

BATHYMETRIC DISTRIBUTION AND POPULATION SIZE  
STRUCTURE OF PAXILLOSID SEASTARS  
(ECHINODERMATA) IN THE CABO FRIO  
UPWELLING ECOSYSTEM OF BRAZIL

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ABSTRACT

Sampling of paxillosid seastars by 20-min trawls was made monthly at depths of 30, 45 and 60 m, from January, 1986 to December, 1988. Bottom water and sediments were analyzed. Four thousand one hundred twenty-one individuals comprising five species were collected: *Astropecten cingulatus* (54.6%); *A. brasiliensis* (26.4%); *Luidia ludwigi scotti* (18.9%); *L. alternata* (<1%) and *Tethyaster vestitus* (<1%). *Astropecten brasiliensis* occurred primarily at 30 m (from very well to well-sorted medium sand) and 45 m (from well to moderately-well sorted medium sand), while *A. cingulatus* and *L. ludwigi scotti* were most common at 45 m and 60 m (from well to moderately-well sorted fine sand). Differences in size-frequency distributions of *A. brasiliensis* were recorded at 30 and 45 m depths. Population densities were higher and body size smaller ( $R = 4\text{--}5$  cm) at the shallower depth (30 m). At deeper depth (45 m), individuals were larger ( $R = 7\text{--}10$  cm) and coexisted with other species of seastars. *Astropecten cingulatus* showed similar size-frequency distributions at both 45 and 60 m depths ( $R = 4$  cm). No species showed a pattern of seasonal variation in density. Highest densities occurred when sea water temperatures were lower than 18°C, suggesting some relation with periods of upwelling. Differences in population size structures of seastars suggest that the recruitment rate is independent of local densities.

The distribution of different species may be studied on several scales. The larger-scale approach allows a biogeographic analysis based on patterns of distribution of species and genera. The smaller-scale approach gives details of spatial variations in density with and between species. It is important to quantify patterns of distribution and to identify the processes that determine such patterns (Thrush, 1991). In both approaches species' distribution relates to the nature of the abiotic environment. The small-scale spatial distribution may also be affected by biological interactions. Both intraspecific and interspecific interactions as well as density-dependent factors influence spatial distribution (Mukai et al., 1986; Thrush, 1991).

Distribution data of species are also useful for determination of adaptive zones of a supraspecific taxon (Van Valen, 1971; Blake, 1990). Paxillosid asteroids have a distinct adaptive zone. They live in shallow to deep environments, feeding on large prey and small particles from substrate (Jangoux, 1982; Blake, 1990). Most paxillosidans lack suckered disks on the tube feet and are apparently limited to soft substrata (Blake, 1990). Paxillosid adaptive zones seem to be well defined, but further details of depth distribution and population size structure of sympatric species are necessary to provide background information for a better understanding of the group.

Studies on population biology of seastars along the coast of Brazil have focused primarily on taxonomy and systematics (Tommasi, 1958, 1961, 1970, 1974, 1985; Bernasconi, 1957; Brito, 1968; Manso, 1989). Only a few studies have examined the relationship between the distribution or abundance of seastars and environmental characteristics of sediment or bottom water (Carrera-Rodriguez and Tommasi, 1977; Manso, 1989). However, the seastars are an ecologically important and numerically dominant group in soft-bottom marine communities of Brazil.

The purpose of this study was to describe the bathymetric distribution, abundance and population size structure of seastars from an upwelling region of the Cabo Frio continental shelf. These aspects are interpreted in the light of sea water salinity and temperature data as well as information on sediment grain size and organic content.

### STUDY AREA

The Cabo Frio region (23°S; 42°W) is in the central-southern littoral zone of Brazil. The shore line bends inwards abruptly from N-S to E-W, and the continental shelf becomes narrow. Consequently, 100 and 200 m depths occur near the coast (Valentin, 1984) (Fig. 1). During spring-summer (September to March) the prevailing E-NE winds and Coriolis effects cause upwelling of subtropical waters (South Atlantic Central Water, SACW), resulting in temperatures lower than 18°C, salinities lower than 36‰ and nitrate concentration higher than 10 mmol·m<sup>-3</sup> (Thomsen, 1962; Valentin et al., 1987; Rodriguez et al., 1992). Downwelling occurs when S-SW winds cause the replacement of SACW with tropical warmer water (Brazil Current, BC and Coastal Water, CW). The upwelling cycle is interrupted most frequently during winter (June to August) (Valentin, 1984; Valentin et al., 1987; Rodriguez et al., 1992).

### MATERIALS AND METHODS

Seastars were sampled by conducting one 20-min trawl monthly along Maçambaba Beach, Arraial do Cabo, RJ (22°57'S, 23°00'W; 47°07'W, 42°11'W) at depths of 30, 45 and 60 m from January 1986 to December 1988. The otter-trawl was equipped with a 12-m footrope and cod-end mesh with a size of 25 mm. All trawls were conducted in daylight (10 AM to 3 PM), at a speed of approximately 3.0 kn. The area sampled in each trawl was approximately 2,620 m<sup>2</sup>, as estimated by methods of Alverson (1971) and Pauly (1984). Bottom sea water was sampled with a Nansen bottle at six oceanographic stations (Fig. 1). Water temperature was measured at each station using a reversing thermometer. Salinity was measured with a Beckman induction salinometer and dissolved oxygen by the Winkler method (Strickland and Parsons, 1972).

Sediment samples were collected using a Van-Veen grab (0.1 m<sup>2</sup>) at each depth from April 1986 to February 1987. Granulometrical sediment fractions were determined according to Ingram (1971). The size-distribution of grains was expressed in dry weight and statistical grain parameters were calculated according to Buchanan (1984). A portion of the sediment samples (100 g) was used for measuring the proportion of calcium carbonate and organic carbon. The former was expressed as percent weight loss after HCl treatment, and the latter by chromic acid organic matter oxidation, both on a dry weight basis (Buchanan, 1984).

