

DISTRIBUTION AND CO-OCCURRENCE OF *Calanoides carinatus* AND LARVAE OF *Sardinella brasiliensis* AND *Engraulis anchoita* OVER THE SOUTHERN BRAZILIAN CONTINENTAL SHELF

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Abstract

The distribution of adults and juveniles of *Calanoides carinatus* with co-occurring copepods along two continental shelf transects off São Sebastião-Ubatuba and Paranaguá in the SE and S Brazil respectively, during December to February and May from 1975 to 1977 were studied by analysing plankton samples from 5 stations collected along each transect from 5 m above the bottom to the surface with a 0.333 mm mesh Bongo net. *C. carinatus* is present over the shelf along both transects only during late spring and early summer (December to February). Its density is approximately 20% and 5% of the mean copepod density estimated for São Sebastião-Ubatuba and Paranaguá respectively. Distribution of *C. carinatus* coincides with both that of *Engraulis anchoita*'s larvae and the spatial distribution of the South Atlantic Central waters over the São Sebastião-Ubatuba shelf from December to February. Both *C. carinatus* and larvae of *Sardinella brasiliensis* are locally abundant from December to February but do not co-occur.

Descriptors: Crustacea, Copepoda, *Calanoides carinatus*, Abundance, Neritic province, Pisces, fish larvae, *Sardinella brasiliensis*, *Engraulis anchoita*, Geographical distribution, São Sebastião-Ubatuba, Paranaguá, SW Atlantic, Brazil.

Descritores: Crustacea, Copepoda, *Calanoides carinatus*, Abundância, Província nerítica, Pisces, larvas de peixe, *Sardinella brasiliensis*, *Engraulis anchoita*, Distribuição geográfica, São Sebastião-Ubatuba, Paranaguá, Atlântico Sul Ocidental, Brasil.

Introduction

Calanoides carinatus is widespread in the tropical neritic zones of the three large oceans and in the western Mediterranean (Brodskiĭ, 1972; Vervoort, 1949). In the Atlantic Ocean, it is distributed from 47°N to 37°S in waters with temperature ranging from 12°C in the southern subtropical convergence to 25°C in the Gulf of Guinea (Courties, 1978; Vervoort, 1949). It is considered an indicator of waters from the Malvinas Current off Argentina (Ramirez, 1977) and of subtropical water upwelling off Brazil (Björnberg, 1981; Valentin, 1984b). The copepod has been studied in upwelling areas off western Africa but also is present along the Congo-gabonese continental shelf even in the absence of

upwelling if the surface waters are cool and trophically rich (Petit & Courties, 1976).

In the SE African marine ecosystem, *C. carinatus* has a similar role as that of *Calanus finmarchicus* in the North Atlantic and of *Calanus acutus* in the southern Atlantic (Bainbridge, 1972). It is considered the most important trophic link between the phytoplankton and the fishes in upwelling areas (Hirche, 1980). The distribution of *C. carinatus* over the shelf has been correlated with that of the ichthyoplankton (Weikert, 1984) and adult fish species (Brenning, 1985), especially clupeids (Bainbridge 1960, 1972; Binet, 1983; Binet & Suisse de Sainte Claire, 1975).

In the Brazilian neritic waters, the species occurs from 21°15'S to 30°03'S in depths ranging from 15 to 150 m (Björnberg 1963, 1965, 1981; Campaner 1985, 1986; Valentin, 1984a,b). In this same region (22-29°S), spawning areas, stock biomass, and distribution pattern of eggs and larvae of *Sardinella*

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brasiliensis and *Engraulis anchoita* have been studied by Matsuura (1979, 1983) and Nakatani (1982) based on material and data collected during ten oceanographic cruises of the R/V "Prof. W. Besnard" sponsored by the FINEP/IOUSP (Financiadora de Estudos e Projetos/Instituto Oceanográfico da Universidade de São Paulo). In this paper a quantitative, seasonal survey of the occurrence of *Calanoides carinatus* in two distribution areas of these two fish species' larvae is presented with a discussion of their possible trophic relationships.

Material and methods

Plankton samples were collected with a 0.333 mm mesh Bongo net towed obliquely from 5 m above the bottom to the surface at five stations of each transect I and II, respectively on the continental shelf off São Sebastião-Ubatuba and Paranaguá (Fig. 1) during December '75, January '76, May '76, December '76, and Jan./Feb. '77 (R/V "Prof. W. Besnard" cruises I-III and V-VI). Copepods were

counted under the stereomicroscope in a Bogorov's counting chamber either from the whole sample or from one subsample drawn off with a Folsom splitter (Cf. Campaner, 1985). Adult males and females, and juveniles (nauplii and copepodites I-V) of *Calanoides carinatus* were counted separately.

Results and discussion

Table 1 shows the copepod densities and furnishes the water mass composition in the upper 150 m of the water column at each station. The predominant relationship of the Coastal, Shelf, Tropical, and SA Central water masses (vide Campaner, 1985) was calculated by the percentage value of each water mass in the water column where 10 means 100% of the water. Areas of unprecise delimitation or where there is the overlap of two or more water masses were referred to as mixing zones.

