

DISTRIBUTION OF PARACALANIDAE SPECIES (COPEPODA, CRUSTACEA) IN THE CONTINENTAL SHELF OFF SERGIPE AND ALAGOAS STATES, NORTHEAST BRAZIL*

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ABSTRACT

The spatial and seasonal distribution of the Paracalanidae species were studied in eighteen stations in the continental shelf off Sergipe and Alagoas States, northeast Brazil, in December, 2001 and 2003, and in June, 2002 and 2003. The Paracalanidae family was constituted by coastal and shelf species such as *Parvocalanus crassirostris*, *Paracalanus quasimodo*, *P. indicus* and *P. aculeatus* and oceanic species, *Calocalanus pavo* and *Acrocalanus longicornis*. Density values were higher in stations located at 10 m isobath with respect to those located at 20 and 30 m depths. Paracalanidae abundance presented differences between seasons with values higher in June (2002, 2003) than in December (2001, 2002). All species were more abundant in the rainy season except *Parvocalanus crassirostris*. *Paracalanus quasimodo* was the dominant species with average densities of 949, 740 and 41 ind.m⁻³ in December months and 4231, 2389 and 1185 ind.m⁻³ in June months, at stations with local depths of 10, 20 and 30 m, respectively. Canonical correspondence analysis showed that salinity and temperature were the environmental variables that presented significant correlation with the distribution of Paracalanidae species, probably because these variables are influenced by the estuarine waters and by the dynamic of oceanic water masses in the continental shelf.

RESUMO

A distribuição espacial e sazonal das espécies de Paracalanidae foram estudadas em dezoito estações na plataforma continental dos Estados de Sergipe e Alagoas, nordeste do Brasil, em dezembro de 2001 e 2003 e junho de 2002 e 2003. A família Paracalanidae esteve constituída por espécies costeiras e de plataforma tais como *Parvocalanus crassirostris*, *Paracalanus quasimodo*, *P. indicus* e *P. aculeatus* e por espécies oceânicas, *Calocalanus pavo* e *Acrocalanus longicornis*. Os valores de densidade total foram mais elevados nas estações localizadas em isóbata de 10 m decrescendo nas estações localizadas em profundidades de 20 e 30 m. A abundância de Paracalanidae apresentou padrão de flutuação sazonal, com valores mais elevados em junho (2002, 2003) do que em dezembro (2001, 2002). Todas as espécies foram mais abundantes no período chuvoso com exceção do *Parvocalanus crassirostris*. *Paracalanus quasimodo* foi a espécie dominante, com densidades médias de 949, 740 e 41 ind.m⁻³, nos meses de dezembro e de 4231, 2389 e 1185 ind.m⁻³, nos meses de junho, em isóbatas de 10, 20 e 30 m, respectivamente. A análise de correspondência canônica mostrou que a salinidade e a temperatura foram os fatores ambientais que apresentaram relação significativa com a distribuição das espécies de Paracalanidae, provavelmente porque estes fatores foram influenciados pelas águas estuarinas e pela dinâmica das massas de água oceânicas na plataforma continental.

Descriptors: Alagoas, Sergipe, Brazil, Tropical, Zooplankton, Paracalanidae.

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INTRODUCTION

The continental shelf off Sergipe and Alagoas is narrow varying from 18 km at the extreme south of this area to 42 km in front of the city of Maceió. It has an average width of 30 km. Most part

of this shelf has depths of less than 50 m and presents an abrupt slope interrupted by two large submarine canyons of the São Francisco and Japarutuba Rivers that reach up to 10 km from the shore line. These canyon heads are steep-walled, V-shaped in cross-section, and narrow with wall heights locally reaching about 800 m (França *et al.*, 1976; Summerhayes *et al.*, 1976). This shelf has a predominance of carbonatic biogenic sediments and the only exception is the area under the influence of the São Francisco River (Coutinho, 1981).

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The shelf and oceanic areas of the northeast Brazil are affected by the Tropical (TW) and South Atlantic Central Waters (SACW). The SACW (temperature < 20 °C and salinity < 36.4 psu) cover the upper ocean of the subtropical South Atlantic and spreads northward underneath the Tropical Water (temperature > 20°C and salinity > 36,4 psu) (Stramma *et al.*, 1990; Castro & Miranda, 1998).

Five estuaries (São Francisco, Japarutuba, Sergipe, Vaza-Barris and Piauí-Real) discharge their waters into the Sergipe coast. The most important river is the São Francisco with 3161 km of length and 2850 m³.s⁻¹ of average outflow (Cunha & Guerra, 2003).

Copepods are numerous and abundant and they may sometimes form up to 90-97% of the biomass of marine zooplankton. Therefore, copepods are an important link in marine food webs and marine economy (Bradford-Grieve *et al.*, 1999). The Paracalanidae family is compounded by the genera *Acrocalanus*, *Bestiolina*, *Calocalanus*, *Delius*, *Paracalanus* and *Parvocalanus* and from these only *Bestiolina* has not been registered in the South Atlantic (op. cit.). *Paracalanus* is one of the most important genus in the neritic region of the Brazilian coast and according to Lopes *et al.* (1999) its distribution pattern mirrored that of total copepods.

