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Bathymetric distribution of brachyuran crab (Crustacea, Decapoda) communities on coastal soft bottoms off southeastern Brazil

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ABSTRACT: The communities of brachyuran crabs living on soft bottoms off Ubatuba in SE Brazil were studied with respect to their structure, bathymetric distribution, composition, diversity and indices of similarity. The data were analyzed using multivariate techniques of classification and ordination. Most of the individuals caught during summer were the swimming crab *Portunus spinicarpus* at the 35 m isobath, which contributed to the much-decreased diversity in this season and site. Multivariate analysis indicated that the species were distributed according to depth and also in relation to environmental gradients.

KEY WORDS: Sublittoral communities · Distribution patterns · Species composition · Crustacea · Brachyura

INTRODUCTION

According to Hecker (1990) and Schaff et al. (1992), the zonation of fauna living in soft bottom marine habitats is probably related to a complex group of physical and biological factors, with the relative importance of each factor varying among different areas. Aschan (1990), Hyland et al. (1991), Blake & Grassle (1994), Borg & Schembri (1999) and Soto et al. (1999) all suggested that variations in the composition of benthic communities are associated with the depth gradient. Diversity in benthic marine communities may be linked to many factors such as productivity, trophic relationships and biological interactions, which vary in importance according to depth (Rex 1981).

Although the number of researchers dealing with the ecology of decapod crustaceans has increased in recent years, information on the bathymetric distribution of their communities is still scarce. In the region off Ubatuba in southeastern Brazil, only Pires (1992) and Sumida & Pires-Vanin (1997) have studied the distribution of benthic organisms as a whole, in association with environmental factors and depth gradients, to determine community structures. The present work analyzed the community structure of brachyuran crabs from the soft bottom sublittoral zone off Ubatuba, focusing on community composition in relation to depth, and diversity patterns. The influence of environmental factors on the species distribution patterns was also investigated.

MATERIALS AND METHODS

Data collection. Crabs were collected monthly from January through December 2000 from a shrimp boat equipped with 2 otter-trawl nets (double-rig) with the following net specifications: length 11 m, mouth 4.5 m, body mesh diameter 25 mm, cod-end mesh diameter 15 mm. Each of 9 transects (2 km each) was trawled for a 30 min period, sampling a total area of about 18 000 m^2. Four transects, which included the bays of Ubatumirim, Ubatuba and Mar Virado, were sampled once during each season of the year at the 2, 5, 10, and

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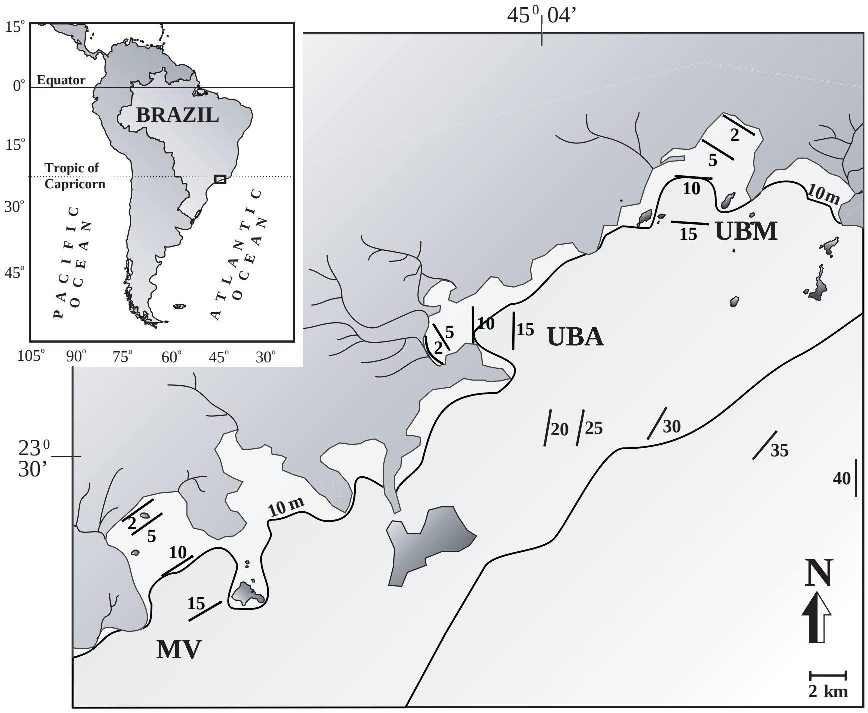