Abundance of seastars was determined considering the number of individuals sampled per trawl.

Size-distributions of seastars were estimated by measuring the radius (*R*) (the distance from the mouth to the longest arm tip, 1 mm accuracy). Bathymetric differences in the size-distributions of seastars and in the bottom sea water and sediment parameters were statistically analyzed using a Chi-square test and Mann-Whitney and Kruskal-Wallis rank tests, respectively (Siegel, 1975; Sokal and Rohlf, 1981). The Tukey's test for non-parametric randomized block analysis of variance was calculated following Kruskal-Wallis Analysis (Zar, 1984).

After measurement, seastars were fixed in 5% formaldehyde and preserved in 70% alcohol. All species collected were identified according to Tommasi (1970), Clark (1982) and Clark and Downey (1992). Specimens were deposited in the Echinodermata collection of the Museu Nacional (Universidade Federal do Rio de Janeiro).

### RESULTS

*Abiotic Features of Bottom Water and Sediment.*—Bottom sea water temperature ranged from 12.8°C (November 1988 at 45 m) to 24.2°C (May 1988 at 30 m). Of all samples, 64% were collected in cold water (lower than 18°C), mostly occurring in summer (33%) and spring (29%). Low sea water temperatures were less frequent in autumn (22%) and winter (16%). Warmer sea water bottom temperatures were recorded more frequently in winter (50%) and autumn (34%) than in spring (9%) and summer (6%). Monthly variations in bottom sea water temperature reflect this tendency for colder water to be present during summer and spring (Fig. 2). Mean bottom sea water temperatures decreased with increasing

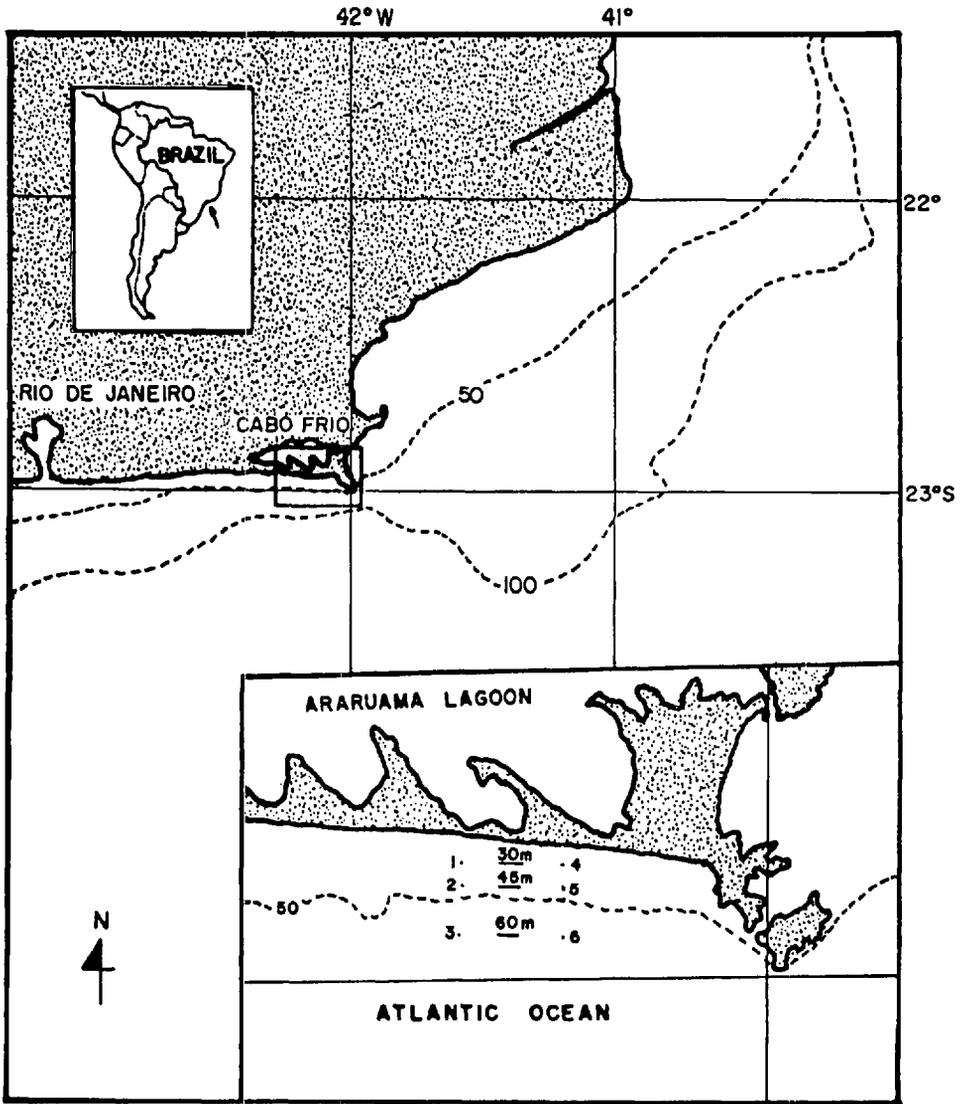


Figure 1. Map of the Cabo Frio region; squared-off area is expanded to indicate details of the study sites. Striped area show where the trawls were taken.

depth, from 30 to 60 m depth. Salinity and dissolved oxygen changed only slightly. The former ranged from 34.3‰ (November 1988 at 60 m) to 36.51‰ (June 1988 at 30 m) and the latter from 3.54 ml·liter<sup>-1</sup> (May 1987 at 60 m) to 6.62 ml·liter<sup>-1</sup> (September 1988 at 45 m). Mean monthly temperature, salinity and dissolved oxygen did not differ significantly ( $P < 0.05$ ; Kruskal-Wallis Analysis) among depths. It was possible to identify three distinct water masses in the study area: South Atlantic Central Water (SACW) ( $<18^{\circ}\text{C}$  and  $<36.0\text{‰}$ ); Coastal Water (CW) ( $>18^{\circ}\text{C}$  and  $<36.0\text{‰}$ ) and Brazilian Current Water (BC) ( $>18^{\circ}\text{C}$  and  $>36.0\text{‰}$ ).

