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Ecological distribution of the shrimp *Pleoticus muelleri* (Bate, 1888) (Decapoda: Penaeoidea) in southeastern Brazil

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Abstract

The abundance and ecological distribution of the shrimp *Pleoticus muelleri* as a function of certain environmental factors were investigated from January 1998 through December 1999 in the region of Ubatuba, São Paulo, Brazil. The collections were made monthly in the bays of Ubatumirim (UBM), Ubatuba (UBA) and Mar Virado (MV). Each bay was divided into six sampling transects, four transects parallel to the shoreline and two near the rocky shores on the opposite side. We employed a commercial shrimp boat equipped with two double-rig nets. A total of 6252 shrimp were collected, including 3321 from MV, 1467 from UBM, and 1464 from UBA. Most of the shrimp were caught in the deeper, higher-salinity areas. The high abundance of *P. muelleri* observed in the southern part of the region studied was related to a sediments with a higher percentage of silt and clay. The numbers of *P. muelleri* were positively correlated with periods of cooler temperatures. Thus, temperature and the type of sediment were determinant factors in the distribution of *P. muelleri* in this region.

Introduction

The shrimp *Pleoticus muelleri* Bate, 1888 is commercially important along the Argentinean coast, with annual production around 12,000 tons (Macchi *et al.*, 1992). According to D'Incao et al. (2002), the shrimp fisheries of southeastern Brazil target more profitable species such as the pink shrimp [*Farfantepenaeus brasiliensis* (Latreille, 1817) and *F. paulensis* (Pérez-Farfante, 1967)], the white shrimp [*Litopenaeus schmitti* (Burkenroad, 1936)], and the seabob shrimp [*Xiphopenaeus kroyeri* (Heller, 1862)]. The growth of the fishing fleet and the decrease in catches of normally exploited species have contributed to the increasing interest in *P. muelleri*.

Pleoticus muelleri has a wide geographic distribution along the Atlantic coast from 20° S, Espírito Santo, Brazil, to 50°, Santa Cruz, Argentine Patagonia (Boschi, 1989). Its greatest concentrations occur along the Patagonian coast, in areas with temperatures between 6 and 20 °C and salinity between 31.5 and 33.5‰ (Boschi, 1986). Several environmental factors, such as food availability, sediment type, salinity, depth, and temperature, are fundamental parameters affecting its spatial and temporal distribution (Boschi, 1963). In addition, Dall et al. (1990) verified that the migrations within the biological cycles of each shrimp species are of utmost importance in influencing the temporal, spatial, and seasonal distribution.

Few studies have focused on shrimps in the coastal areas of the state of São Paulo, Brazil, particularly their ecological aspects, as well as examining the best seasons for harvest and the sites with greatest concentrations. Most of the studies (Nakagaki & Negreiros-Fransozo, 1998, Fransozo et al., 2000; Castro et al., in press) have treated the population and reproductive biology of *Xiphopenaeus kroyeri*. Some other shrimp species have been mentioned; for instance, Costa & Fransozo (2004) evaluated the abundance and the ecological distribution of *Rimapenaeus constrictus* (Stimpson, 1874). Costa et al. (2000) and Fransozo et al. (2002, in press) investigated the composition and abundance of penaeoideans and the ecological distribution of *Artemesia longinaris* Bate, 1888; all in the region of Ubatuba.

There have been no ecological studies on *P. muelleri* along the coast of São Paulo. Therefore, the objective of this work was to verify the ecological distribution of this species as a function of selected environmental factors.

Material and methods

Shrimp were collected monthly from January 1998 to December 1999 at Mar Virado (MV), Ubatuba (UBA), and Ubatumirim (UBM) bays, located in the Ubatuba region. Each bay was divided into six subareas (transects), selected based on their relation to the bay mouth, the presence of a rocky outcrop or a beach along the shore, the inflow of fresh water, the proximity of offshore water, depth, and sediment texture. Four transects were located at mean depths of 5 (IV), 10 (III), 15 (II), and 20 m (I), and the other two transects were sited adjacent to rocky shores (an exposed and a sheltered shore, transects V and VI, respectively) (Fig. 1). A shrimp trawler equipped with two double-rig nets (mesh size 20 and 15 mm in the cod end) was used. Each transect was trawled over a 30-min period.