In the shelf and open ocean off northeast Brazil the Paracalanidae family is represented by *Paracalanus aculeatus*, *P. quasimodo*, *Parvocalanus crassirostris*, *Acrocalanus longicornis*, *Calocalanus pavo* and *C. pavoninus* (Araujo *et al.*, 1991; Neumann-Leitão *et al.*, 1998; 1999). In the southeast and south,

besides the species mentioned *Paracalanus indicus*, *P. campaneri*, *P. nanus*, *P. parvus* and *Calocalanus contractus* were also registered (Björnberg, 1980; Campaner, 1985; Valentin & Monteiro-Ribas, 1993; Dias, 1996; Vega-Pérez & Hernandez, 1997; Lopes *et al.*, 1999). *Paracalanus quasimodo* has been cited as the most abundant species and is associated to coastal and neritic waters (Björnberg, 1980; 1981; Vega-Pérez & Hernandez, 1997; Lopes *et al.*, 1999).

The present study was part of a large monitoring program on the continental shelf off Sergipe and Alagoas, where the company Petróleo Brasileiro S.A. develops its activities of gas and oil production. This paper describes the spatial and seasonal distribution of the Paracalanidae species collected in eighteen stations in December 2001, 2002 and June 2002, 2003.

MATERIAL AND METHODS

Sampling and Sample Processing

The studied area is located in the northeastern coast of Brazil (Lat. 10°30' and 11°27'S; Long. 36°20' and 37°16'W).

Sampling was carried out in eighteen stations during the dry season (December 2001, 2002) and the rainy season (June 2002, 2003) on the continental shelf off Sergipe and Alagoas States. The stations were positioned at 10, 20 and 30 m isobaths along six transects, perpendicular to the shore line (Fig. 1).

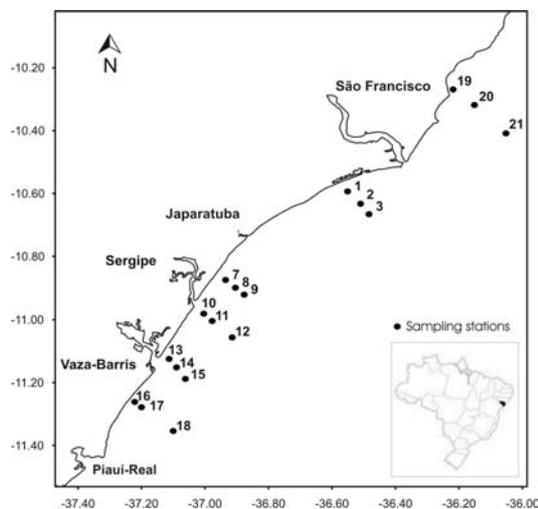


Fig. 1. Continental shelf off Sergipe and Alagoas with the sampling stations.

Water samples were taken with a Van Dorn bottle at two levels in the water column (surface and near the bottom) to analyze the environmental variables including salinity (refractometer), pH (digital pH meter), dissolved oxygen and chlorophyll-*a* (Strickland & Parsons, 1965) and nutrients (ammonia, nitrite, nitrate, phosphate and silicate – according to APHA, 1995). In each station, water temperature (°C) and water transparency (Secchi disc) were also determined before each plankton haul.

Oblique plankton tows were done during the day, using a plankton net with a 200 µm mesh size and 0.60 m diameter. A General Oceanic flowmeter was adjusted to the net mouth for measuring the water volume sampled during each haul. Samples were preserved in a buffered 4% formaldehyde solution.

Taxonomic composition and abundance were determined in subsamples obtained with a 5 ml Stempel pipette. The species abundance was expressed as number of individuals per cubic meter (ind.m⁻³).

Data Analysis

The cluster analysis was applied to the density matrix, after being normalized by log (x+1) transformation. The Bray Curtis dissimilarity coefficient and the Ward cluster method were used. The species were codified by four letters, the first two corresponding to genus name and the other two to species name.

Association among the copepod community and environmental variables were analyzed using canonical correspondence analysis - CCA with the Canoco program (ter Braak, 1987; 1989). The relation between the inertia associated with CCA and the inertia of CA (correspondence analysis) indicated the extent to which the measured variables explained the variability in the species community. The robustness of this analysis was determined using the Monte Carlo's permutation test (ter Braak, 1986).

RESULTS

During the studied period the water temperature values ranged from 23.0 at station 9 (bottom layer) to 29.5°C at station 17 (surface and bottom layers). Maximum differences between surface and bottom temperatures values were registered in December, 2001 at station 2 (3.0°C), station 3 (2.5°C), stations 9 and 12 (2.0°C) and in December, 2002 at stations 2 and 3 (2.0°C) (Table 1).

Salinity varied from 25.8 psu at station 3 (surface layer) to 39.3 psu at station 20 (bottom layer), both values registered in the rainy months (Table 1). In most stations salinity values of the bottom layer were slightly higher than those of the surface. However a higher salinity gradient was observed at stations 1, 2 and 3, located in the São Francisco plume, especially

in June, 2002 (station 2 - 12.3 psu and station 3 - 13.3 psu).

Dissolved oxygen ranged from 5.8 mg.L⁻¹ at the 10 m isobath (bottom) to 8.9 mg.L⁻¹ at the 10 m isobath (both layers). Higher values were measured in the rainy months in the surface layer of the water column. The pH values were above 8.0 in all water samples. Chlorophyll-*a* concentrations were low in general and its highest value was 2.8 µg.L⁻¹ measured at the 10 m isobath in the dry season (Table 2).