Fig. 1. The Ubatuba region, indicating the sampling depths in the bays of Ubatumirim (UBM), Ubatuba (UBA), and Mar Virado (MV) and in the outer zone (20 to 40 m)

15 m isobaths. Extra trawls were made monthly in the middle zones of these bays along the 20, 25, 30, 35 and 40 m isobaths (Fig. 1), here considered as an outer zone. An ecobathymeter coupled with a GPS was used to record the depths at the sampling sites.

After each trawl, the brachyuran crabs were sorted, placed in plastic bags, labeled, and stored on shaved ice. In the laboratory, specimens were counted and identified according to Melo (1996). The classification adopted for brachyurans was that of Martin & Davis (2001).

Salinity (‰) and temperature (°C) were measured in bottom-water samples, obtained each month for each transect, by means of a Nansen bottle.

Sediment samples were collected seasonally with a 0.06 m^2 Van Veen grab. In the laboratory, the sediment was oven-dried at 70°C for 72 h. For analysis of grain size composition, two 50 g sub-samples were separated, treated with 250 ml of a 0.2 N NaOH solution and stirred for 5 min to release silt and clay particles. Sub-samples were then rinsed on a 0.063 mm sieve. Sediments were sieved through 2 mm (gravel); 2.0–1.0 mm (very coarse sand); 1.0–0.5 mm (coarse sand); 0.5–0.25 mm (medium sand); 0.25–0.125 mm (fine sand); 0.125–0.063 mm (very fine sand); smaller particles were classified as silt-clay. Cumulative particle size curves were computer-plotted using the phi scale and phi values corresponding to the 16th, 50th and 84th percentiles were read from the curves to determine the mean diameter of the sediment. This was calculated by the formula Md = $(\varphi_{16} + \varphi_{50} + \varphi_{84})/3$. The value of phi was calculated by the formula $\varphi = -\log_2 d$, where d = grain diameter (mm).

The organic matter content of the sediment was calculated by the difference between the ash-free dry weights of three 10 g substrate subsamples incinerated in porcelain crucibles at 500°C for 3 hr.

All the procedures for sediment analysis followed Hakanson & Jansson (1983) and Tucker (1988).

Data analysis. Species diversity was calculated using the Shannon-Wiener index (Pielou 1966): $H' = \sum_{i=1}^{s} P_i \cdot \log_2 P_i$, where s is the number of species and P_i is the proportion of the ith species. Evenness (J') was calculated as indicated by Pielou (1975): $J' = H'/\log_2 s$.

Prior to the multivariate analysis, the data were simplified by eliminating species which appeared less than 3 times in the collections, as well as individuals which could not be identified to species level.

Cluster analysis was performed among species (mode R) and among sites (mode Q), using the Canberra metric similarity coefficient, after the data were square-root transformed (Lance & Williams 1967). The linking method utilized was unweighted-pair group averaging (UPGMA); this technique is commonly used in ecology and may be the best for translating affinity dendrograms of the original matrix (Gauch & Whittaker 1981).

The data were ordered by canonical correlation analysis (Gittins 1985) to reveal patterns among different depths and seasons of the year.

The statistical analyses were performed with the SAS statistical package (version 6.12) (SAS Institute 1996). The diversity index and the matrices of similarity were provided by the Krebs program (version 0.9) (Krebs 1998).

RESULTS

Environmental data

The sediment from the 20 and 35 m depths was poorly sorted and had a smaller mean diameter (phi) (Fig. 2). Sediment organic matter content varied with depth, with the highest mean percentage (6.2%) at 10 m and the lowest (2.1%) at 30 m (Fig. 3).

