DISTRIBUTION PATTERNS OF *Arenaeus cribrarius* (LAMARCK, 1818) (CRUSTACEA, PORTUNIDAE) IN FORTALEZA BAY, UBATUBA (SP), BRAZIL

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(With 6 figures)

ABSTRACT

The abundance of the swimming crab *A. cribrarius* in Fortaleza Bay, Ubatuba (SP) was analysed in order to detect the influence of some environmental factors in its distribution. The collections were made by using two otter-trawls deployed from a shrimp-fishing vessel and occurred monthly during one year. The Fortaleza Bay was sampled in 7 radials of 1 km each. Each environmental factor (temperature, salinity and dissolved oxygen of the bottom water, depth, granulometric composition and organic matter of the sediment), sampled in the middle point of each transect, was correlated with the abundance of 5 groups (adult males, ovigerous females, non-ovigerous adult females, juveniles, and total number of specimens), by Pearson's linear and canonical correlation analyses. The total amount of specimens revealed a positive linear correlation with temperature and very fine sand fraction, and a negative linear correlation with organic material contents. Different association patterns appeared in relation to the abundance of the groups mentioned above, such as depth and granulometry. Ovigerous females were the only group which was associated with the whole set of granulometric fractions of the sediment. Among the studied factors, the most effective ones for influence on the spatial distribution of *A. cribrarius* were the texture, organic matter of the sediment and depth. Although the temperature could also be significant, its influence should be more relevant along of the months of year, and not spatially.

Key words: *Arenaeus*, distribution, environmental factors, Portunidae.

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RESUMO

Padrões de Distribuição de *Arenaeus cribrarius* (Lamarck, 1818) (Crustacea, Brachyura, Portunidae), na Enseada da Fortaleza, Ubatuba (SP), Brasil

A abundância do siri *A. cribrarius* foi analisada na Enseada da Fortaleza, Ubatuba (SP), com a finalidade de verificar a influência de alguns fatores ambientais em sua distribuição. As coletas foram realizadas mensalmente durante um ano usando duas redes de arrasto do tipo "otter-trawl". Em cada coleta, sete áreas foram amostradas por uma extensão de 1 km, sendo os fatores ambientais (temperatura, salinidade e oxigênio dissolvido na água junto ao fundo, profundidade, composição granulométrica e teor de matéria orgânica do sedimento) amostrados em seu ponto médio. Uma análise de correlação (Pearson e canônica) foi realizada entre cada variável ambiental e a abundância dos exemplares de cada grupo de interesse (machos adultos, fêmeas ovígeras, fêmeas adultas sem ovos, jovens e total de exemplares). Uma associação positiva e significativa foi observada entre a abundância da espécie e a temperatura, com a fração arenosa muito fina, embora com o teor de matéria orgânica a correlação obtida tenha sido negativa. Foram constatados diferentes modelos de associação dos grupos de interesse com a profundidade e a composição granulométrica. O conjunto de fatores ambientais mostraram uma associação significativa com os grupos de interesse de *A. cribrarius*, excetuando-se as fêmeas adultas com ovos, onde uma correlação significativa foi verificada somente com a composição granulométrica do sedimento, que apresenta uma grande importância durante a desova por funcionar como uma cavidade incubadora artificial.

Palavras-chave: *Arenaeus*, distribuição, fatores ambientais, Portunidae.

INTRODUCTION

Studies on the distribution patterns of certain crab species in relation to environmental dynamics have been partially approached. Many studies of brachyuran distribution deal with economically important species, such as members of the Portunidae.

The individual or collective action of certain environmental factors can increase or limit the area of the species distribution. Studies on the disturbance of the marine fauna and the effects of the environmental factors on its composition have been done since early century (Alle, 1923; Anderson, 1972; Jones, 1976 and Fransozo *et al.*, 1992).

Water temperature and salinity play a special role in regulating distributions of portunids (*Callinectes sapidus, C. danae, Scylla serrata*), grapsids (*Goniopsis cruentata, Sesarma* spp.) and ocypodid crabs (*Uca* spp.). These species can live environments such as estuaries, mangals and lagoons, where environmental variations are significant. Besides this, other environmental variables can be among the main limiting factors to distribution, specially in small areas.

The concept of "distribution pattern" is the recurrence of one the fact, and the possibility to predict its new occurrence (Melo, 1985). In nature, however, the recurrence is not always identical, because intra- or inter-specific factors (competition, prey-predator relations, etc.) which can act together with the environmental factors. In order to minimize these effects the majority of the researchers choose intensive and continuous sampling.