Mean amounts of calcium carbonate, organic carbon, grain median diameter and inclusive graphic standard deviation of shallow (30 and 45 m) and deep (60

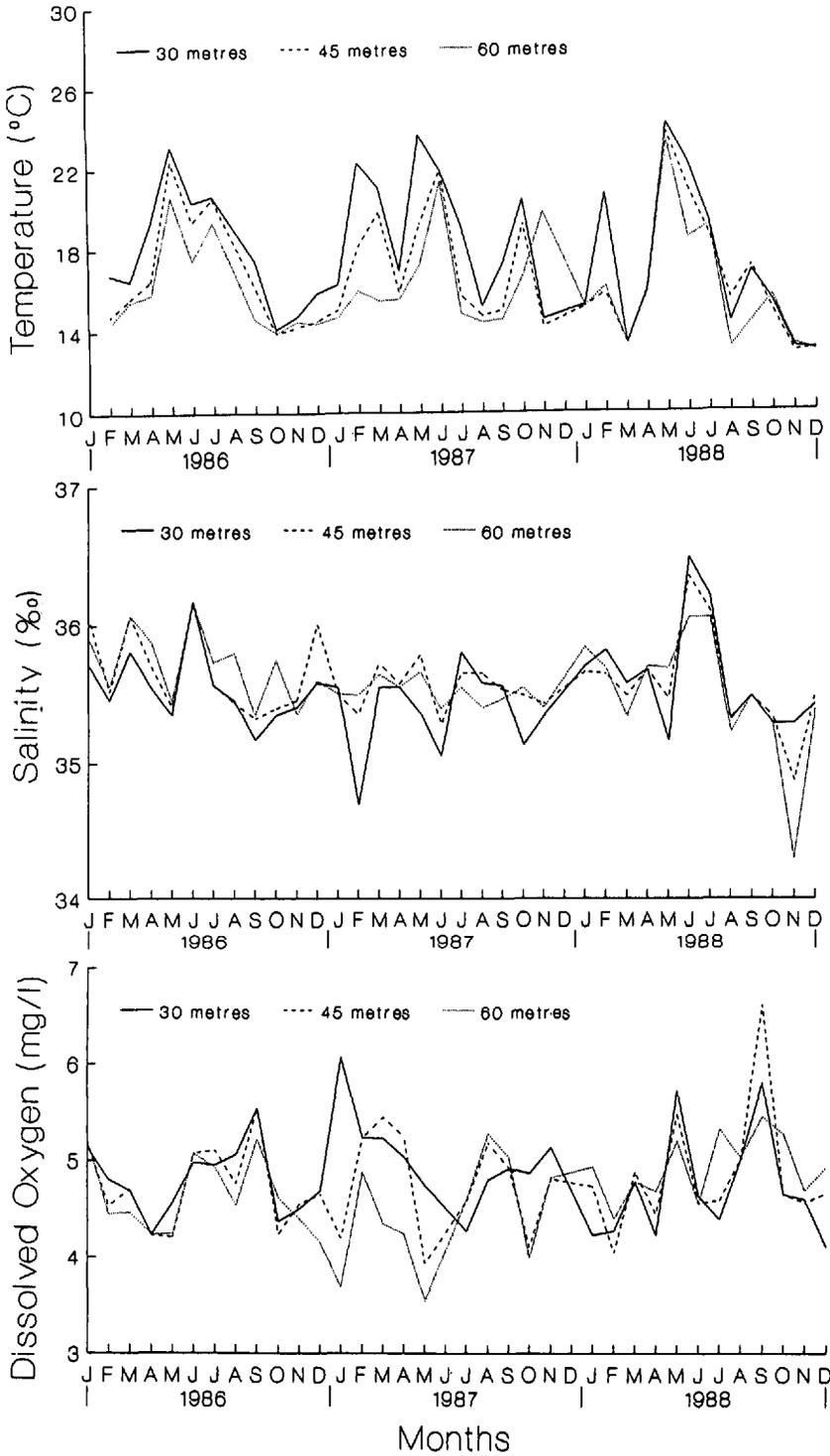


Figure 2. Monthly variations in sea water temperature, salinity and dissolved oxygen at oceanographic stations.

Table 1. Mean values of calcarium (Ca), organic carbon (OC), mean grain size diameters (MGSD) and inclusive graphic standard deviation (IGSD) of sediments

Depths (m)	Ca (mg·g <sup>-1</sup> )	OC (%)	MGSD (phi)	IGSD (phi)	Classification*
30	3.38 ± 1.32	0.21 ± 0.01	1.70 ± 0.48	0.40 ± 0.08	Well-sorted medium sand
45	10.15 ± 5.53	0.21 ± 0.01	1.82 ± 0.58	0.59 ± 0.22	Moderately well-sorted medium sand
60	19.82 ± 10.36	0.51 ± 0.01	2.67 ± 0.34	0.68 ± 0.22	Moderately well-sorted fine sand

\* Wentworth grade classification.

m) depths (Table 1) differed significantly ( $P < 0.05$ ; Kruskal-Wallis Analysis). Tukey's test showed that these differences occurred between 30 and 60 m stations, and between 45 and 60 m in all but one parameter (calcium carbonate). The only differences in calcium carbonate levels were recorded between stations 1 (30 m) and 2 (45 m) and stations 5 (45 m) and 6 (60 m) (Fig. 1). Shallower depths had larger grain sizes as compared to the 60 m depth (Kruskal-Wallis Analysis). Therefore, sediments were similar at 30 and 45 m depths where lower values of organic carbon were detected.