Salinity (‰) and temperature (°C) were measured in bottom-water samples, obtained monthly on each transect using a Nansen bottle. An ecobathymeter coupled with a GPS was used to record the depths at the sampling sites. Sediment samples were collected each season with a Van Veen grab, enclosing a bottom area of 0.06 m^2. Grain size categories followed the American standard, for which sample 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); 0.0625 mm (very fine sand), and smaller particles classified as silt-clay. Grain-size fractions were expressed on the phi (ϕ) scale, thus accounting for the central tendency of sediment samples. Procedures for sediment analysis followed Hakanson & Jansson (1983) and Tucker (1988).

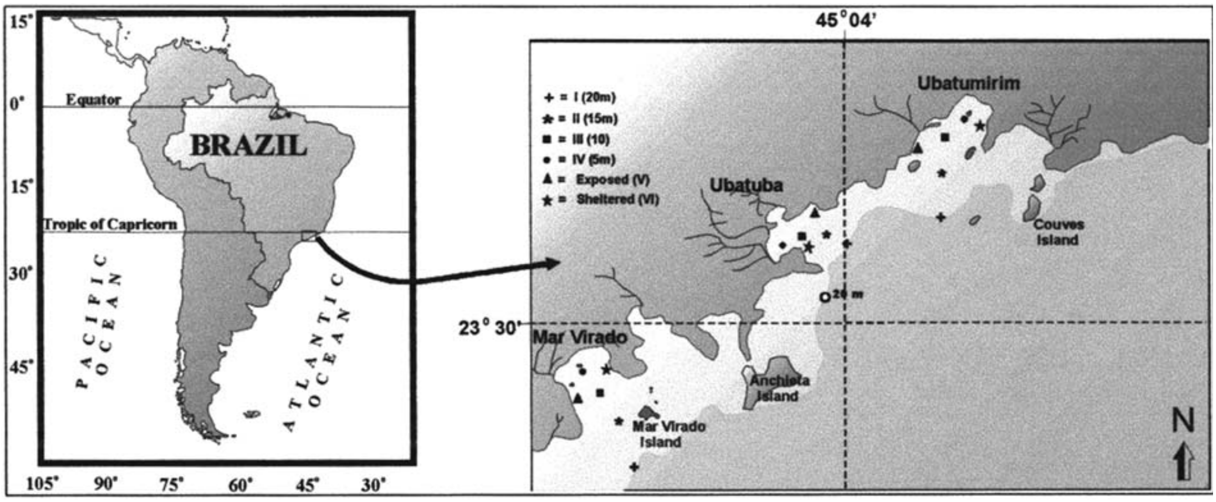

Figure 1. Map of the region indicating collection localities.

Sediment texture was graphed on a triangular diagram using the three most representative granulometric classes, as in Magliocca & Kutner (1965). Granulometric class A corresponds to sediments in which intermediate sand (IS), coarse sand (CS), very coarse sand (VCS), and gravel (G > 0.25 mm) account for more than 70% by weight. In class B, fine sand (FS) and very fine sand (VFS) make up more than 70% by weight of sediment samples (0.25—] 0.0625 mm). More than 70% of sediments in class C are silt and clay (S + C). These three categories are further combined to form six different groups:

PA = (IS + CS + VCS + G) > 70%;
PAB = prevalence of A over B (FS + VFS);
PAC = prevalence of A over C (S + C);
PB > 70%;
PBA = prevalence of B over A;
PBC = prevalence of B over C;
PC > 70%;
PCA = prevalence of C over A;
PCB = prevalence of C over B.