Species of the genus *Callinectes* are among the best studied brachyurans (Churchill, 1919; Darnell, 1959; Paul, 1982; Roman-Contreras, 1986; Hines *et al.*, 1987; Buchanan & Stoner, 1988; Schaffner & Diaz, 1988). Besides this genus, there are a few papers that search environmental factors on the Portunidae species biology, such as the one carried out by Hill (1979) with *Scylla serrata*. In spite of the relatively broad distribution of *Arenaeus cribrarius* (Lamarck, 1818) – Vineyard Sound, Massachussets, USA to La Paloma, Uruguay (Juanicó, 1978; Williams, 1984) – there are very few publications about it. At the Folly beach (SC), USA, the high abundance of this swimming crab was reported by Anderson *et* *al.* (1977) representing 82% of the swimming marine invertebrates.

In Brazil, *A. cribrarius* is primarily important in the northeast region, where this crab is widely accepted as food (Fausto-Filho, 1968).

The present study characterizes the influence environmental factors on *A. cribrarius* spacial and seasonal distribution in the Fortaleza Bay, Ubatuba (SP), Brazil.

MATERIAL AND METHODS

Monthly samples were taken and 7 transects of 1 km length, in the Fortaleza bay, Ubatuba (SP) from November, 1988 to October, 1989 (Fig. 1). The samples were taken by a shrimp-fishing vessel equipped with two otter-trawls (3.7 m wide mouth; 15 mm mesh net body; 10 mm mesh cod end liner).

Crabs were removed from the trawl catches, placed in labeled plastic bags, and stored in ice chests during the trip to the NEBECC's laboratory in the "Departamento de Zoologia – Instituto de Biociências, UNESP, Botucatu" where they were kept frozen until they were analyzed at a later date.

After each trawl, the boat went back to the mid point of the radial (= station), where the data on environmental factors were measured. Bottom water was collected with Nansen bottle in order to record the water temperature, salinity and dissolved oxygen.

Temperature (°C) was measured with a thermometer; salinity (‰) was estimated with a specific optical rephractometer (American Optical); and oxygen content was determined by Winkler method modified by the addition of sodium azide (NaN3).

Depth determination of each station was made by means of a rope graduated at 0.5 m intervals, that was attached to the van Veen grab (1/40 m^2) used to obtain samples of the sediments. In the laboratory, about 300 g of sediments were put in a labeled Petri dish and left in a drying oven at

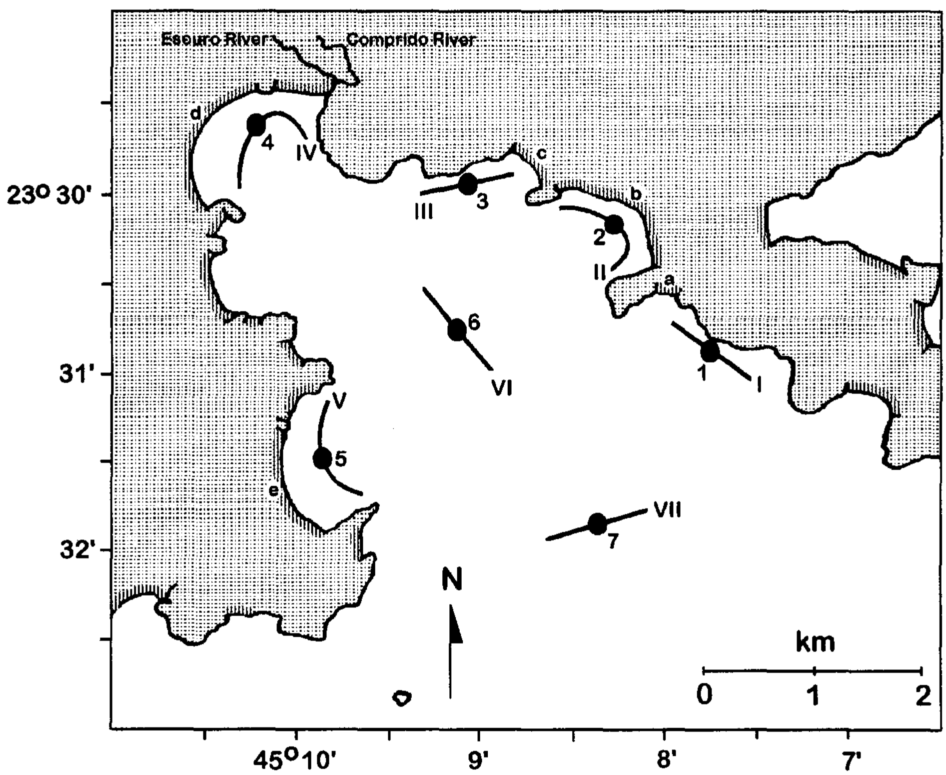

Fig. 1 — Localization of the seven stations (arabical numbers) and radials (roman numbers) in Fortaleza Bay, Ubatuba (SP), Brazil (a = Sununga beach; b = Lázaro beach; c = Domingas Dias beach; d = Dura beach; e = Fortaleza beach).