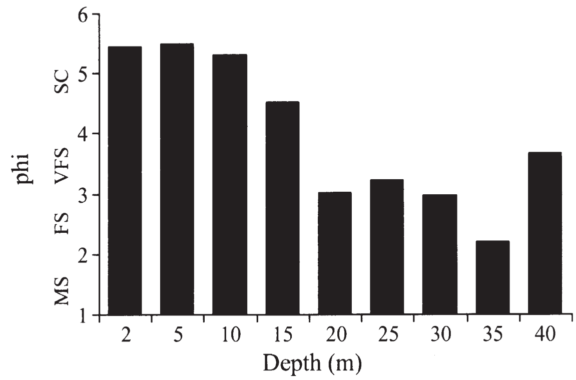

Fig. 2. Central tendency of bottom sediments represented by mean diameter (phi) for each sampled depth (MS = medium sand; FS = fine sand; VFS = very fine sand; SC = silt + clay)

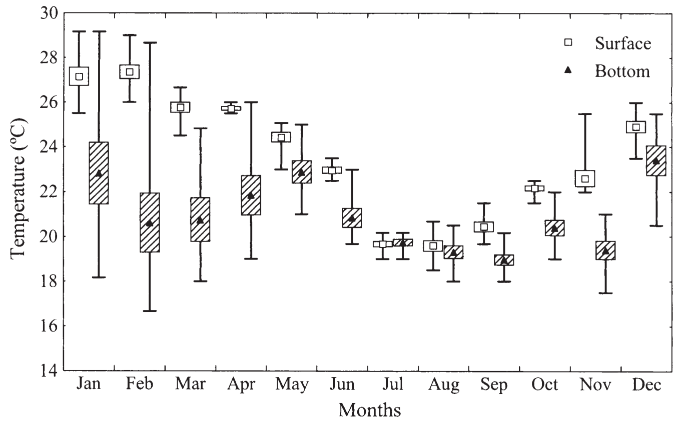

Fig. 5. Monthly means and ranges of variation of the surface and bottom water temperatures. (Box = standard error)

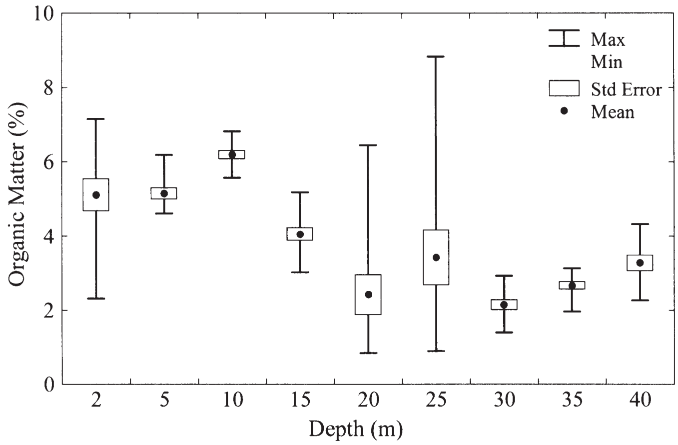

Fig. 3. Mean, maximum, and minimum content of organic matter for the sediments at each sampling depth

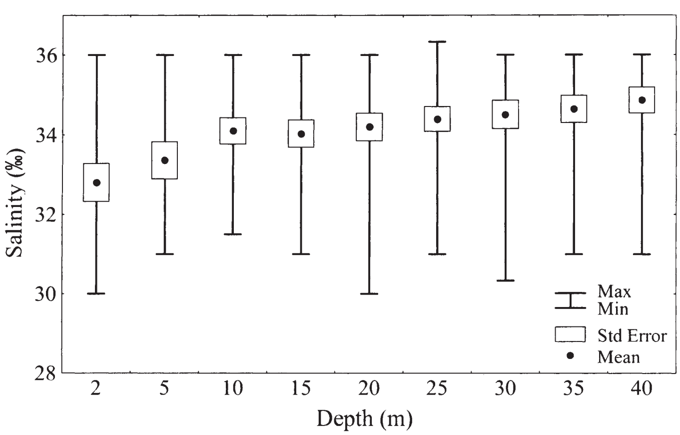

Fig. 4. Mean, maximum, and minimum salinity at each sampling depth

Mean bottom salinity was lowest at 2 m (33.1‰) and highest at 40 m (35.4‰) (Fig. 4).