**Bathymetric Distribution and Abundance of Species.**—A total of 4,121 specimens comprising 5 species were collected from 96 trawls. *Astropecten cingulatus* Sladen, 1889; *Astropecten brasiliensis* Muller and Troschel, 1842 and *Luidia ludwigi scotti* Bell, 1917 were the most frequently collected and abundant species. Only one specimen of *Tethyaster vestitus* (Say, 1825) and of *Luidia alternata* (Say, 1825) were collected during the entire study (Table 2). *A. cingulatus* was the most numerous species sampled (54.6%), followed by *A. brasiliensis* (26.4%) and *L. ludwigi scotti* (18.95%) (Table 2).

The bathymetric distributions of these species showed the same patterns during 1986, 1987 and 1988. Differences between the observed numerical distribution of seastars according to depths and those expected under a null hypothesis of random distribution were highly significant (Table 3). At 30 m depth, *A. brasiliensis* was the most abundant and frequently collected species (Fig. 3; Tables 2, 4). At 45 m depth, *A. brasiliensis*, *A. cingulatus* and *L. ludwigi scotti* coexisted, comprising more similar percentages of the populations than at other depths (Fig. 3; Tables 2, 4, 5, 6). At 60 m depth, *A. cingulatus* and *L. ludwigi scotti* predominated, but the former was more abundant and the most frequently collected (Fig. 3; Tables 2, 5, 6).

Temporal variations in the densities of seastars did not show any seasonality (Fig. 3). Nonetheless, the greatest densities were recorded when sea water temperatures and salinities were lower than 18°C and 36.0‰, respectively (Fig. 4). In 1988, the greatest densities of seastars were recorded at 30, 45 and 60 m depth (Fig. 3; Tables 2, 4, 5, 6).

**Size Structure of Seastar Populations.**—Size-frequency distributions of seastars showed variations by depth and year ( $P < 0.05$ ; Mann-Whitney test) (Fig. 5; Table 7). *A. brasiliensis* showed a similar distribution at 30 m ( $\bar{x} \pm 1$  SD,  $R = 5.99 \pm 1.33$ ) and 45 m ( $\bar{x} \pm 1$  SD,  $R = 6.07 \pm 1.49$ ) depths in 1986. Larger individuals (6–10 cm,  $R$ ) were more frequent at 45 m ( $\bar{x} \pm 1$  SD,  $R = 6.64 \pm 1.75$ ) in 1987. In 1988, size-frequency distributions were basically bi-modal at 30 ( $\bar{x} \pm 1$  SD,  $R = 5.52 \pm 2.08$ ) and 45 m ( $\bar{x} \pm 1$  SD,  $R = 5.01 \pm 2.57$ ) depths and significantly different from one another. Smaller individuals (1–3 cm,  $R$ ) were more frequent in 1988. *A. cingulatus* populations were composed of smaller in-

Table 2. Total number of individuals and frequency in trawls (in parentheses) for species of seastars sampled from January 1986 to December 1988

Species	1986				1987				1988				Total	%
	30 m	45 m	60 m	60 m	30 m	45 m	45 m	60 m	30 m	45 m	45 m	60 m		
<i>A. brasiliensis</i>	72 (7)	48 (8)	12 (4)	143 (9)	146 (10)	2 (2)	248 (12)	406 (11)	11 (3)	1,080	26.40			
<i>A. cingulatus</i>	13 (5)	57 (8)	144 (6)	11 (3)	110 (7)	372 (9)	1 (1)	113 (9)	1,429 (10)	2,250	54.60			
<i>L. ludwigi scotti</i>	2 (1)	1 (1)	12 (2)	3 (3)	88 (6)	126 (7)	11 (5)	197 (11)	341 (9)	781	18.95			
<i>L. alternata</i>	0	0	0	0	0	0	1 (1)	0	0	1	0.03			
<i>T. vestitus</i>	0	0	1 (1)	0	0	0	0	0	0	1	0.03			
Total of specimens	87	106	169	157	344	500	261	716	1,781	4,121				
Total of trawls	8	9	9	12	12	11	12	12	11	96				
Individuals/trawls	10.9	11.8	18.8	13.1	28.7	45.5	21.7	59.7	161.9	42.9				

Table 3. Observed and expected (in parentheses) number of individuals of seastar species

Depth (m)	Period	Species			$\chi^2$
		<i>A. brasiliensis</i>	<i>A. cingulatus</i>	<i>L. ludwigi scotti</i>	
30	1986	72 (31.81)	13 (51.57)	2 (3.61)	$P < 0.01$
45		48 (38.76)	57 (62.84)	1 (4.40)	
60		12 (61.43)	144 (99.59)	12 (5.58)	
30	1987	143 (45.64)	11 (77.32)	3 (34.03)	$P < 0.01$
45		146 (100.00)	110 (169.42)	88 (74.57)	
60		2 (145.35)	372 (246.25)	126 (108.39)	
30	1988	248 (62.71)	1 (145.51)	11 (51.77)	$P < 0.01$
45		406 (172.70)	113 (400.72)	197 (142.58)	
60		11 (429.58)	1,429 (996.77)	341 (354.65)	

individuals than other species (reaching only 6 cm, *R*). At 60 m depth, where they occurred in greatest densities, size-frequency distributions revealed a mode at approximately 4-cm radius ( $\bar{x} \pm 1$  SD,  $R = 4.18 \pm 0.81$  in 1986;  $3.92 \pm 0.73$  in 1987 and  $4.08 \pm 0.80$  in 1988). At 60 m, mean sizes were smaller than at 45 m ( $\bar{x} \pm 1$  SD,  $R = 4.40 \pm 0.69$  in 1986;  $4.54 \pm 1.01$  in 1987 and  $4.66 \pm 0.67$  in 1988). *L. ludwigi scotti* was the most easily damaged species with many individuals losing arms during trawls. Therefore, estimating the size-frequency distribution of the population was difficult. Size distributions of individuals with entire arms are shown in Figure 5. In 1987, the mode of sizes peaked at 3 cm radius at 60 m depth ( $\bar{x} \pm 1$  SD,  $R = 3.68 \pm 1.67$ ). A bi-modal size distribution was recorded at 45 m depth (minor mode about 3 cm,  $R$  and major mode about 9 cm,  $R$ ;  $\bar{x} \pm 1$  SD,  $R = 5.79 \pm 2.66$ ). In 1988, this species was more abundant than in 1986 and 1987. At 60 m depth, the size structure of the population approximated a normal distribution (mode about 5 cm,  $R$ ;  $\bar{x} \pm 1$  SD,  $R = 5.58 \pm 1.83$ ), and at 45 m depth ( $\bar{x} \pm 1$  SD,  $R = 4.35 \pm 2.17$ ) an irregular distribution was recorded (Fig. 5).