70°C for 72 hours. After drying, the sediment samples were divided in sub-units from which the amount of organic material was determined and bulk granulometry analyses were made.

Organic matter content of sediment was obtained by ash-free dry weight (expressed in percentage). Granulometric fractions of the sediment were obtained by the differential sifting, after burry in a muffle furnace, based on the Wentworth scale (Wentworth, 1922).

During analysis, the frozen brachyurans samples were trawed, identified to species and counted. All the *A. cribrarius* were selected for further enumeration and recorded by sex, maturation stage and presence of brooded eggs. Individuals were classified as juveniles if they had sealed abdominal somites according to van Engel (1958) and Taissoun (1970).

Five categories of *A. cribrarius* (adult males, non-ovigerous adult females, ovigerous females, juveniles and total) were tested for association with environmental variables. The absolute abundance for each of these was based on the number of *A. cribrarius* individuals registered at each collecting radial per month.

The association of each variable with the absolute abundance of each interest category was analyzed graphically and by means of Pearson linear correlation.

The canonical correlation analysis (Dempster, 1969; Morrison, 1976) was employed to test the association between the environmental variable groups and the absolute abundance of each crab category. Two groups were established being one represented by the seven granulometric fractions of the sediment and other by the remaining ones. The chi-square test (χ^2) was utilized to establish the significance level of the canonical coefficients.

The statistical similarity in relation to environmental factors among the stations can be verified in Negreiros-Fransozo *et al.* (1991) who studied the physical and chemical parameters in the Fortaleza Bay. The statistical analysis were made by "Pólo Computacional de Rubião Júnior, UNESP – Campus de Botucatu" with the software MCANO.

RESULTS

Environmental factors differed significantly among stations and months (Tab. I, Fig. 2). Stations 2 and 5 as well as 1 and 6 were statistically similar in relation to depth. The organic contents

TABLE I

Caracterization of the environmental factors at each station in Fortaleza Bay, recorded from Nov/1988 to Oct/1989 (mean values of 12 measurements ± standard deviation). The statistic similarity between stations was realized by comparison of station means with Tukey test ($p < 0.05$).

Stations	Environmental factors				
	Temperature (°C)	Salinity (‰)	Dissolved oxygen (mg/l)	Depth (m)	Organic matter (%)
1	22.63 ± 2.26*a	34.79 ± 0.78 b	5.61 ± 0.94 ab	11.17 ± 0.94 d	4.42 ± 2.45 c
2	23.79 ± 2.67 b	34.33 ± 1.32 b	5.41 ± 0.99 ab	6.96 ± 0.89 b	6.65 ± 2.37 e
3	23.88 ± 2.52 b	34.38 ± 1.05 b	5.28 ± 1.12 ab	8.46 ± 0.86 c	2.32 ± 1.27 b
4	24.44 ± 2.67 b	33.25 ± 1.54 a	5.86 ± 1.38 ab	4.42 ± 0.60 a	1.84 ± 1.26 a
5	23.46 ± 2.10 ab	34.42 ± 1.14 b	6.10 ± 0.81 b	7.13 ± 0.83 b	3.54 ± 1.36 b
6	23.83 ± 2.67 b	34.42 ± 1.06 b	4.95 ± 1.25 a	11.08 ± 1.18 d	5.16 ± 1.84 d
7	22.71 ± 2.46 a	34.92 ± 1.73 b	4.99 ± 1.31 a	13.33 ± 1.57 e	4.56 ± 3.57 d
MSD (5%)	1.02	0.91	1.11	1.30	0.05
CV (%)	3.47	2.12	16.39	11.67	17.10

MSD = Minimal significative difference; CV = Coefficient of variation; *The mean values with at least one same letter in the row does not differ statistically.