The abundance of shrimps was compared among years, bays, transects, and seasons of the year using analysis of variance (Anova). The influence of environmental factors on species abundance was evaluated by multiple linear regression, and was also compared by analysis of variance (Anova). Thus, the data were transformed by natural logarithm for the purpose of satisfying the premises of the analyses. All statistical procedures followed Zar (1999), and the significance level adopted was $p < 0.05$.

Results

The mean depths of the transects were: I (22.2 m), II (16.5 m), III (11.6 m), IV (5.9 m), V (9.2 m) and VI (6.8 m).

The mean values of sediment composition varied from sand to silt + clay. As indicated in Table 1, greater quantities of silt + clay occurred in the southernmost part of the study area.

In Mar Virado, the silt + clay fraction predominated on all transects (phi > 4.0), comprising the greatest part with more than 75% of the sample (Table 1, Fig. 2). In Ubatuba and especially Ubatumirim, fine and very fine sand associated with silt + clay predominated, except for transects IV (PC) and VI (PCA) in Ubatuba and I (PA) in Ubatumirim. In general, the highest organic matter contents were measured on transects III, IV, V and VI; the lowest were transects I and II (Fig. 3).

There was a clear difference in the temperatures at depth, between the transects during the spring and summer. The temperatures on transects I and II were lower than on IV and VI (Fig. 4). There were no other differences in mean temperatures during the other seasons.

The variations in mean salinity are presented in Figure 5. Numerical differences among the bays are evident; the lowest mean salinities were recorded in Mar Virado. In general, the widest variations in salinity were found on transects I, and the least on transects IV and VI.

The monthly abundances of *P. muelleri* in the bays are listed in Table 2. The results of the

Table 1. Pleoticus muelleri. Groups of sediment classes, quantity of mud (% silt-clay) and number of shrimp by trawl (*n*) on each transect in each bay sampled from 1998 to 1999 (see text for definitions and abbreviations)

Transects	Bays								
	Mar Virado			Ubatuba			Ubatumirim		
	Group	% Mud	*n*	Group	% Mud	*n*	Group	% Mud	*n*
I	PCB	46.8	22	PB	16.0	9.6	PA	2.6	13.6
II	PC	75.3	101.7	PB	21.2	23.3	PBC	23.9	16.8
III	PC	88.3	4.4	PCB	61.9	11.2	PBC	35.7	28.9
IV	PC	81.2	4.3	PC	76.3	1.0	PCB	49.6	0.2
V	PC	79.7	5.8	PCB	47.3	15.3	PB	22.2	0.8
VI	PCB	64.4	0.2	PCA	36.8	0.7	PBC	33.4	0.8
Total			23.1			10.2			10.2

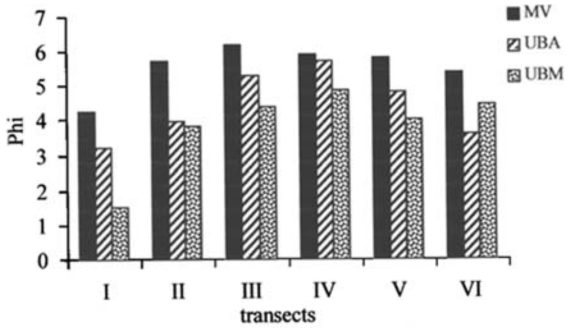

Figure 2. Mean grain diameter of sediment (phi) of each transect in each bay sampled. (MV = Mar Virado, UBA = Ubatuba, and UBM = Ubatumirim).

