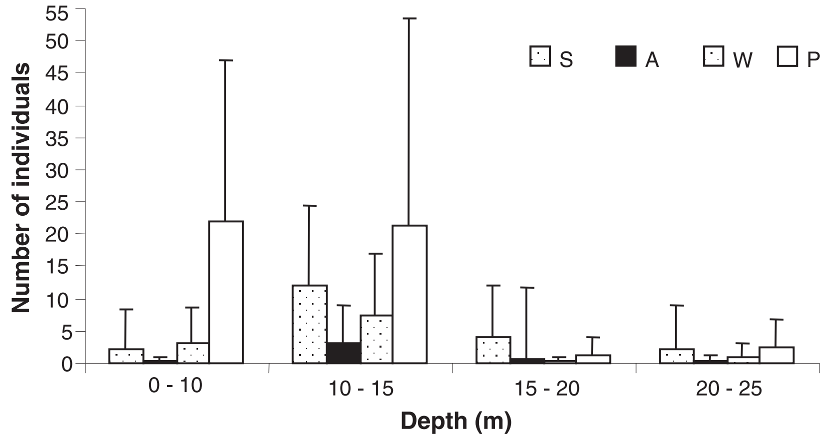

Figure 7. Distribution of the mean (±sd) number of shrimp by depth class per trawl by season (S = summer, A = autumn, W = winter, P = spring).

The spatial distribution of many penaeidean shrimps is mainly influenced by texture and organic content of the substratum (Dall et al. 1990). However, the organic matter content of sediments does not seem to affect the distribution of *S. dorsalis* for this area. The data obtained in the present study has confirmed the influence of texture of the sediment, therefore the distinct features of the sediment in each bay contributes in a significant way to the occurrence of the shrimps along the studied region. The distribution of the penaeids species *Metapenaeus macleayi* (Hasweell, 1879), *Penaeus monodon* Fabricius, 1798, *Penaeus esculentus* Haswell, 1879, *P. semisulcatus* De Haan, 1884 and *R. constrictus* are more influenced by grain size than by the availability of food (Ruello 1973, Brandford 1981, Somers 1987, Costa and Fransozo 2004). Although water temperature and sediment type offer a most convincing explanation for distributional patterns of *S. dorsalis*, it is important to realize that other factors such as diurnal and nocturnal variation, competition and predation may also influence its distribution.

ACKNOWLEDGMENTS

We are grateful to the Fundação de Amparo à Pesquisa do Estado de São Paulo for providing financial support (#94/4878-8, #97/12108-6, #97/12106-3, #97/12107/0 and #98/3134-6). We are also thankful to the NEBECC coworkers for their help during field work, to Dr. L. Trinca (Biostatistics Department, Biosciences Institute, UNESP) for her statistical support, and to F.A.M. Freire for his assistance with the map illustration. All collections in this study were conducted in compliance with current applicable state and federal laws.

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