Ammonia, nitrate and silicate were higher in the rainy months and nitrite and phosphate in the dry months. In the continental shelf off Sergipe and Alagoas, nutrients (ammonia, nitrite, nitrate and phosphate) presented great variation, with the following ranges: ammonia (1.4 µg.L⁻¹ - 30 m to 18.8 µg.L⁻¹ - 10 m); nitrite (0.1 µg.L⁻¹ to 9.2 µg.L⁻¹ - both in 10 m); nitrate (0.03 µg.L⁻¹ - 20 m to 124.5 µg.L⁻¹ - 30 m); phosphate (0.6 µg.L⁻¹ to 37.7 µg.L⁻¹ - 20 m); silicate (9.9 µg.L⁻¹ - 20 m to 855.6 µg.L⁻¹ - 30 m) (Table 2).

The Paracalanidae family was represented by six species: *Paracalanus quasimodo* Bowman, 1971; *Paracalanus indicus* Wolfenden, 1905; *Paracalanus aculeatus* Giesbrecht, 1888; *Parvocalanus crassirostris* F. Dahl, 1894; *Calocalanus pavo* (Dana, 1849) and *Acrocalanus longicornis* Giesbrecht, 1888.

Paracalanidae species densities in the continental shelf off Sergipe and Alagoas presented spatial and seasonal variations with higher values at the stations located at 10 m isobath and in the rainy season.

Paracalanus quasimodo was the dominant species, recorded in 95.8% of all analyzed samples and its relative abundance considering all studied period was 76.7%. Mean density values considering the dry months were 949, 740 and 41 ind.m⁻³ and the rainy months were 4231, 2389 and 1185 ind.m⁻³ in the 10, 20 and 30 m isobaths, respectively (Table 3). In fact, 81.9% of individuals of this species were registered in the June months. Density values were higher in the rainy months when the greatest abundance (9909 ind.m⁻³) was recorded at 10 m isobath. In the dry months the maximum of 6359 ind.m⁻³ was recorded at 20 m isobath. It was registered in salinity values between 25.8 and 39.3 psu and temperature values between 23.0 and 29.5°C.

Paracalanus indicus occurred in 75% of the samples but the relative abundance was low (6.30%). Total means of the density values were 40, 53 and 19 ind.m⁻³ in the dry months and 164, 175 and 362 ind.m⁻³ in the rainy months at 10, 20 and 30 m isobaths, respectively. *P. indicus* was more abundant in the rainy months and even reached the maximum value of 2433 ind.m⁻³ at 30 m isobath (Table 3). In the present study this species was recorded in salinity values from 25.8 to 39.3 psu, and temperature values from 24.0 to 29.5°C.

Table 1. Continental shelf off Sergipe and Alagoas. Temperature (°C) and salinity (psu) values in December 2001/2002 and June 2002/2003, at 10, 20 and 30 m isobaths. Surface (s); Botton (b).

10m isobath		December/2001						December/2002						
Stations		1	7	10	13	16	19	1	7	10	13	16	19	M
Salinity - s (psu)		36.6	35.5	36.0	35.2	35.2	35.1	36.2	35.7	35.6	35.5	35.7	36.3	36.3
Salinity - b (psu)		38.3	38.1	35.0	35.7	34.9	35.2	36.3	35.8	35.7	35.8	36.7	36.4	36.4
Temperature - s (°C)		27.0	26.0	25.0	26.0	27.0	27.0	25.0	26.0	26.5	27.0	26.0	27.0	27.0
Temperature - b (°C)		26.0	25.0	25.0	26.0	26.0	26.5	24.0	25.5	26.0	25.0	25.0	27.0	27.0
		June 2002						June 2003						
Salinity - s (psu)		35.0	37.7	38.6	36.9	37.0	37.3	29.9	32.5	34.4	35.4	35.6	35.7	35.5
Salinity - b (psu)		38.3	38.4	38.9	37.2	37.6	38.5	38.0	32.7	35.0	35.8	36.1	35.8	36.9
Temperature - s (°C)		26.0	27.0	27.0	27.0	27.0	27.0	29.0	29.0	29.0	28.0	28.0	29.0	27.8
Temperature - b (°C)		27.0	27.0	27.0	27.0	27.0	27.0	29.0	29.0	29.0	27.5	28.0	29.0	27.8
20m isobath		December/2001						December/2002						
Stations		2	8	11	14	17	20	2	8	11	14	17	20	
Salinity - s (psu)		34.0	35.1	35.7	34.8	34.8	35.4	33.3	35.6	35.4	35.3	35.7	35.1	
Salinity - b (psu)		38.2	36.6	36.4	35.3	36.0	35.7	36.6	35.8	35.8	36.0	36.4	36.3	
Temperature - s (°C)		27.5	25.0	25.1	26.0	26.0	26.0	26.0	26.0	27.0	25.0	26.0	26.0	
Temperature - b (°C)		24.5	24.0	24.0	26.0	25.0	26.0	24.0	25.5	26.0	26.0	25.0	25.2	
		June 2002						June 2003						
Salinity - s (psu)		26.5	38.4	38.8	37.2	36.6	38.0	37.2	31.7	35.5	34.8	36.0	36.0	
Salinity - b (psu)		38.8	38.5	37.8	37.4	36.9	39.3	37.7	36.7	37.0	35.9	36.2	37.4	
Temperature - s (°C)		26.0	26.0	26.0	26.0	26.5	29.0	28.5	28.5	28.0	28.0	29.5	27.4	
Temperature - b (°C)		26.0	27.0	27.0	26.0	26.0	27.0	29.0	29.0	28.0	28.0	29.5	27.6	
30m isobath		December/2001						December/2002						
Stations		3	9	12	15	18	21	3	9	12	15	18	21	
Salinity - s (psu)		36.2	35.5	36.4	35.8	35.7	35.6	34.2	35.7	35.3	35.5	35.9	36.2	
Salinity - b (psu)		38.4	36.6	36.6	36.9	36.4	35.9	36.4	36.0	35.5	36.1	36.3	36.4	
Temperature - s (°C)		26.0	25.0	26.0	26.0	26.0	26.5	26.0	26.5	27.0	25.0	25.0	25.9	
Temperature - b (°C)		23.5	23.0	24.0	25.0	25.5	26.0	24.0	25.0	25.5	24.5	25.0	24.8	
		June 2002						June 2003						
Salinity - s (psu)		25.8	38.7	38.4	37.4	36.8	38.9	37.1	33.6	35.3	36.3	36.4	35.9	
Salinity - b (psu)		39.2	38.7	37.4	37.5	36.8	39.1	37.3	36.9	36.9	36.6	36.4	37.4	
Temperature - s (°C)		26.0	27.0	26.0	26.0	26.0	27.0	29.0	28.5	27.0	28.0	29.0	28.5	
Temperature - b (°C)		26.5	27.0	26.0	26.0	26.0	27.0	28.5	29.0	28.0	27.5	28.4	27.3	