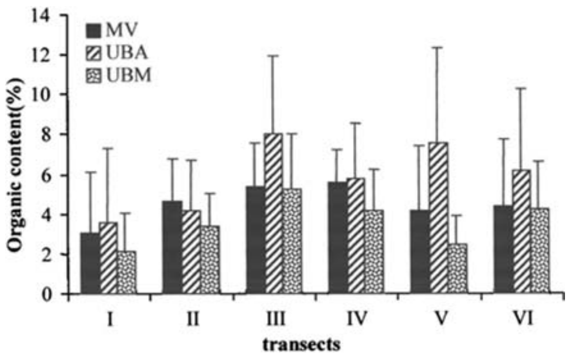

Figure 3. Mean values of organic matter content of the sediment (%) of each transect in the three bays sampled (MV = Mar Virado, UBA = Ubatuba, and UBM = Ubatumirim).

analysis of variance comparing the abundance of shrimp among bays, years, transects, and seasons are presented in Table 3.

During the sampling period 6252 shrimps were caught. In the first year of collection ($n = 376$) the shrimp occurred mainly on transects I and II. The second year ($n = 5876$) showed a significant increase ($p < 0.05$). There were no significant differences among the bays.

In MV and UBA, almost all individuals of *P. muelleri* were caught on transects I and II. In Ubatumirim Bay, the most individuals were collected on transect III (Fig. 6). These transects differed, principally relative to transects IV and VI of the three bays, including transect V of Ubatumirim (Anova, $p < 0.05$).

In 1998, although more shrimp were caught in autumn, the differences among seasons were not significant. In the second year, more shrimp were caught in the final periods of autumn and spring; this increase was statistically significant, in relation to other periods, as well as with the seasons of 1998 (Anova, $p < 0.05$, Table 2).

As shown in Figure 7, *P. muelleri* was recorded mainly at salinities between 34‰ and 38‰ and at temperatures below 22 °C. We obtained the most individuals of this species in areas with higher percentages of silt and clay.

Multiple linear regression analysis showed that the environmental variables relating to the abundance of *P. muelleri* were ($r = 0.53$, $p = 1.23^{E-29}$, $F = 41.896$). The parameters which proved significant in the abundance of this species were bottom temperature, depth, salinity at depth, and the central tendency of the sediment (Table 4). The following equation expresses this relationship:

$$A = -5.29 - 0.16t + 0.22s + 0.08d + 0.28\phi,$$

where: A = abundance; t = bottom temperature; s = bottom salinity; d = depth; ϕ = phi.

Discussion

The difference in the distributional model of *P. muelleri* seems to be associated with the spatial and seasonal fluctuations of temperature, salinity, and sediment type.

The present study was confined to the inner area of the bays, where depths do not exceed 25 m. According to Castro-Filho et al. (1987), this region is directly influenced by the dynamics of Coastal Waters. This water mass is characterized by temperatures higher than 20 °C and salinity always below 36‰. Apart from this current, the cool South Atlantic Central Waters (SACW), always below 20 °C, prevail during summer, penetrating deeper areas up to nearby, shallower coastal zones and forming a sharp thermocline. The intrusion of SACW was detected in this study during spring and summer at the 10- and 15-m isobaths.

Our results suggest that bottom temperature may be the main factor influencing the temporal distribution of *P. muelleri*. In the second year of sampling, mainly during spring, we recorded lower temperatures, and obtained the largest hauls of this shrimp. At this time of year, temperatures are