Both surface and bottom temperatures (Fig. 5) underwent wide seasonal changes, with the lowest mean temperatures in winter (July through September).

Community analysis

The total catch of 9315 brachyurans included representatives of 9 superfamilies, 24 genera, and 38 species. Species records by season are represented in Table 1. The highest numbers of crabs were caught in summer, when the swimming crab *Portunus spinicarpus* was extremely abundant at the 35 m isobath.

Similar numbers of species were found at the different bottom depths. However, the species composition changed gradually with depth, mainly on bottoms deeper than 25 m. For example, the swimming crabs *Callinectes ornatus* and *Callinectes danae* occurred mainly in the inner areas; while *Leurocyclus tuberculosus*, *Parthenope pourtalesii*, *Portunus spinicarpus* and *Pilumnoides coelhoi* were restricted to the outer areas.

Table 2 lists the spatial distributions of the individual species. Only 3, *Hepatus pudibundus*, *Libinia spinosa* and *Pyromaia tuberculata*, appeared at all depths. *Portunus spinimanus* and *Callinectes ornatus* were never collected at 2 and 40 m, respectively.

The estimated diversity index was lowest at the 35 m isobath; a low evenness value (0.19) was obtained at this site, resulting in a lower estimated diversity (0.72) than at the other sites. The highest diversity was estimated at the 25 m isobath (2.51) because of the greater evenness of the data (0.68) (Fig. 6a). Diversity was lowest in summer because of the huge numbers of *Portunus spinicarpus* present at that time, which caused a decrease in evenness (Fig. 6b).

Table 1. Number of individuals of each crab species collected off Ubatuba from January through December 2000, by season

Superfamily/ Species	Season Summer	Fall	Winter	Spring	Total
Dromioidea					
Cryptodromiopsis antillensis	5		3	3	11
Homoloidea					
Homola barbata		1			1
Calappoidea					
Hepatus pudibundus	367	461	549	431	1808
Leucosioidea					
Persephona lichtensteinii	1				1
Persephona mediterranea	33	29	102	30	194
Persephona punctata	9		2	1	12
Majoidea					
Collodes rostratus			1		1
Libinia ferreirae			1	8	9
Libinia spinosa	172	97	69	36	374
Microphrys bicornutus	1	1	5	1	8
Notolopas brasiliensis			1		1
Pyromaia tuberculata	16	12	9	3	40
Pelia rotunda			2		2
Leucippa pentagona	4	4	3	1	12
Leurocyclus tuberculosus	10	57	7	12	86
Rochinia sp.			23		23
Rochinia gracilipes	16	19	1	6	42
Stenorhynchus seticornis			3	15	18
Parthenopoidea					
Parthenope aylthoni	1				1
Parthenope fraterculus	1		1		2
Parthenope pourtalesii		3		1	4
Portunoidea					
Arenaeus cribrarius	46	42	39	36	163
Callinectes sp.		1			1
Callinectes danae	124	191	242	65	622
Callinectes ornatus	931	219	1177	609	2936
Callinectes sapidus		3			3
Charybdis hellerii			3		3
Portunus ordwayi	1				1
Portunus spinicarpus	1800	334	183	135	2452
Portunus spinimanus	19	48	157	179	403
Xanthoidea					
Hexapanopeus paulensis	17	13	6	1	37
Hexapanopeus schmitti		3	3	2	8
Menippe nodifrons	1				1
Pilumnus reticulatus	1				1
Pilumnoides coelhoi	6	5	4		15
Pilumnoides hassleri	9		1	3	13
Pilumnoides perlatus	1				1
Pinnotheroidea					
Pinnixa sp.			2	3	5
Total of individuals	3592	1544	2599	1581	9315
Number of species	25	20	28	22	38