Table 2. Continental shelf off Sergipe and Alagoas. Value ranges of the environmental variables in the dry months (December 2001/2002) and in the rainy months (June 2002/2003) at 10, 20 and 30 m depths. Surface (s); bottom (b).

Isobaths	10 m		20m		30m	
	Dry months	Rainy months	Dry months	Rainy months	Dry months	Rainy months
Transparence (m)	1.0 - 3.5	1.2 - 4.0	1.5 - 12.0	1.2 - 9.0	3.5 - 19.0	1.5 - 17.0
pH - s	8.1 - 8.3	8.1 - 8.3	8.0 - 8.3	8.1 - 8.3	8.0 - 8.3	8.1 - 8.3
pH - b	8.1 - 8.3	8.1 - 8.3	8.0 - 8.3	8.1 - 8.3	8.0 - 8.3	8.1 - 8.3
D. oxygen-s (mg.L ⁻¹)	6.2 - 7.7	6.7 - 8.9	6.2 - 7.8	6.7 - 8.5	6.2 - 8.1	6.4 - 8.7
D. oxygen-b (mg.L ⁻¹)	5.9 - 7.7	5.8 - 8.9	6.1 - 7.7	6.0 - 8.2	6.6 - 7.7	6.1 - 7.6
Ammonia-s (µg.L ⁻¹)	2.9 - 8.4	2.3 - 14.5	2.2 - 7.9	2.1 - 12.8	2.0 - 8.3	1.4 - 12.5
Ammonia-b (µg.L ⁻¹)	3.1 - 18.8	4.1 - 14.0	2.9 - 9.6	3.8 - 13.5	2.3 - 9.3	2.6 - 11.8
Nitrite-s (µg.L ⁻¹)	0.1 - 9.2	0.1 - 4.2	0.1 - 5.5	0.1 - 3.6	0.1 - 5.8	0.1 - 3.6
Nitrite-b (µg.L ⁻¹)	0.1 - 4.2	0.1 - 6.4	0.1 - 5.5	0.1 - 3.3	0.1 - 6.7	0.1 - 3.6
Nitrate-s (µg.L ⁻¹)	0.7 - 47.1	0.7 - 79.0	0.03 - 61.6	0.7 - 79.3	0.7 - 34.5	0.7 - 107.5
Nitrate-b (µg.L ⁻¹)	0.2 - 43.3	0.7 - 81.1	0.7 - 33.9	0.7 - 103.1	0.7 - 26.3	0.7 - 124.5
Phosphate-s (µg.L ⁻¹)	0.6 - 21.0	0.6 - 4.5	0.6 - 23.6	0.6 - 7.1	0.6 - 21.0	0.6 - 0.6
Phosphate-b (µg.L ⁻¹)	0.7 - 13.3	0.6 - 12.2	1.9 - 37.7	0.6 - 4.5	1.9 - 21.0	0.6 - 3.2
Silicate-s (µg.L ⁻¹)	33.9 - 469.7	84.1 - 817.3	45.9 - 632.3	77.3 - 773.1	26.7 - 548.6	73.5 - 855.6
Silicate-b (µg.L ⁻¹)	29.1 - 475.3	84.1 - 547.3	9.9 - 418.9	81.9 - 214.3	14.7 - 424.6	72.8 - 228.3
Chlorophyll a (µg.L ⁻¹)	0.1 - 2.8	0.1 - 1.2	0.0 - 0.8	0.0 - 1.2	0.1 - 0.7	0.0 - 1.6

Paracalanus aculeatus was registered in 75% of the total samples but it was less abundant. This population compounded 3.9 % of the Paracalanidae assemblage during the studied period. Overall means of the density values were 24, 22 and 4 ind.m⁻³ in the dry months and 230, 146 and 57 ind.m⁻³ in the rainy months, at 10, 20 e 30 m isobaths, respectively. Densities were higher in the rainy months when the maximum abundance (1682 ind.m⁻³) was registered at 10 m isobath (Table 3). In the shelf off Sergipe and Alagoas *P. aculeatus* occurred in salinity values

between 25.8 and 39.3 psu, and temperature values between 23.5 and 29.5°C.