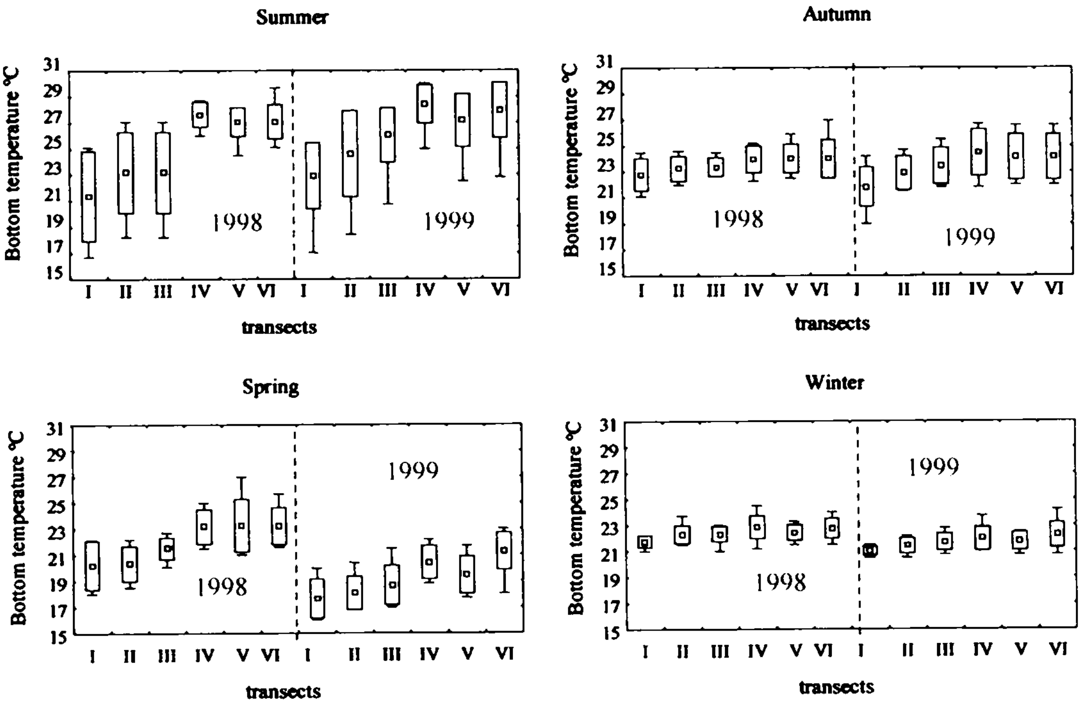

Figure 4. Bottom temperature, mean, maximum, and minimum for each transect and season of the year, during the sampling period.

Table 2. Pleoticus muelleri: monthly catch of shrimp in each bay from 1998 to 1999 and total catch for each season; seasons with at least one of the same letters did not differ statistically (ANOVA; $p < 0.05$)

Months	Bays									
	MV		UBA		UBM		Total		Season	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Jan	19	158	0	6	3	19	22	183	Summer	
Feb	9	37	4	3	1	25	14	65	71^{a}	252^{ac}
Mar	3	4	10	0	22	0	35	4		
Apr	107	2	15	18	6	93	128	113	Fall	
May	15	168	5	20	6	11	26	199	196^{ac}	2090^{b}
Jun	16	707	11	631	15	440	42	1778		
Jul	3	138	0	81	0	170	3	389	Winter	
Aug	4	4	0	30	2	62	6	96	16^{a}	572^{c}
Sep	5	25	0	30	2	32	7	87		
Oct	5	364	0	121	0	106	5	591	Spring	
Nov	38	364	6	276	2	154	46	794	93^{a}	2962^{b}
Dec	3	1123	27	170	12	284	42	1577		
Total	227	3094	78	1386	71	1396	376	5876	6252	

Table 3. Results of the analysis of variance for the mean number of *P. muelleri* collected (log-transformed)

Source	GL	QM	*F*	*p*
Bay	2	2.21	1.76	0.1741
Transect (bay)	15	7.74	6.15	0.0001
Year	1	99.20	78.82	0.0001
Season	3	10.23	8.13	0.0001
Season vs. year	3	5.15	4.09	0.0071

GL = degrees of freedom; QM = mean square; F = Qm factor/QM residual and p = probability of significance.

close to those in the temperate zone of Argentina, where this species is very abundant. As Boschi (1969, 1989) stated, *P. muelleri* prefers temperatures below 20 °C and is abundant at temperatures from 10 to 15 °C on the Argentine coast.