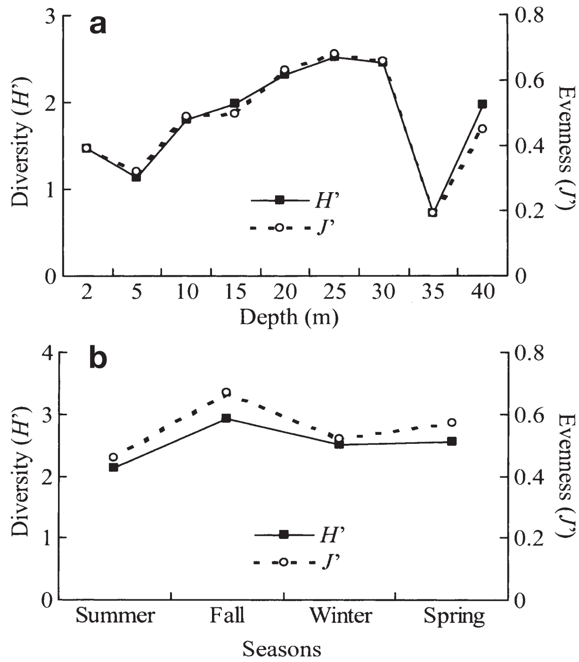

Fig. 6. (a) Spatial and (b) seasonal changes in diversity (H') and evenness (J') of the crab community off Ubatuba from January through December 2000

Canonical analysis

After the species caught in fewer than 3 collections were eliminated, the remaining 22 species were included in the multivariate analysis.

The canonical correlation analysis of species abundance (SP) and the environmental factors (EF) revealed 2 significant pairs ($p = 0.001$) of canonical variates, which together explained 88% of the total variation of the data. The coefficients of correlation between the original variables and the canonical variates (SP_1, SP_2, EF_1, EF_2) are listed in Table 3.

The canonical variate group for species of the first pair of canonical variates ($SP_1 \times EF_1$) was principally represented by 8 species, of which *Portunus spinicarpus*, *Rochinia gracilipes*, *Leurocyclus tuberculosus*, *Pilumnoides coelhoi* and *Pilumnoides hassleri* showed positive coefficients; while *Arenaeus cribrarius*, *Callinectes ornatus* and *Callinectes danae* showed negative coefficients. The canonical variate group for environmental factors (EF_1) was represented by a depth factor with a positive coefficient; bottom temperature and mean grain diameter (phi), both with negative coefficients. These results indicate that the

Table 2. Number of individuals of each crab species collected off Ubatuba from January through December 2000, by sampling depth

Superfamily/ Species	Depth (m) 2	5	10	15	20	25	30	35	40	Total
Dromioidea										
C. antillensis								8	3	11
Homoloidea										
H. barbata									1	1
Calappoidea										
H. pudibundus	52	127	244	593	228	232	53	15	264	1808
Leucosioidea										
P. lichtensteinii				1						1
P. mediterranea			6	73	59	46	3	1	6	194
P. punctata	2	2	5	3						12
Majoidea										
C. rostratus							1			1
L. ferreirae	1	6	1			1				9
L. spinosa	4	5	11	37	41	120	70	44	42	374
M. bicornutus			1	2	4		1			8
N. brasiliensis					1					1
P. tuberculata	2	1	4	6	3	4	8	5	7	40
P. rotunda		1		1						2
L. pentagona					1	4	1	2	4	12
L. tuberculosus						8	17	39	22	86
Rochinia sp.						2		19	2	23
R. gracilipes							1		41	42
S. seticornis									18	18
Parthenopoidea										
P. aylthoni									1	1
P. fraterculus								2		2
P. pourtalesii								2	2	4
Portunoidea										
A. cribrarius	77	32	17	26	11					163
Callinectes sp.	1									1
C. danae	448	117	46	5		6				622
C. ornatus	1010	1142	315	285	74	93	14	3		2936
C. sapidus	2				1					3
C. hellerii	2	1								3
P. ordwayi						1				1
P. spinicarpus				1		22	157	1640	632	2452
P. spinimanus		3	1	50	85	184	49	22	9	403
Xanthoidea										
H. paulensis	12	4	1	13			3		4	37
H. schmitti	4		3		1					8
M. nodifrons				1						1
P. reticulatus				1						1
P. coelhoi								3	12	15
P. hassleri					1			3	9	13
P. perlatus									1	1
Pinnotheroidea										
Pinnixa sp.	2								3	5
Total of individuals	1619	1441	655	1098	510	723	378	1808	1083	9315
Total of species	14	12	13	16	13	13	13	15	20	38

species with positive coefficients mainly occurred at greater depths (35 and 40 m), with lower temperatures and lower phi values. The species with negative coefficients occurred more often at the shallower sites, with higher temperatures and higher phi values (Table 3 & Fig. 7).