Parvocalanus crassirostris occurred in 34.7% of the samples and its density values were low. This species was more frequent and abundant in stations located in the inner shelf during the dry season in contrast with the other species which presented higher densities in the rainy months. The maximum value was 329 ind.m⁻³, recorded at 10 m isobath (Table 3). The distribution of *P. crassirostris* occurred in salinity values between 29.9 and 38.3 psu and temperature values between 24.0 and 29.0°C.

Table 3. Continental shelf off Sergipe and Alagoas. Density values (ind.m⁻³) of the Paracalanidae species in December 2001/2002 (dry months) and June 2002/2003 (rainy months) at 10, 20 and 30 m isobaths, monthly mean (MM) and total mean (TM).

10m Isobath																
Stations	December 2001						December 2002									
	1	7	10	13	16	19	MM	1	7	10	13	16	19	MM	TM	
<i>Acrocalanus longicornis</i>	0	0	0	0	0	7	1.2	0	0	0	0	0	0	0	0.0	1
<i>Paracalanus aculeatus</i>	11	17	30	0	7	14	13.0	28	45	0	95	47	0	35.7	24	
<i>Paracalanus indicus</i>	0	100	123	0	59	0	47.0	0	0	9	152	16	26	33.8	40	
<i>Paracalanus quasimodo</i>	1652	2796	1165	708	1621	568	1418.4	57	101	249	1404	703	364	479.7	949	
<i>Paracalanus spp.</i>	100	268	114	0	119	0	100.2	25	20	36	210	109	51	75.3	88	
<i>Parvocalanus crassirostris</i>	155	82	10	0	329	118	115.7	0	0	27	210	74	26	56.1	86	
<i>Calocalanus pavo</i>	0	4	20	0	0	0	4.1	6	28	1	0	12	0	7.9	6	
June 2002																
<i>Acrocalanus longicornis</i>	0	0	0	0	0	42	7.0	0	0	0	0	0	0	0.0	4	
<i>Paracalanus aculeatus</i>	238	246	176	1682	194	211	457.9	0	7	0	7	2	0	2.7	230	
<i>Paracalanus indicus</i>	0	0	22	1004	470	422	319.5	6	0	18	19	5	3	8.6	164	
<i>Paracalanus quasimodo</i>	9476	7485	4026	4828	3904	9909	6604.7	756	3380	1824	166	487	4533	1857.6	4231	
<i>Paracalanus spp.</i>	0	0	44	841	745	7716	1557.7	60	34	18	5	25	23	27.5	793	
<i>Parvocalanus crassirostris</i>	0	0	0	81	32	0	19.0	3	0	0	2	0	20	4.1	12	
<i>Calocalanus pavo</i>	48	0	0	27	32	0	17.9	3	0	0	0	0	0	0.5	9	
June 2003																
<i>Acrocalanus longicornis</i>	0	0	0	0	0	42	7.0	0	0	0	0	0	0	0.0	4	
<i>Paracalanus aculeatus</i>	238	246	176	1682	194	211	457.9	0	7	0	7	2	0	2.7	230	
<i>Paracalanus indicus</i>	0	0	22	1004	470	422	319.5	6	0	18	19	5	3	8.6	164	
<i>Paracalanus quasimodo</i>	9476	7485	4026	4828	3904	9909	6604.7	756	3380	1824	166	487	4533	1857.6	4231	
<i>Paracalanus spp.</i>	0	0	44	841	745	7716	1557.7	60	34	18	5	25	23	27.5	793	
<i>Parvocalanus crassirostris</i>	0	0	0	81	32	0	19.0	3	0	0	2	0	20	4.1	12	
<i>Calocalanus pavo</i>	48	0	0	27	32	0	17.9	3	0	0	0	0	0	0.5	9	
20m Isobath																
Stations	December 2001						December 2002									
	2	8	11	14	17	20	MM	2	8	11	14	17	20	MM	TM	
<i>Acrocalanus longicornis</i>	0	0	0	0	0	0	0.0	2	1	0	0	0	0	0.5	0.2	
<i>Paracalanus aculeatus</i>	21	8	11	0	4	9	8.9	23	28	5	7	150	0	35.6	22	
<i>Paracalanus indicus</i>	48	79	0	267	65	9	78.0	20	44	26	37	32	4	27.2	53	
<i>Paracalanus quasimodo</i>	521	117	16	6359	516	677	1367.6	91	16	51	214	274	25	111.6	740	
<i>Paracalanus spp.</i>	62	0	11	267	45	92	79.5	20	1	3	96	108	0	38.1	59	
<i>Parvocalanus crassirostris</i>	41	4	0	93	65	0	33.9	4	0	0	15	124	0	23.8	29	
<i>Calocalanus pavo</i>	7	25	6	0	0	0	6.3	21	0	1	1	0	0	4.0	5	
June 2002																
<i>Acrocalanus longicornis</i>	0	0	0	0	0	93	15.5	0	0	7	0	0	3	1.7	9	