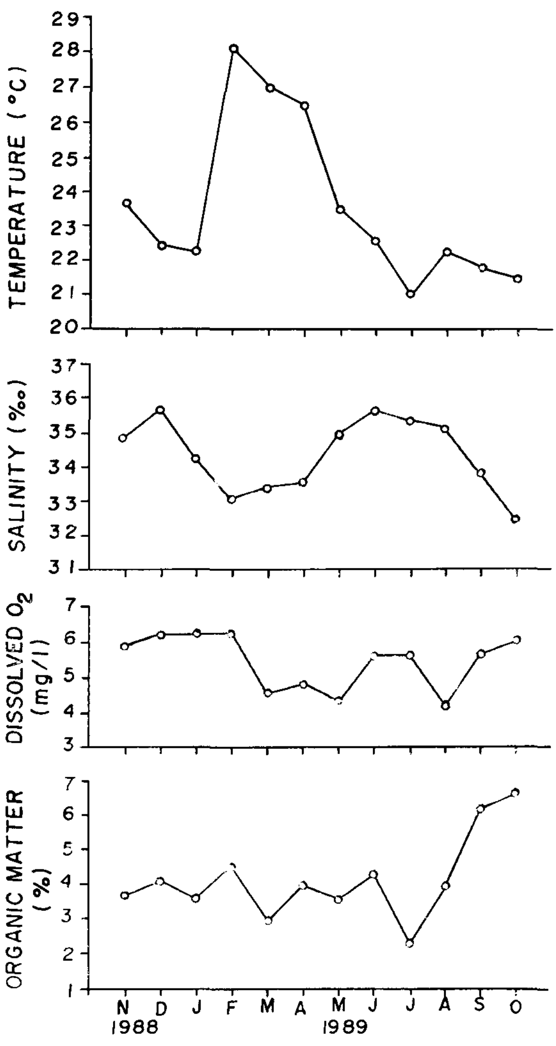

Fig. 2 — Fortaleza Bay. Caracterization of the mean values of temperature, salinity, dissolved oxygen and organic matter reported in each month from Nov/1988 to Oct/1989.

of the sediment at the stations 3 and 5 was similar between them as well as in the stations 6 and 7 but it were different between the others. In the stations 3, 4, 6 and 7, some similarity in relation to granulometric composition of the sediments was observed where the fine sand fraction was predominant. The other stations presented a distinguished composition with the presence of two modes in station 1 (medium sand and very fine sand), predominance of fine sand in the station 5 and certain homogeneity in all the granulometric fractions in the station 2 (Fig. 3).

At radials I, III and V, the presence of marine macrophytes belonging to Rhodophyta (*Callithamnion* sp.) and Phaeophyta (*Dictyota* sp. and *Dictyopteris* sp.) division was frequently observed.

A total of 84 samples were taken from the Fortaleza Bay obtaining 245 individuals of *A. cribrarius*, of which 81 were adult males, 43 non-ovigerous adult females, 33 ovigerous females and 88 juveniles (28 males and 60 females).

The highest abundance of this swimming crab occurred at the radials III, IV and I with respectively 103, 75 and 39 individuals (Fig. 4). Adult males and juveniles were more abundant in radials IV and III while non-ovigerous adult females were more abundant in radials I and III. Although the ovigerous females were most abundant in radial I.

A. cribrarius occurred during all the collecting months but it is most abundant in March, May and July and the adults but non-ovigerous females were most abundant in March (Fig. 5). Both adult males and non-ovigerous adult females were not registered in October. Ovigerous females did not occur in July, August and September and their highest peak of abundance occurred in March.

The significative associations with the environmental factors can be seen in Table II, through the Pearson's correlation coefficient. Adult male and juvenile abundance was negatively correlated with depth and the opposite occurred with the non-ovigerous adult females. Concerning the temperature, a positive and significative association was verified with the total of specimens, non-ovigerous adult females and juveniles. A negative and significative association occurred between the organic matter and the abundance of adult males, juveniles and the total of specimens. Adult males and all juveniles were correlated with the very fine sand fraction of the sediments, while all the adult females were associated with coarse and/or medium sand.

In Table III, the organic matter contents, the depth and the temperature had the most significative coefficients in the canonical correlation. The group of environmental factors presented positive and significative association with the abundance of each interest category, except with the ovigerous females.