## DISCUSSION

*Abiotic Features.*—Bottom sea water temperature and salinity variations recorded during this study are in accordance with the local hydrological patterns (Moreira da Silva, 1965; Mascarenhas et al., 1971; Ikeda et al., 1971; Valentin, 1984; Valentin et al., 1987). The high frequency of cold waters in conjunction with low salinity (SACW) in spring and summer (October to March, mainly) and warm tropical water and higher salinity (BC and CW) in autumn and winter are due to prevailing E–NE and S–SW winds, respectively. Costa and Fernandes (1993) showed the relationship between the direction and intensity of wind variations and upwelling periods from November 1986 to December 1987 and from May 1988 to October 1988 on the same study area. Upwelling occurred when pre-

Table 4. Number (mean  $\pm$  SD) and biomass of individuals of *Astropecten brasiliensis* per 100 m<sup>2</sup>

Depth (m)	1986		1987		1988	
	No.	Wet weight (g)	No.	Wet weight (g)	No.	Wet weight (g)
30	0.26 $\pm$ 0.32	4.72 $\pm$ 5.08	0.46 $\pm$ 1.17	6.16 $\pm$ 15.02	0.71 $\pm$ 0.79	11.74 $\pm$ 15.19
45	0.19 $\pm$ 0.23	3.21 $\pm$ 3.99	0.46 $\pm$ 0.74	9.47 $\pm$ 15.56	1.29 $\pm$ 0.94	17.93 $\pm$ 15.85
60	0.06 $\pm$ 0.09	0.21 $\pm$ 0.47	0.01 $\pm$ 0.02	0.13 $\pm$ 0.31	0.04 $\pm$ 0.08	0.26 $\pm$ 0.51

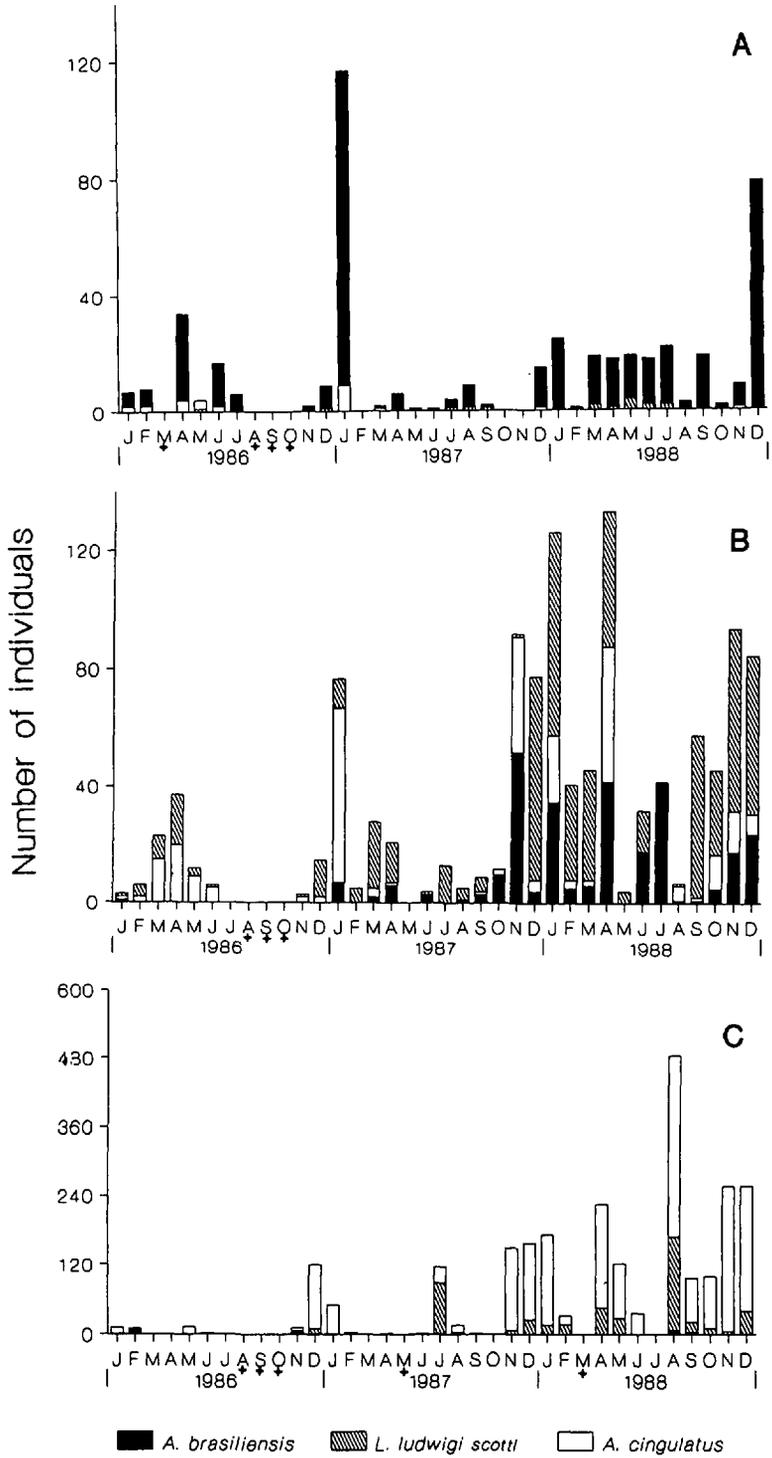


Figure 3. Monthly variations in abundance (number of individuals per trawl) of seastars sampled. A = 30 m; B = 45 m; C = 60 m. (+) month that no trawl was taken.