<i>Paracalanus aculeatus</i>	240	321	274	293	138	248	252.5	27	45	66	35	24	45	40.4	146	
<i>Paracalanus indicus</i>	96	0	165	352	746	217	262.5	79	45	15	143	121	121	87.4	175	
<i>Paracalanus quasimodo</i>	6096	4125	2745	1702	2899	1208	3129.1	1320	4740	184	863	1360	1421	1647.9	2389	
<i>Paracalanus spp.</i>	0	0	467	293	828	650	373.1	36	307	217	62	82	129	139.1	256	
<i>Parvocalanus crassirostris</i>	0	0	0	0	0	0	0.0	0	15	0	4	0	0	3.1	2	
<i>Calocalanus pavo</i>	0	0	137	0	0	217	59.0	6	0	0	0	2	5	2.3	31	
June 2003																
<i>Acrocalanus longicornis</i>	0	0	0	0	0	93	15.5	0	0	7	0	0	3	1.7	9	
<i>Paracalanus aculeatus</i>	240	321	274	293	138	248	252.5	27	45	66	35	24	45	40.4	146	
<i>Paracalanus indicus</i>	96	0	165	352	746	217	262.5	79	45	15	143	121	121	87.4	175	
<i>Paracalanus quasimodo</i>	6096	4125	2745	1702	2899	1208	3129.1	1320	4740	184	863	1360	1421	1647.9	2389	
<i>Paracalanus spp.</i>	0	0	467	293	828	650	373.1	36	307	217	62	82	129	139.1	256	
<i>Parvocalanus crassirostris</i>	0	0	0	0	0	0	0.0	0	15	0	4	0	0	3.1	2	
<i>Calocalanus pavo</i>	0	0	137	0	0	217	59.0	6	0	0	0	2	5	2.3	31	
30m Isobath																
Stations	December 2001						December 2002									
	3	9	12	15	18	21	MM	3	9	12	15	18	21	MM	TM	
<i>Acrocalanus longicornis</i>	0	0	0	0	0	0	0.0	0	0	0	0	0	6	1.0	0.5	
<i>Paracalanus aculeatus</i>	5	0	0	12	0	0	2.9	8	3	0	9	3	1	4.3	4	
<i>Paracalanus indicus</i>	0	0	0	37	0	14	8.4	37	20	0.5	76	36	10	30.0	19	
<i>Paracalanus quasimodo</i>	5	0	18	16	2	16	9.5	280	8	0	96	31	19	72.3	41	
<i>Paracalanus spp.</i>	0	0	0	0	0	0	0.0	100	0	0	20	0	0	20.0	10	
<i>Parvocalanus crassirostris</i>	0	0	0	4	0	0	0.7	0	0	0	0	0	0	0.0	0	
<i>Calocalanus pavo</i>	0	5	0	4	2	5	2.8	8	1	0	4	1	18	5.2	4	
June 2002																
<i>Acrocalanus longicornis</i>	37	0	122	90	0	123	62.0	0	3	35	2	5	6	8.6	35	
<i>Paracalanus aculeatus</i>	112	108	92	180	0	31	87.1	18	31	79	12	5	21	27.6	57	
<i>Paracalanus indicus</i>	2433	0	31	900	0	276	727.9	21	9	223	58	4	25	56.6	362	
<i>Paracalanus quasimodo</i>	8122	1424	0	2099	28	123	1966.1	338	938	529	379	2	239	404.2	1185	
<i>Paracalanus spp.</i>	1048	0	0	60	0	123	205.1	37	83	4	39	7	0	28.4	117	
<i>Parvocalanus crassirostris</i>	0	0	0	0	0	0	0.0	0	3	0	0	0	0	0.5	0.2	
<i>Calocalanus pavo</i>	225	39	122	270	85	184	154.1	7	0	4	0	12	4	4.7	79	
June 2003																
<i>Acrocalanus longicornis</i>	37	0	122	90	0	123	62.0	0	3	35	2	5	6	8.6	35	
<i>Paracalanus aculeatus</i>	112	108	92	180	0	31	87.1	18	31	79	12	5	21	27.6	57	
<i>Paracalanus indicus</i>	2433	0	31	900	0	276	727.9	21	9	223	58	4	25	56.6	362	
<i>Paracalanus quasimodo</i>	8122	1424	0	2099	28	123	1966.1	338	938	529	379	2	239	404.2	1185	
<i>Paracalanus spp.</i>	1048	0	0	60	0	123	205.1	37	83	4	39	7	0	28.4	117	
<i>Parvocalanus crassirostris</i>	0	0	0	0	0	0	0.0	0	3	0	0	0	0	0.5	0.2	
<i>Calocalanus pavo</i>	225	39	122	270	85	184	154.1	7	0	4	0	12	4	4.7	79	

Calocalanus pavo and *Acrocalanus longicornis* were mainly recorded at the 30 m isobath and presented low abundances. *C. pavo* presented a density peak (270 ind.m⁻³) in the rainy season. It was identified in 56% of all analyzed samples, in the salinity range from 25.8 to 39.3 psu, and in temperatures ranging from 23.5 to 29.5°C. *Acrocalanus longicornis* presented maximum density (123 ind.m⁻³) in the rainy season. This species occurred in salinities ranging from 25.8 to 39.3 psu and temperatures from 24.0 to 29.0°C.