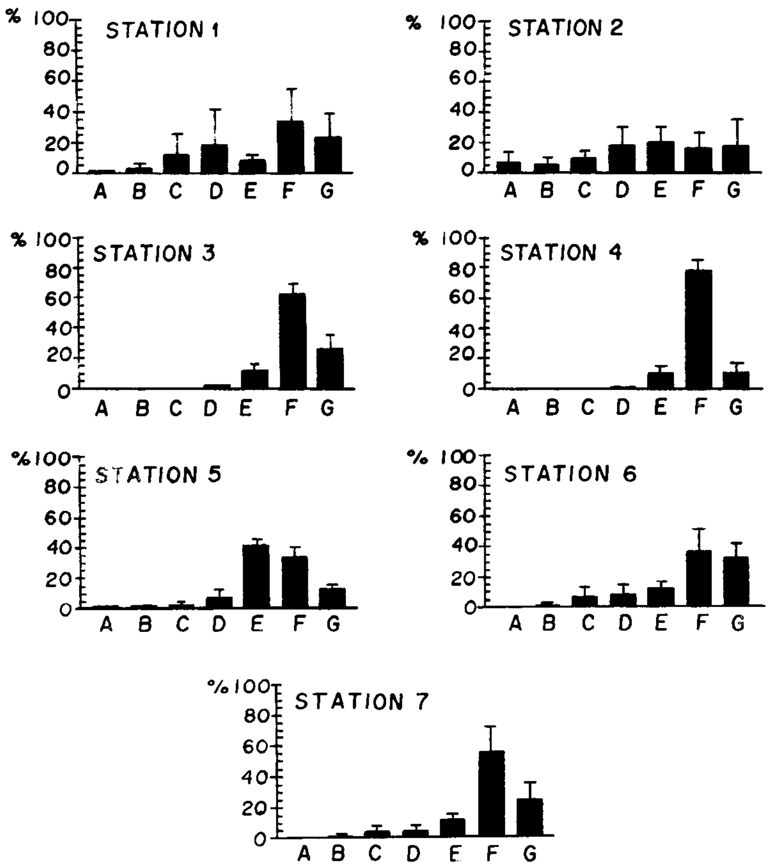

Fig. 3 — Fortaleza Bay. Granulometric caracterization of each station from Nov/1988 to Oct/1989 (column = mean value; line = standard deviation) (A = Gravel; B = Very Coarse Sand; C = Coarse Sand; D = Medium Sand; E = Fine Sand; F = Very Fine Sand; G = Silt-Clay).

The results of the mean number of individuals per catch (abundance index) in each environmental factor stratum can be seen in figure 6. The highest abundance values occurred in low organic matter contents (0 to 3%), in warmest temperature (28 to 31°C), in salinity between 31 and 33‰. With reference to the dissolved oxygen there was slightly association and to the depth, the juveniles and adult males were most abundant from 0 to 4 meters while the non-ovigerous adult females were most abundant between 8 and 12 meters.

DISCUSSION AND CONCLUSIONS

According to Vernberg and Vernberg (1970), the distribution of marine organisms is mainly determined by the action of certain environmental factors, where those with the most significant variations are the ones that limit the occurrence area. This fact was verified in the present work because the factors most variable (sediment texture, its organic content and the depth) were the ones which presented influence on distribution of this swimming crab.

In spite of *A. cribrarius* having already been recorded even in 68 meters of depth by Williams (1984), this range could be reflected by the non-significant coefficient by Pearson's correlation when the total of individuals was grouped. This assertion is similar to the one presented by Anderson *et al.* (1977) and Vanin (1989). Due to the brachyuran's capacity to alter their bathymetric distribution searching for better environmental conditions (Melo, 1985), the action of this factor can be covered up. The high occurrence of *A. cribrarius* juveniles in shallow water appears to be a constant in papers about portunids, as already ob-

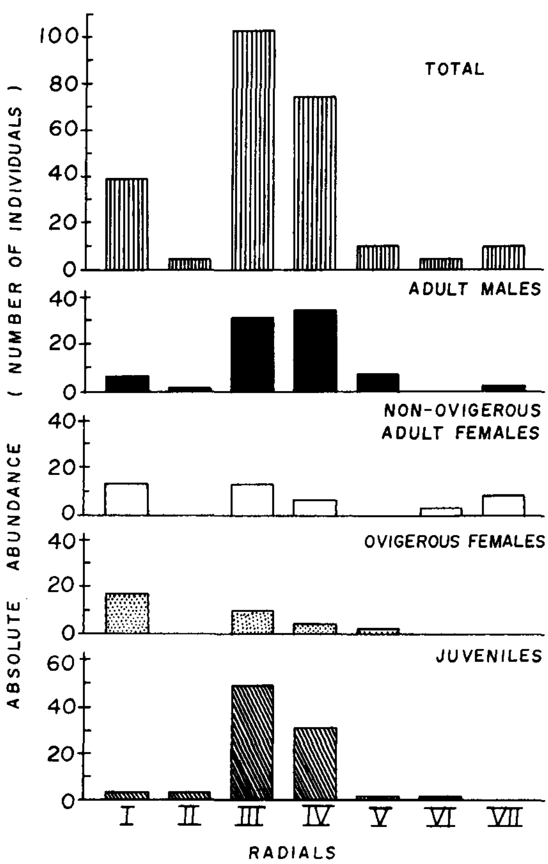

Fig. 4 — *Arenaeus cribrarius* (Lamarck, 1818). Number of individuals (absolute abundance) of each crab category in the 7 radials from Nov/1988 to Oct/1989.

served on *Callinectes* spp. by Churchill (1919), Norse and Estevez (1977), Buchanan and Stoner (1988) and *S. serrata* by Hill (1979).