Table 5. Number (mean  $\pm$  SD) and biomass of *Astropecten cingulatus* per 100 m<sup>2</sup>

Depth (m)	1986		1987		1988	
	No.	Wet weight (g)	No.	Wet weight (g)	No.	Wet weight (g)
30	0.05 $\pm$ 0.06	0.71 $\pm$ 0.69	0.04 $\pm$ 0.10	1.38 $\pm$ 4.60	0.0003 $\pm$ 0.01	0.04 $\pm$ 0.12
45	0.24 $\pm$ 0.26	2.65 $\pm$ 3.44	0.35 $\pm$ 0.74	4.46 $\pm$ 9.17	0.36 $\pm$ 0.52	4.73 $\pm$ 6.65
60	0.71 $\pm$ 1.42	4.83 $\pm$ 13.36	1.31 $\pm$ 2.03	11.14 $\pm$ 17.74	5.43 $\pm$ 3.72	48.81 $\pm$ 37.09

vailing E-NE winds attained 9.5 m·sec<sup>-1</sup>, and was interrupted when S-SW winds became stronger, increasing from 2.5 m·sec<sup>-1</sup> in November-February 1987 to 7.5 m·sec<sup>-1</sup> in June-July 1987. Sporadic upwelled waters may also occur due to changes in wind direction and intensity as recorded in March and August 1987 and August 1988. Such changes were caused by predominantly E-NE winds (Costa and Fernandes, 1993). Changes in surface sea water temperature and salinity can occur after as little as 48 hours during E-NE winds averaging 8.0 m·sec<sup>-1</sup> (Ikeda, 1976).

As suggested by Rowe (1985), the benthic subsystem in upwelling ecosystems may be divided to two categories: 1) those overloaded with organic matter, anaerobic and dominated by sulfate reduction (for example Peru and SW Africa); and 2) those that are not overloaded with organic matter and remain aerobic (for example NW Africa and Baja California). The benthos of the area studied should be classified primarily as an aerobic system. Dissolved oxygen in bottom water fluctuated around 5.0 ml·liter<sup>-1</sup> ( $\bar{x} \pm 1$  SD = 4.766  $\pm$  0.494 ml·liter<sup>-1</sup>) and the percentages of organic carbon of sediment were lower than 0.55%.

**Abundance and Bathymetric Distribution.**—Primary productivity of surface waters and depth are major factors determining benthic biomass, especially when oxygen contents of sediment are not limited (Rowe, 1971 and 1985). Even though local water column chlorophyll levels appear very low (reaching 6  $\mu$ g·liter<sup>-1</sup>; Valentin and Coutinho, 1990) when compared to other upwelling regions (25  $\mu$ g·liter<sup>-1</sup> at NW Africa; Herbland et al., 1973), Cabo Frio upwelling is characterized by high levels of detritus (Barth, 1973) and zooplanktonic biomass (annual average of organic matter of 66 mg·m<sup>-3</sup>, reaching 280 mg·m<sup>-3</sup>; Valentin and Moreira, 1978). The greatest abundance of seastars was recorded during periods of upwelling (Fig. 4) when densities of the crab *Portunus spinicarpus* (Brisson, 1992) and cephalopods (Costa and Fernandes, 1993) were also highest. Therefore, variations in densities of seastars and other major macrobenthic organisms may be related to upwelling cycles rather than seasons. However, the impact of upwelling on benthic biomass and secondary production is not known. Significant temperature fluctuations can yield changes in the sexual maturity cycles and duration of planktonic stages of macrofauna (Glèmarec and Menesguen, 1980). Such

Table 6. Number (mean  $\pm$  SD) and biomass of individuals of *Luidia ludwigi scotti* per 100 m<sup>2</sup>

Depth (m)	1986		1987		1988	
	No.	Wet weight (g)	No.	Wet weight (g)	No.	Wet weight (g)
30	0.01 $\pm$ 0.02	0.004 $\pm$ 0.01	0.01 $\pm$ 0.02	0.01 $\pm$ 0.05	0.04 $\pm$ 0.05	0.13 $\pm$ 0.15
45	0.005 $\pm$ 0.01	—*	0.28 $\pm$ 0.55	1.08 $\pm$ 1.98	0.63 $\pm$ 0.61	1.58 $\pm$ 2.05
60	0.06 $\pm$ 0.12	0.08 $\pm$ 0.21	0.44 $\pm$ 0.99	0.75 $\pm$ 1.68	1.30 $\pm$ 1.80	5.01 $\pm$ 7.14

\* Arm-broken individual.