Cluster analysis revealed two groups of species. Group 1 compounded by oceanic species *Calocalanus pavo* and *Acrocalanus longicornis* and group 2 by coastal and shelf species such as *Parvocalanus crassirostris*, *Paracalanus quasimodo*, *Paracalanus aculeatus*, *Paracalanus indicus* and *Paracalanus* spp. (Fig. 2). Among the species of group 2 *P. crassirostris* was far apart from the other ones because it is a coastal species whose abundance was high in the dry season and basically remains restrict to 10 m isobaths.

The correlation analyses between the abiotic and biotic variables performed by the canonical correspondence analysis (CCA) revealed that samples of December 2001 and 2002 were correlated directly to nitrite and phosphate and inversely correlated to temperature. Conversely the samples of June 2002 and 2003 were directly correlated to nitrate, ammonia and temperature. The spatial gradient was associated with depth and salinity. The measured variables explained 35% of biotic data variance. (Fig. 3).

The Monte Carlo permutation test revealed that the Paracalanidae species distribution presented

significant correlation to salinity, temperature and depth ($p < 0.05$).

DISCUSSION

In the shelf off Sergipe and Alagoas States the Paracalanidae family was constituted by coastal and shelf species such as *Parvocalanus crassirostris*, *Paracalanus quasimodo*, *P. indicus* and *P. aculeatus* and by oceanic species as *Calocalanus pavo* and *Acrocalanus longicornis*. They are common copepods in the Brazilian coast and have been cited by Björnberg (1963; 1981), Valentin & Monteiro-Ribas (1993), Vega-Pérez & Hernandez (1997), Lopes *et al.* (1999) and Neumann-Leitão *et al.* (1999).

In the present study *P. quasimodo* was the dominant and most frequent species in all sampled months. The mean density values of this species were higher in the 10 m isobath, decreasing towards 20 and 30 m isobaths. It has been registered in other regions of the continental shelf off Northeast Brazil but not as one of the most abundant species (Neumann-Leitão *et al.*, 1998; 1999). Björnberg (1963; 1980) characterized this species as abundant in coastal waters with salinity above 30 psu and in shelf waters of tropical regions. The dominance of *P. quasimodo* in the Brazilian shelf waters has been cited by Campaner (1985), Araujo *et al.* (1991), Vega-Pérez & Hernandez (1997) and Lopes *et al.* (1999). It was also registered in the mouth of estuarine areas where tidal currents have a great influence (Montú & Cordeiro, 1988; Lopes, 1994; Eskinazi-Sant'Anna & Tundisi, 1996).

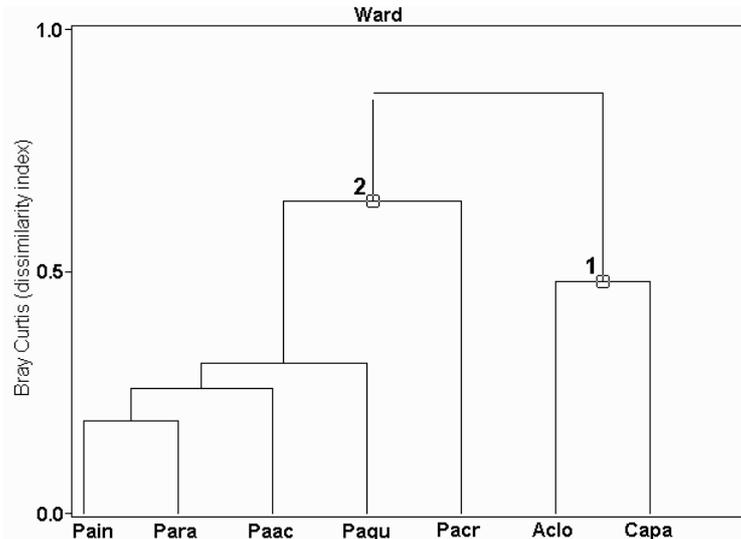


Fig. 2. Dendrogram showing affinity between species.