Probably *A. cribrarius* does not use directly the organic matter of the sediments as food because the major abundance of this species was verified in the radials III and IV. Such radials had a low amount of organic matter contents in the sediments because the water movements hinders the sedimentation, leaving better conditions for the settlement of a particular fauna composed by suspension feeders.

According to Warner (1977) the portunids are carnivorous, with a little portion of their diet represented by meat in decomposition. Confirming this assertion Wade (1967) and Leber (1982) have reported *A. cribrarius* feeding on *Donax* and *Emerita* spp., that are suspension feeder animals characteristics of these environments.

Sandy fractions facilitates this species to bury more easily and quickly so that the animals can escape the unstable breaker zone and predators (Williams, 1984). This habit provides protection and cover from where they could easily spy and capture agile preys, such as some fishes (Schafer, 1954).

The close association between *A. cribrarius* and very fine sand is in accordance with Camp *et al.* (1977) and Melo (1985) who classified this species as stenotopic.

A,differential distribution between the sexes was also verified in *A. cribrarius* in relation to the sediments. This fact can be considered as a reproductive strategy, since the females search for a more stable bottom to spawn. The highest abundance of ovigerous females in the radial I may be related to its sediment composition, shelter availability near rocky shores, and the facility for larvae dispersion by the proximity of the mouth bay.

The Portunidae crabs do not have a natural brood pouch and most of them have a large egg mass. In *A. cribrarius* females the sediments act

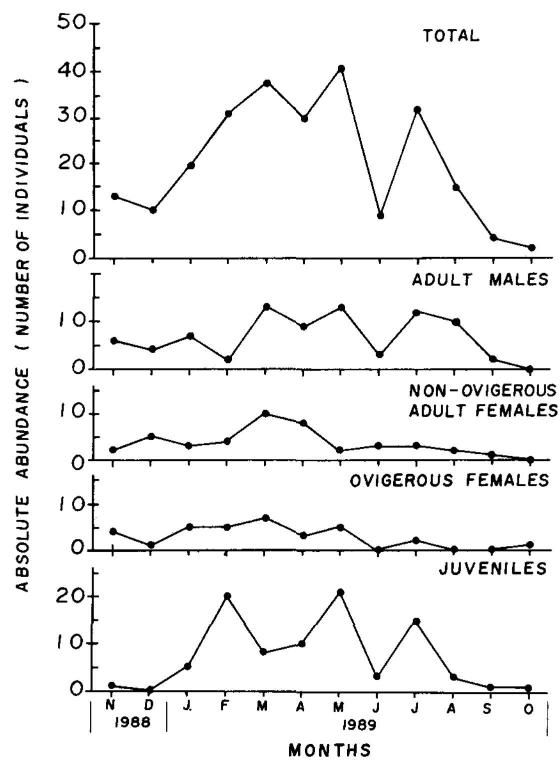

Fig. 5 — *Arenaeus cribrarius* (Lamarck, 1818). Number of individuals (absolute abundance) of each crab category in the months from Nov/1988 to Oct/1989.

TABLE II
Coefficients of Pearson's linear correlation carried out between the abundance of each category of *Arenaeus cribrarius* and the sampled environmental factors (N=84).

Variables	Pearson's coefficients in each crab category				
	Adult males	Non-ovigerous adult females	Ovigerous females	Juveniles	Total of individuals
Physical and chemical					
Depth	–0.36**	0.22*	0.07	–0.23*	–0.20
Temperature	0.13	0.22*	0.14	0.26*	0.27*
Salinity	–0.05	–0.02	–0.04	–0.13	–0.10
Dissolved oxygen	–0.07	–0.02	0.02	0.01	–0.02
Organic matter	–0.45**	–0.09	–0.15	–0.29**	–0.38**
Sediment fractions					
Gravel	–0.19	–0.12	–0.06	–0.12	–0.17
Very coarse sand	–0.25*	0.03	0.10	–0.20	–0.17
Coarse sand	–0.25*	0.24*	0.40**	–0.22*	–0.08
Medium sand	–0.23*	0.06	0.27*	–0.21*	–0.13
Fine sand	–0.18	–0.30**	–0.18	–0.20	–0.28**
Very fine sand	0.47**	0.08	–0.09	0.34**	0.35**
Silt-clay	–0.19	–0.03	–0.16	–0.01	–0.11

* = $p < 0.05$; ** = $p < 0.01$.

like an artificial brood pouch serving as a support and mold during spawning. The close association between *A. cribrarius* ovigerous females with the granulometric fractions set evidences of its importance in the spatial distribution of this category.