According to Nakagaki et al. (1995), Costa et al. (2000) and Fransozo et al. (2002), *P. muelleri* together with *A. longinaris* can be considered as indicator species of the inbound cold waters of the SACW. Fransozo et al. (in press) assumed that reductions in the bottom temperature in Fortaleza Bay, Ubatuba, which is near the study site, cause modifications in the bathymetric distribution of *A. longinaris*, favoring its migration and establishment in shallow waters.

In Argentinean waters, *P. muelleri* is found from shallow waters to 130 m (Boschi, 1989). In the Ubatuba region, this species was almost

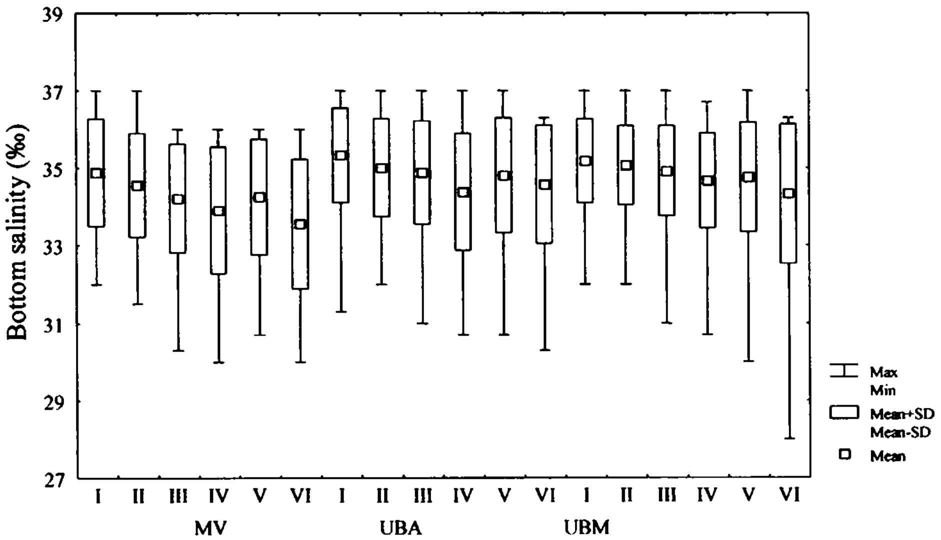

Figure 5. Bottom salinity, mean, maximum, and minimum for each transect, in the three bays sampled from 1998 to 1999 (MV = Mar Virado, UBA = Ubatuba, and UBM = Ubatumirim).

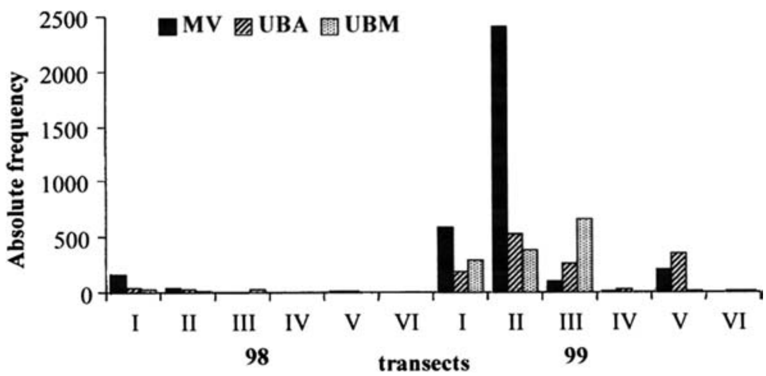

Figure 6. Pleoticus muelleri: distribution of the number of shrimp caught on each transect in the three bays from 1998 to 1999.