The second pairing, $SP_2 \times EF_2$, showed lower coefficients and was represented by 2 species with negative coefficients (*Parthenope pourtalesii* and *Portunus spinimanus*), and only one with a positive coefficient (*Rochinia gracilipes*) because of its phi factor.

Cluster analysis

The dendrogram of sample similarities (mode Q) showed 3 groups. Group A was formed by the outermost samples (35 and 40 m); group B by samples from the intermediate zone (20, 25 and 30 m); and group C by samples from the inner zone (2, 5, 10 and 15 m) (Fig. 8a).

The species groupings also revealed 3 groups, which were closely related to the sites of occurrence of these species. Group A was composed of 6 species, distributed mainly in the intermediate zone, with the exception of *Callinectes ornatus* which occurred most often at depths of 2 and 5 m, although it was found down to 35 m. Group B consisted of species which occur in the outermost zones and group C of species in the shallower areas (Fig. 8b).

DISCUSSION

According to Sumida & Pires-Vanin (1997), the changes in the benthic fauna off Ubatuba clearly follow the depth gradient and are probably related to changes in sediment, and the physical stability of the local water masses. Pires (1992) stated that between 10 and 40 m, sediment type is the predominant factor, and at depths over 40 m, temperature is the principal factor governing faunal distribution. Other studies in the region conducted by Paiva (1990) and Pires-Vanin (1993) also reported changes in macrofaunal composition between 10 and 100 m depth.

The estimated diversity varied with depth and was closely related to the evenness data. In the bays, the highest diversity estimated was at the 15 m isobath, where the sediment contained less silt and clay than in the shallower areas. Lower estimates of diversity were obtained in the 2 to 5 m zone, where the swimming crab *Callinectes ornatus* predominated. In the outer area, the index remained practically constant, with an exception at 35 m where the predominance of the swimming crab *Portunus spinicarpus* generated the lowest diversity value and evenness of the entire area sampled. *P. spinicarpus* reached its greatest abundance at this site during summer and is a good indicator of the cold Southern Atlantic Central Water (SACW) mass. The seasonal entry of SACW causes movements of water and organisms, and a marked change in water temperature. Similarly, Pires (1992) reported that *P. spinicarpus* represents about 90% of the megafauna in the area influenced by the SACW and that in summer, at a depth of 50 m, the diversity index was near zero because of the massive presence of this species.

The lower diversity values estimated for the zones shallower than 15 m were associated with the predominantly silt-clay sediments in these areas, whereas at depths over 20 m the sediment was more heterogeneous and diversity increased. Felder & Chaney (1979), Wenner et al. (1983) and Abelló et al. (1988) showed that sites with heterogeneous sediments support a greater diversity because of the wide variety of microhabitats formed within the substrate.

Menge & Sutherland (1976) explained that diversity gradients are linked to a dynamic interaction of predation, competition and the degree of heterogeneity (spatial and temporal) in the environment, where the predominant factors in any situation depend upon the trophic level of the group being analyzed and the total trophic complexity of the local community.

The results of the multivariate analysis indicated that the species of brachyuran crabs off Ubatuba are distributed mainly according to depth, water temperature and sediment texture. It was, therefore, possible to classify the study area into 3 zones, according to depth and the typical species at each site. The inner zone was characterized by the presence of species which mainly occur down to 15 m. The intermediate zone (20 to 30 m) harbors species with wide bathymetric distributions. The outer zone (35 to 40 m) harbors 9 species, of which only *Portunus spinicarpus*, *Leurocyclus tuberculosus* and *Leucippa pentagona* may occur (in lower numbers) in the shallower zones.