According to Taissoun (1973) and Norse (1978) salinity is a factor of fundamental importance in distributional and reproductive studies of the Portunidae. Although *A. cribrarius* was more abundant in the radial IV which had the lowest mean of salinity in the Bay, it was reported by Coelho (1965) that this species does not occur in the estuarine environment.

The salinity influence was slight in *A. cribrarius* distribution according to the correlation analysis, in spite of being in a lower degree when compared to other more euryhaline portunids. When Williams and Hill (1982) studied the swimming crab *S. serrata*, which is a migratory species that occurs frequently in the estuarine environment, they did not obtain a significative association of salinity ($r = 0.09$). This fact is in agreement with our results.

In relation to dissolved oxygen, the Fortaleza Bay was homogeneous (Negreiros-Fransozo *et al.*, 1991) presenting values near the saturation point. The Portuninae subfamily representatives show high metabolism due to the constant use of the fifth pereiopods as a swimming and digging appendages (Ayers, 1938). Some portunid crabs such as *Callinectes sapidus* go into a state of suspensed animation when oxygen tension is greatly reduced (Gray, 1957). A morphological adaptation of this group to minimize these effects is a major average gill area to oxygenate blood more effectively as reported for *A. cribrarius* by Gray (*op. cit.*).

The water temperature influence in the brachyuran geographical distribution is well known. According to Taissoun (1973) the highest abundance of species occurs in tropical and subtropical waters (87.9%) but decreases towards temperate and polar regions. In relation to water temperature, the abundance of *A. cribrarius* was higher in warmest waters according to Anderson *et al.* (1977) and their observations on the same species in Folly Beach (SC), USA.

The orientation ability of the crustaceans in relation to thermic gradients have been continuously studied (Roberts, 1957; Reynolds and Cas-

TABLE III
Coefficients of Canonical correlation carried out between the abundance of each category of *Arenaeus cribrarius* with two sets of environmental factors.

Variables	Variable coefficients in each crab category				
	Adult males	Non-ovigerous adult females	Ovigerous females	Juveniles	Total of individuals
Physical and chemical					
Depth	–0.54	0.88	0.66	–0.29	–0.15
Temperature	0.05	0.66	0.54	0.49	0.44
Salinity	–0.02	–0.12	–0.21	–0.11	–0.11
Dissolved oxygen	–0.17	–0.19	0.27	0.06	0.02
Organic matter	–0.71	–0.39	–0.75	–0.64	0.77
Canonical coefficient	0.53***	0.37**	0.24 NS	0.39*	0.45**
χ^2	26.60	11.78	4.90	13.67	18.05
Sediment fractions					
Gravel	–0.20	–0.65	1.50	0.18	–0.02
Very coarse sand	–0.05	–0.79	0.90	–0.08	–0.32
Coarse sand	–0.18	0.29	4.72	0.11	0.38
Medium sand	–0.29	–2.93	4.76	0.26	–0.45
Fine sand	–0.48	–2.34	4.94	–0.04	–0.68
Very fine sand	0.58	–3.22	9.82	1.59	0.47
Silt-clay	–0.67	–2.45	5.19	0.30	0.73
Canonical coefficient	0.65***	0.46**	0.57***	0.46**	0.53***
χ^2	43.67	19.19	30.76	18.79	25.94

NS = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

terlin, 1979 a,b). These authors refer to an out break of escape behaviour when the optimum is overreached. Many authors (Gunter, 1950; Dragovich and Kelly, 1964; Anderson *et al.*, 1977; Camp *et al.*, 1977 and Moreira *et al.*, 1988) have reported the occurrence of *A. cribrarius* from 11 to 30.8°C temperature ranges. Even though this species presented a high mean abundance in 28 to 31°C, it cannot be assumed that it is the preferential range for this species because only experimental analyses can confirm such interpretation. The influence of the temperature on *A. cribrarius* was more evident seasonally.

The marine macrophyte occurrence in the radials I and III probably may act associated with the environmental factors mainly on the ovigerous females and juveniles. This subareas are important food resource and protection against predators according to Brook (1978), Bell and Westoby (1986) and Holmquist *et al.* (1989). For this, such environments are known in the literature as a natural nurseries where most of juveniles, specially swimming crabs, find refuge during this fragile life phase.