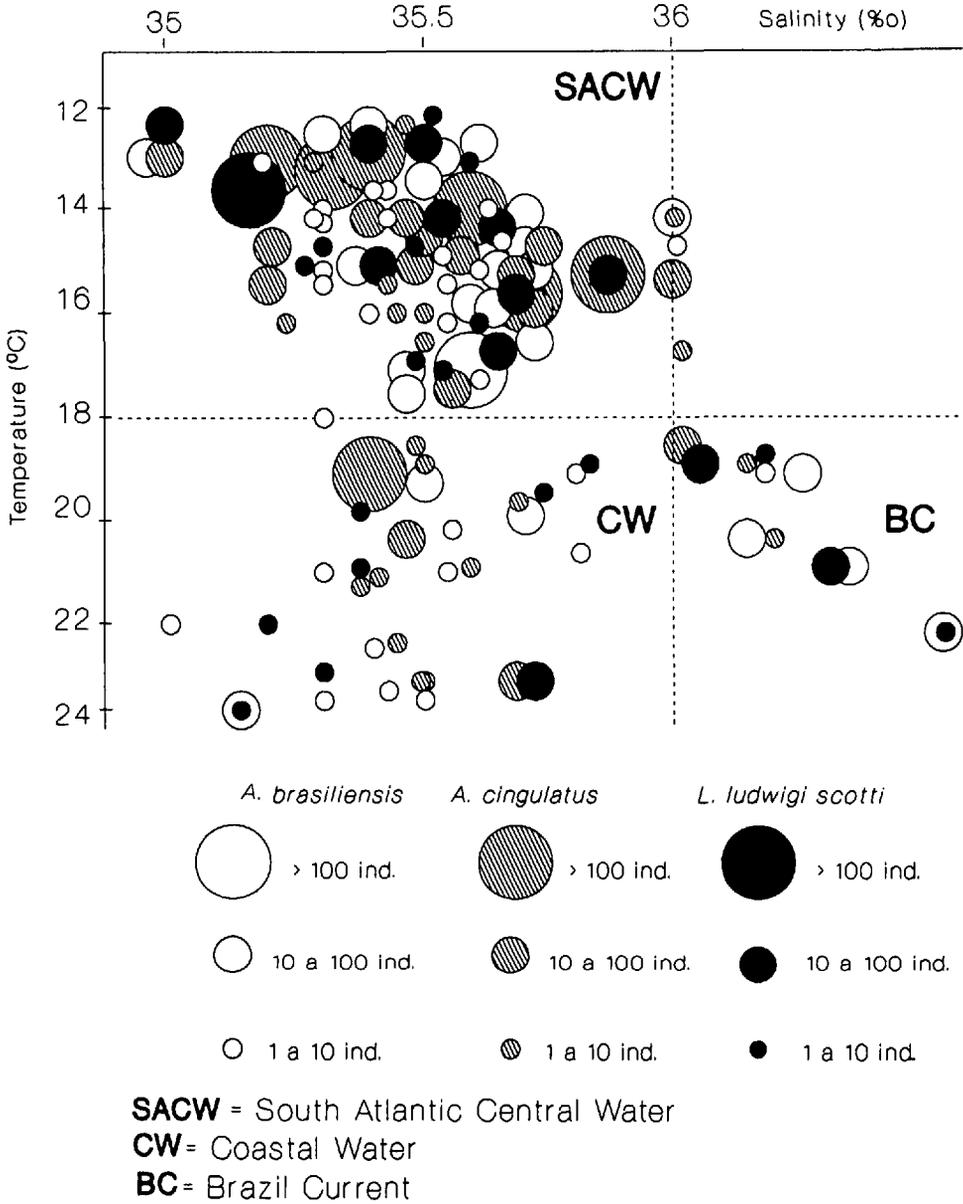


Figure 4. Abundance of seastar species according to the water masses present in the study area. Each point represents the number of individuals collected in one trawl.

irregularities can destabilize the community from one year to the next, both qualitatively and quantitatively (Glèmarec and Menesguen, 1980).

The seastars sampled are tropical and widely distributed in the Atlantic Ocean, extending even to temperate zones which are influenced by warm waters (Tommasi, 1970; Carrera-Rodriguez and Tommasi, 1977; Clark, 1982). Their bathymetric distribution is wide, ranging from shallow water to 200–300 m depths, although the highest densities occur at shallow depths to 100 m (Carrera-Rodriguez and Tommasi, 1977; Clark, 1982). In the study area, a distinct bathymetric