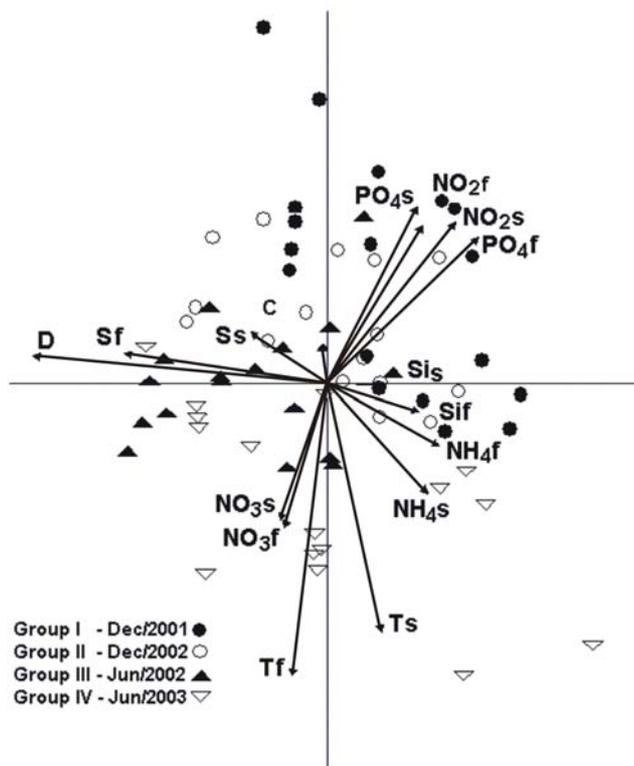


Fig. 3. Projection of stations, months and environmental variables on the first two axis of canonical correspondence analysis.
 D = depth; S = salinity; T = temperature; Si = silicate; s = surface; b = bottom.

Paracalanus indicus seems to be a typically shelf species, more abundant in the 20 and 30 m isobaths. It was the second species in abundance as also recorded by Vega-Pérez & Hernandez (1997) and Lopes *et al.* (1999) in the Brazilian southeast shelf. *P. indicus* is a coastal and shelf species and jointly with *P. quasimodo* and *P. aculeatus* dominate most part of the Paracalanidae assemblages of the Brazilian coast (Björnberg, 1981; Bradford-Grieve *et al.*, 1999).

P. aculeatus is an offshore and shelf species (González & Bowman, 1965; Bowman, 1971) and it has been recorded in the Brazilian coastal and shelf waters (Björnberg, 1963). It occurred in the dry and rainy months in all extension of the continental shelf off Sergipe and Alagoas as well.

P. crassirostris was more abundant on the inshore shelf, confirming its characteristics as an indicator species of coastal waters and reflecting the influence of estuarine outflow on the shelf. In Brazilian waters it was observed only in coastal or

mixed coastal and shelf waters (Björnberg, 1963) and belongs to the central complex of species that appear in all estuaries along the East coast of Brazil (Almeida Prado-Por & Lansac-Tôha, 1984).

Calocalanus pavo and *Acrocalanus longicornis* were more abundant in the outer-shelf stations and in the rainy season. They are thermophile species, common in temperatures above 25°C (Björnberg, 1963). In the Northeastern Brazilian coast (Lat. 2 to 9°) *C. pavo* was the most abundant Paracalanidae species (Neumann-Leitão *et al.*, 1999). In the dry months *P. indicus* and *C. pavo* presented higher abundance at stations located in the 20 m isobath while in the rainy months these populations were more abundant in the 30 m stations, probably avoiding low salinity waters of the inner shelf.

According to Bowman (1971) and Bradford-Grieve *et al.* (1999) *A. longicornis* is limited to oceanic waters of tropical and sub-tropical regions but in the present study it was recorded at 10, 20 and 30 m

isobaths. Although this species had limited influence on community dynamics, its distribution may indicate the influence of oceanic water masses on the Sergipe and Alagoas shelf. Lopes *et al.* (1999) verified that copepod assemblages were strongly related to distinct water masses in the continental shelf off Rio de Janeiro.

The tropical zones of the oceans are usually considered to have low organic production and within this oligotrophic environment, trophic enrichments occur in response to wind-induced coastal upwelling along the continental shore (Dessier & Donguy, 1985). Besides the coastal upwelling contribution, the estuarine mangrove ecosystems play an important role as sources of food for marine food webs (Schwamborn *et al.*, 1999) and replenishes inorganic components, mainly phosphates, nitrogenates and silicates (Eskinazi-Leça *et al.*, 2004).

Although the identified species have been registered in all isobaths, in the dry and rainy months, abundance values of the Paracalanidae assemblage presented very clear spatial and temporal patterns. The spatial pattern included maximum densities at the inner shelf in both seasons and the seasonal pattern was characterized by high abundances in the rainy season, when the water flux from estuarine areas increased.

The CCA analysis showed that samples collected in December (2001, 2002) were associated directly to high nitrite and phosphate values and low temperatures. A slight vertical gradient of temperature was observed at stations located in the 20 and 30 m isobaths. Paes (2004) verified that in the December months the northeast winds transported surface waters (Ekman transport) and allowed the entrance of deep cold waters from SACW into the Sergipe shelf. The lowest temperatures were registered near the canyons of the São Francisco and Japarutuba rivers suggesting that coastal upwelling was occurring in these areas. In these months species densities were low.

In June (2002, 2003) samples were associated to high temperature, nitrate and ammonia values. A salinity vertical gradient was only observed at the stations near the São Francisco river mouth. In the rainy season, runoff increases the water flux coming from estuaries and the surface salinity values decrease. All species presented density peaks during these months except *Parvocalanus crassirostris*.

In the studied area the Paracalanidae species distribution seems to be influenced by the estuarine waters and oceanic water masses as indicated by the significant correlations between salinity and temperature values and species densities in the Monte Carlo's permutation test.

Further studies about the dynamic of water masses at the Sergipe coast are essential to understand

the distribution patterns of the zooplanktonic populations.

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