In the cluster analysis, some species served as indicators of the groups, when they were more frequent and abundant in a series of samples than in others. Per-

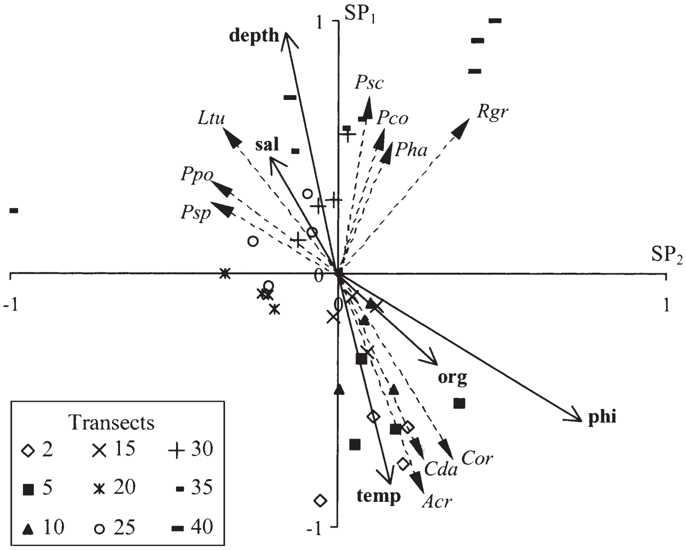

Fig. 7. Canonical variate analysis of sites, crab species, and environmental factors. (Abbreviations as in Table 3)

Table 3. Canonical analysis. Relationships between 5 environmental factors and 22 brachyuran species: correlation between the original variables and canonical variates. (Boldface = species with relatively high correlation coefficients)

Species	Abbreviation	Canonical variate SP_1	SP_2
P. spinicarpus	Psc	**0.66**	0.11
R. gracilipes	Rgr	**0.59**	**0.39**
L. tuberculosus	Ltu	**0.57**	−0.36
P. coelhoi	Pco	**0.55**	0.15
P. hassleri	Pha	**0.53**	0.15
L. spinosa	Lsp	0.43	−0.37
L. pentagona	Lpe	0.39	−0.04
C. antillensis	Can	0.38	−0.03
S. seticornis	Sse	0.36	0.02
P. tuberculata	Ptu	0.34	−0.07
P. portalesii	Ppo	0.33	**−0.39**
P. spinimanus	Psp	0.30	**−0.38**
P. mediterranea	Pme	0.009	−0.15
A. cribrarius	Acr	**−0.84**	0.29
C. ornatus	Cor	**−0.74**	0.30
C. danae	Cda	**−0.70**	0.25
H. schmitti	Hsc	−0.42	0.05
P. punctata	Ppu	−0.37	0.22
L. ferreirae	Lfe	−0.20	0.26
H. paulensis	Hpa	−0.10	0.20
H. pudibundus	Hpu	−0.09	0.21
M. bicornutus	Mbi	−0.08	−0.13
Environmental factors		EF_1	EF_2
Depth		**0.96**	−0.16
Salinity	sal	0.43	−0.23
Bottom temperature	temp	**−0.77**	0.18
Phi		**−0.60**	**0.73**
Organic matter	org	−0.36	0.31
Variance extracted		0.48	0.39
Canonical correlation coefficients		0.99	0.98