Due to the differential action of the environmental factors in the Fortaleza Bay, a greater variety of habitats can be verified and the settlement of marine organisms are most frequent in areas where their morphologic, physiologic and behavioral defense adaptations are used more effectively.

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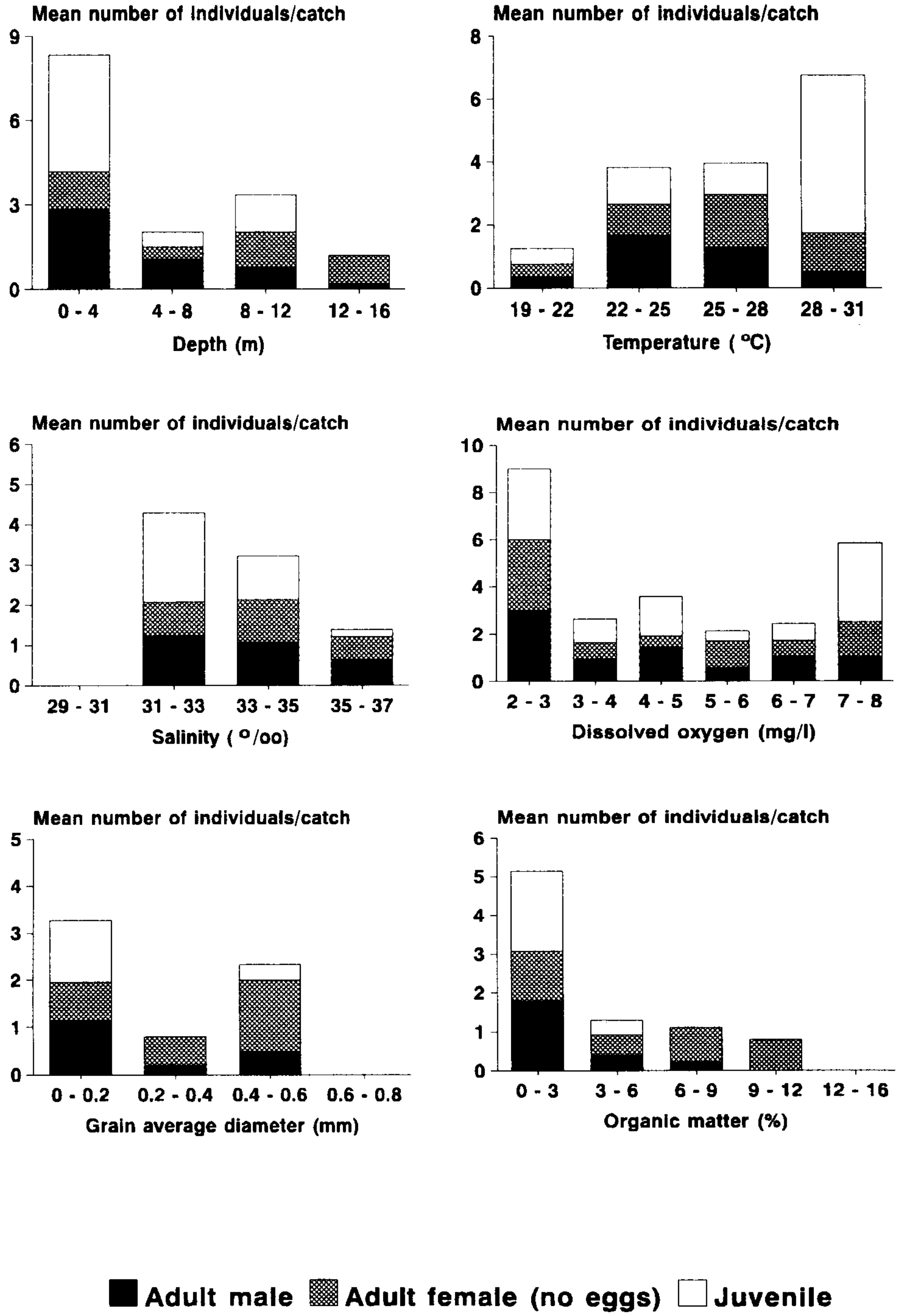

Fig. 6 — *Arenaeus cribrarius* (Lamarck, 1818). Distribution of the mean number of individuals per trawl and by each environmental factor stratum (depth, temperature, salinity, dissolved oxygen, grain average diameter and organic matter) from Nov/1988 to Oct/1989.

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