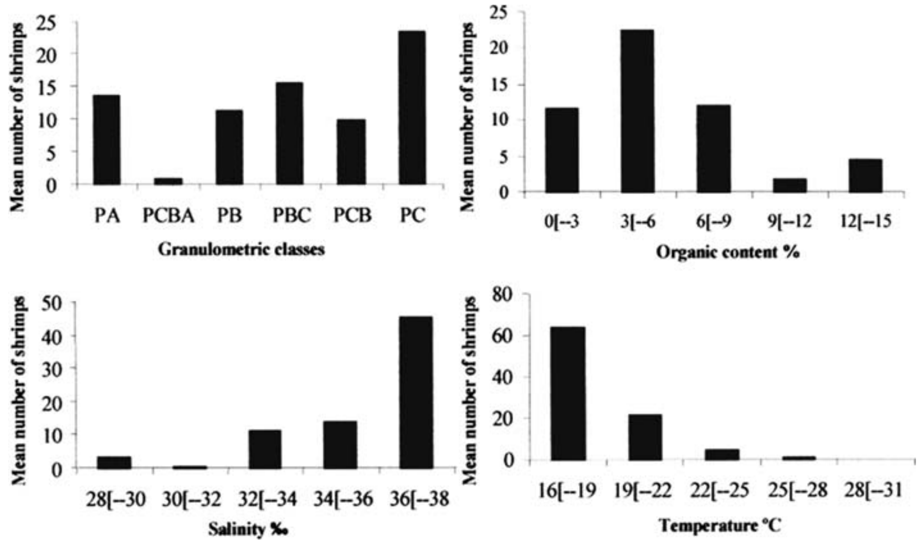

Figure 7. Pleoticus muelleri: distribution of the mean number of shrimp in each class of the abiotic factors.

Table 4. Environmental factors which were significantly correlated with the abundance of *P. muelleri* ($p < 0.05$)

Environmental factor	'*t*'	'*p*'
Bottom temperature	−6.885	-2.07^{E-11}
Bottom salinity	5.058	6.31^{E-07}
Depth	6.018	$3.8E^{-09}$
phi (ϕ)	4.086	$5.25E^{-25}$

exclusively restricted to deeper bays and salinities above 34‰. Small shrimps were encountered close to the coastal areas even during the periods where the sediment type was favorable to the establishment of this species. The combination of lower salinity and high temperature in shallow coastal waters may prevent *P. muelleri* from entering sites shallower than 15 m. This distribution suggests a type-3 life cycle (Dall et al., 1990), i.e., which proceeds from inshore to offshore without the need for lower salinities to complete their cycle.

In the region of Ubatuba, although both *A. longinaris* and *P. muelleri* are numerous, their relative abundance differs among bays. *A. longinaris* tolerates higher temperatures than *P. muelleri*, preferring a sediment mostly composed of fine and very fine sand, as in Ubatuba Bay. The greater abundance of *P. muelleri* in MV Bay is probably due to the higher silt-clay content in that area. The better-sorted sediments in the other embayments, such as on transect VI in UBA, are apparently not preferred by this species. No correlation was observed between organic matter content and the abundance of this shrimp.

For the majority of the penaeoid shrimps, several investigators, among them Brandford (1981a,b), Rulifson (1981), Somers (1987), Stoner (1988) and Dall et al. (1990), have pointed out that the spatial distribution of the species is mainly influenced by the texture and organic content of the substratum. The data obtained in the present study confirmed the influence of sediment texture. Therefore the distinct features of the sediment in each bay contribute significantly, to the representation of the shrimps among the areas studied.

This environmental factor seems to be strongly related to the capacity of the shrimps to circulate water through its branchial chamber when they are buried. Other species of *Penaeus*, such as *P. indicus* H. Milne Edwards, 1837, *P. merguiensis* De Maan, 1888, and *P. setiferus* Linnaeus, 1767, do not seek to embed themselves in very soft sediments, because they are unable to reverse the water current that passes through their branchial chamber to prevent clogging (Penn, 1984).

The ecological distribution of *P. muelleri* revealed an intimate relationship with the environmental parameters analyzed, mainly with temperature, salinity, and the type of sediment.

Probably, the variations in these factors were within the limits of toleration of this species, which favor the continuity of their physiological processes. Other studies such as on reproductive aspects may supply information for better understanding of the biology of these shrimps.

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