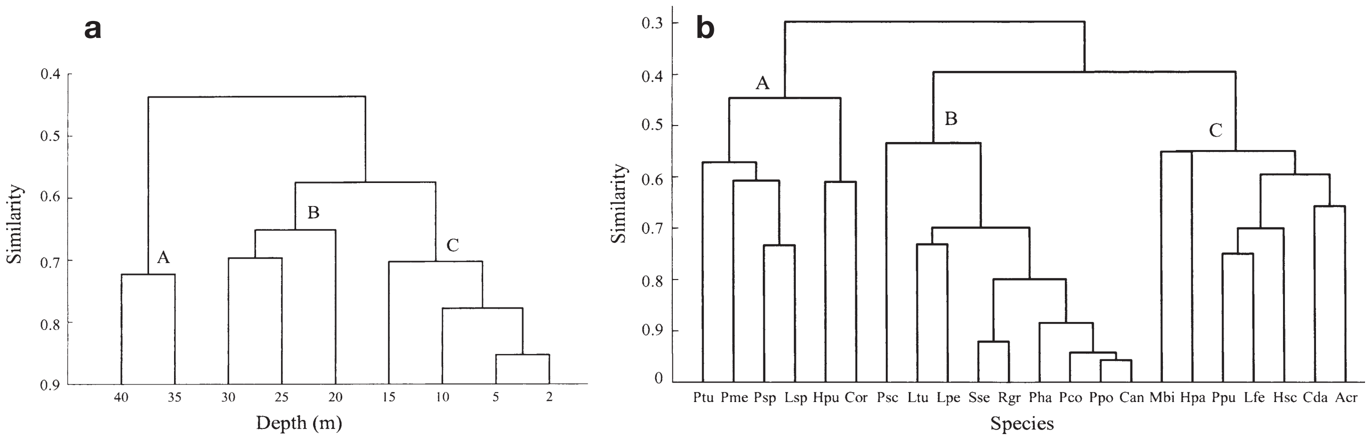

Fig. 8. Groups of (a) sample units and (b) species formed by cluster analysis (UPGMA, Canberra) (Abbreviations as in Table 3)

fect indicators would be when the species are present only in one group and do not appear in others (Field 1971). The swimming crabs *Callinectes danae* and *Arenaeus cribrarius* were indicator-species of the 2 to 15 m group, as they were more abundant and were associated with shallower depths, higher temperatures and finer sediments. Studies of the distribution of *A. cribrarius* by Pinheiro et al. (1996) and *C. danae* by Chacur & Negreiros-Fransozo (2001) also demonstrated that these environmental factors are associated with the greater abundance of this species.

In the intermediate zone, no indicator species was identified because all the species found here also occured in adjacent zones. One example is *Callinectes ornatus*: although 73% of the individuals were collected between 2 and 5 m, its distribution extended down to 35 m. This area apparently represents a transition between the bay interior and the open sea.

On the other hand, of the 9 brachyurans which formed the group characterizing the 35 to 40 m zone, 6 (*Stenorhynchus seticornis*, *Rochinia gracilipes*, *Pilumnoides coelhoi*, *Pilumnoides hassleri*, *Parthenope pourtalesii* and *Cryptodromiopsis antillensis*) can be considered perfect indicators because they occurred only at these depths. *Portunus spinicarpus*, *Leurocyclus tuberculosus* and *Leucippa pentagona* were also good indicators, as demonstrated by canonical correlation analysis in which they were associated with greater depth, lower temperatures and coarser sand. Little is known about the biology of these species; however, Pires (1992) reported that *P. spinicarpus* and *L. tuberculosus* are common in sandy bottoms and cold waters at depths around 50 m on the continental shelf off Ubatuba. Her findings accord with our data, although we found that the 2 species appeared somewhat deeper.

We found that the 2 species *Callinectes ornatus* and *Hepatus pudibundus* were dominant in the inner zone. Previous studies by Fransozo et al. (1992) and Negreiros-Fransozo & Nakagaki (1998) of brachyurans in the bays of the Ubatuba region also found that these species are dominant. The scarcity of *H. pudibundus* at the 35 m isobath is probably influenced by the locally coarse sediment, which is difficult for the crab to burrow in. Previous reports by Negreiros-Fransozo et al. (1999a,b) and Mantelatto & Fransozo (2000) showed that *C. danae* is the second-most dominant species in this environment. The difference in order of abundance may result from the design of their studies, in which the collection points were located near river mouths where *C. danae* occurs in high densities.

In the outer zone, *Portunus spinicarpus* dominated. Although it is present in large numbers only in summer, *P. spinicarpus* plays an important role in the dynamics of the benthic community. Pires (1992) stated that this portunid is one of the most important species in the Ubatuba shelf community and is especially abundant in the frontal zone of the SACW.

Even though the area examined in our study did not cover a wide depth range, as did the studies of Pires (1992) and Sumida & Pires-Vanin (1997), it was still possible to note changes in the composition and abundance of species that followed the depth gradient. *Portunus spinicarpus* was extremely important in the community on bottoms deeper than 35 m and *Callinectes ornatus* dominated in the inner zone.

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