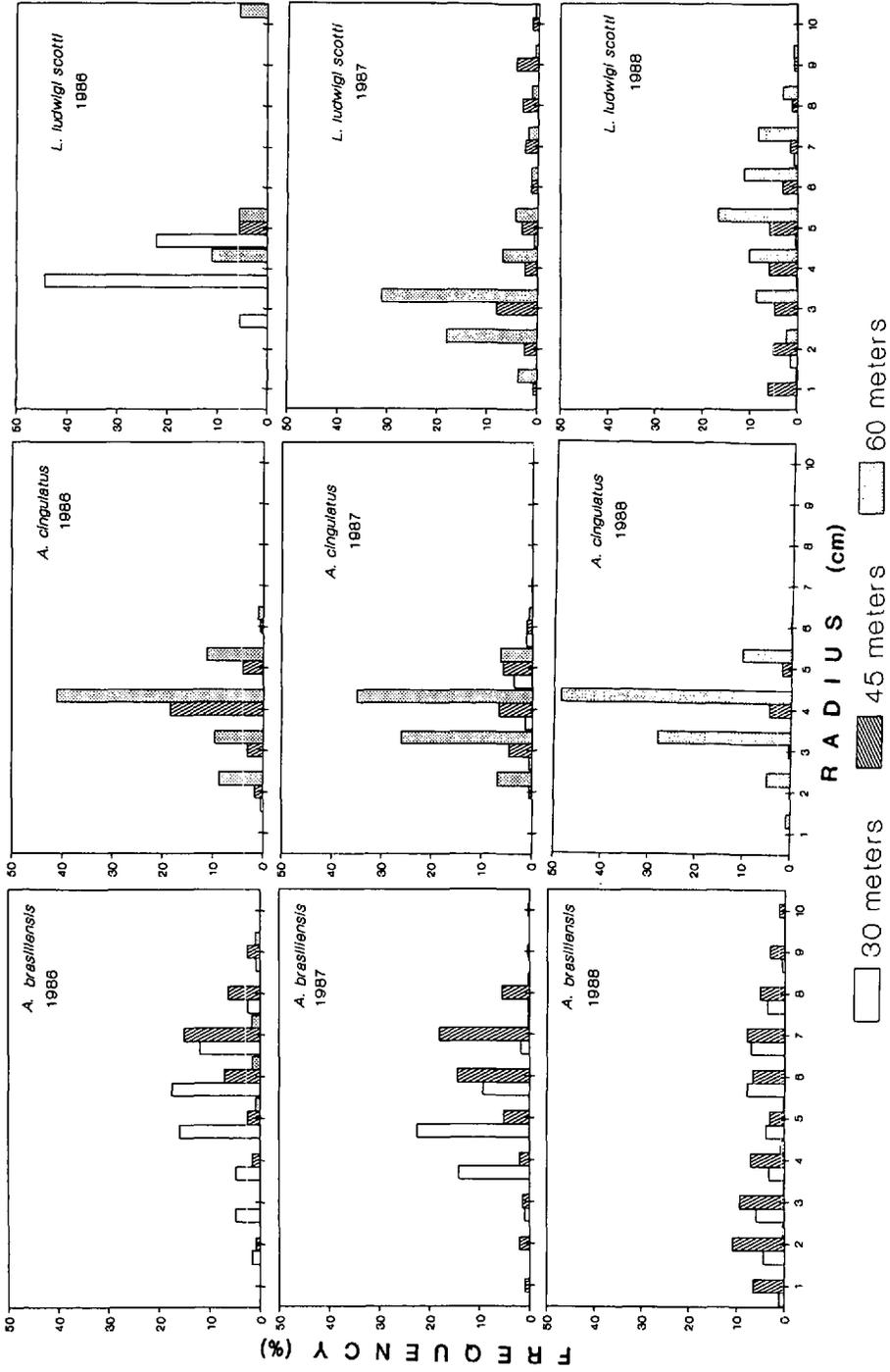


Figure 5. Size-frequency distributions of seastar species by depth and year.

Table 7. Intraspecific comparisons of size-distributions of seastars (Mann-Whitney test) (significance level = 0.05; \* significant difference)

Depths (m)	<i>A. brasiliensis</i>		<i>A. cingulatus</i>		<i>L. ludwigi scotti</i>	
	Calculated values	Associated probabilities	Calculated values	Associated probabilities	Calculated values	Associated probabilities
	1986					
30 × 45	0.6143	0.5390	—	—	—	—
45 × 60	—	—	-2.1170*	0.0343	—	—
	1987					
30 × 45	8.8643*	<0.0003	—	—	—	—
45 × 60	—	—	-5.6930*	<0.0001	-4.7188*	<0.0001
	1988					
30 × 45	-2.9112*	<0.0004	—	—	—	—
45 × 60	—	—	-5.0568*	<0.0001	4.4379*	<0.0001

distribution of seastars is evident. This pattern seems to be related to characteristics of sediments which vary according to depth. Hence, *A. brasiliensis* was more frequently collected and numerically abundant where sediments were coarser (medium sand at 30 m); *A. cingulatus* and *L. ludwigi scotti* were more frequent in the finer sediment with higher amounts of organic matter (fine sand at 60 m). At 45 m, where sediments were mixed, three species co-occurred in similar frequencies. Thus, substrate conditions changed gradually and significantly over a narrow bathymetric interval. Gomes (1989) also considered the 45 m isobath a transitional zone where species of pelecypods characteristic of 30 and 60 m depths were found in the same study area. The distinct depth distribution of seastars may be directly related to spatial variations in density of their prey (Ventura, 1991), since astropectinids and luidiids are recognized as infaunal predators, feeding especially on mollusks (Jangoux, 1982; Nojima, 1988). Similar patterns of bathymetric distribution of *A. brasiliensis* and *A. cingulatus* have been described along the southern Brazilian coast (Carrera-Rodriguez and Tommasi, 1977).

*Population Size Structures.*—Analysis of size-frequency structures of seastar populations revealed variations among 3 years, mainly in 1988. Certainly, the apparent lack of recruitment in 1986 and 1987 is not an artifact of cod-end mesh since small individuals (1–3 cm, *R.* chiefly *A. brasiliensis* and *L. ludwigi scotti*) were collected in the highest frequency in 1988 using the same sampling technic. The rarity of small individuals is often observed in long-term monitoring of echinoderm populations. The successful recruitment may vary over long periods. Loosanoff (1964) reported only two mass recruitments of the seastar *Asterias forbesi* over 25-year period. Zann et al. (1987) observed only a single large recruitment of juvenile seastar *Acanthaster planci* in 9 years of monitoring. Also, Ebert (1983) recorded only one significant settlement in 16 years of monitoring of the sea urchin *Strongylocentrotus purpuratus* population. Unpredictable and rare successful recruitments are not surprising in these species since they have a long-lived (of several weeks) pelagic larval phase (Johnson, 1992). The larvae are subject to hydrological processes which may provide long dispersal distances. Therefore, the recruitment rate is independent of local densities. As a result, the local populations are generally open (since all recruits may come from other regions) and recruitment-limited (Roughgarden and Iwasa, 1986; Karlson and Levitan, 1990). Considering hydrological dynamics of the studied area, it is possible that local larvae could be transported to the offshore. Pedrotti and Fenaux

(1992) reported a maximal dispersal distance of echinoderm larvae of 28 miles in an upwelling area of Mediterranean. However, coastal upwelling may act as efficient or inefficient factor on larval dispersal, according to its intensity and frequency (Ebert and Russell, 1988; Pedrotti and Fenaux, 1992). Up to now, there is not enough information on seastar reproduction or larval dispersal from the studied area to be related to upwelling events.

Size-frequency distributions of *A. brasiliensis* showed that the largest individuals (6–10 cm, *R*) were most common at the depth of 45 m, where they coexisted with smaller (1–6 cm, *R*) *A. cingulatus*. The smallest individuals (1–5 cm, *R*) were abundant at 30 m, where *A. brasiliensis* was dominant. Size-frequency distributions of *A. cingulatus* were similar at 45 and 60 m depths. Similar situation was described by Ribi et al. (1977) for other *Astropecten* species in Mediterranean. Differences between diets of each species led the authors to suggest that character displacement was occurring. Further information on the feeding preferences of *Astropecten* species and prey abundance (Ventura et al., in prep.) are necessary to understand the distribution pattern of these seastars in Cabo Frio region.

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