The water masses had a similar distribution pattern as obtained by Matsuura (1986) for the SE-S Brazilian

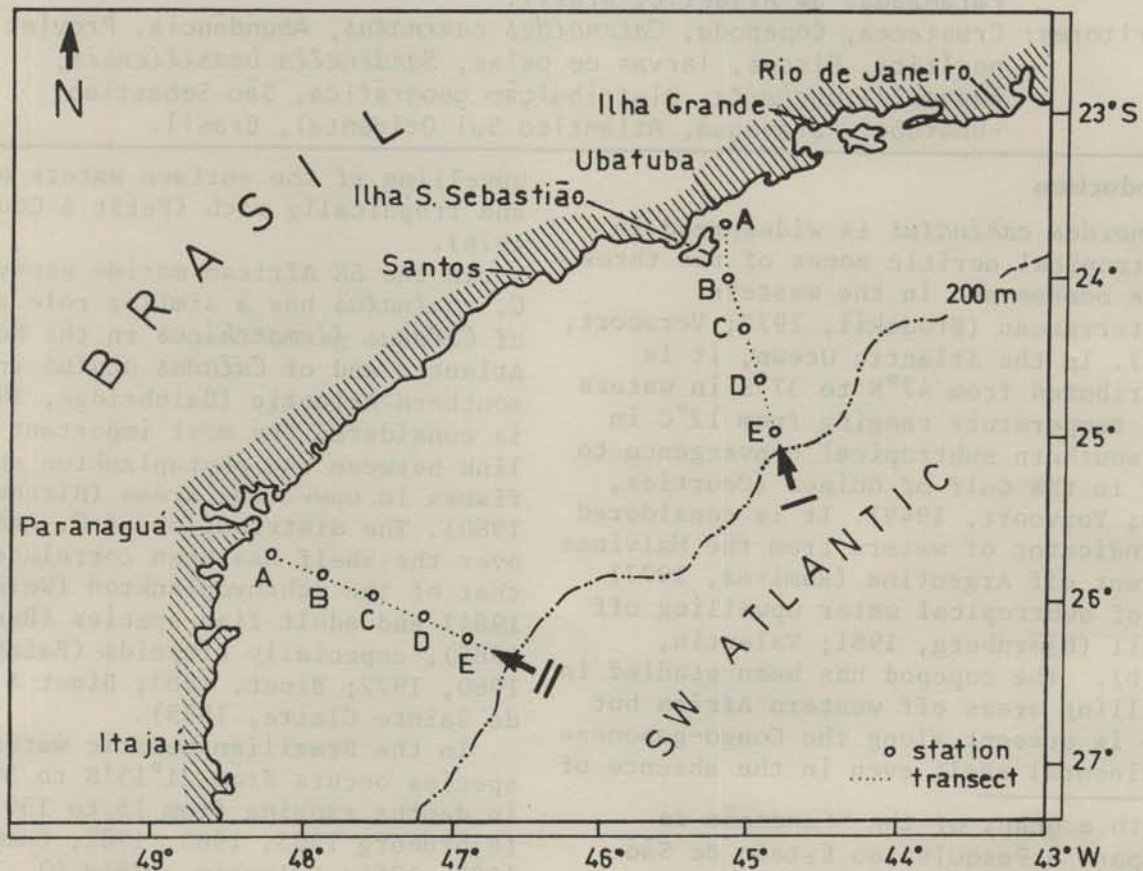


Fig. 1. Station and transect positions in the sampling area.

neritic region. The coastal waters were only recorded in the shallower station off Paranaguá (Table 1: St. A, Transect II), probably due to the influence of estuarine waters. Tropical waters occupied the São Sebastião area more extensively, especially in Dec.'76 than

off Paranaguá, showing larger oceanic influence in the first area. Although spatial extent differed, shelf waters were always present and situated above the SA Central waters. These were more shallower in Dec./Jan. and deeper, far from the coast in May.

Table 1. Relationship of the water masses, density of *Calanoides carinatus*, the other copepod species, and the copepod total in each station of transects I (São Sebastião-Ubatuba) and II (Paranaguá) on the southern Brazilian continental shelf from Dec.'75 to Jan./Fev.'77. Abbreviations: C= Coastal waters, T= Tropical waters, S= Shelf waters, A= SA Central waters, M= mixing zones, ad.= adults, juv.= juveniles (nauplii + copepodites I-V)

Transect Season	Station	Local depth (m)	Predominant relationship of water masses C : T : S : A : M	C o p e p o d d e n s i t i e s					(No . m ⁻³) Copepod Total
				<i>Calanoides carinatus</i>		other spp			
				ad. ♀	ad. ♂	juv.	Total		
Dec.'75	I A	18	0 : 0 : 10 : 0 : 0	-	-	0.64	0.64	145.84	146.48
	B	63	0 : 0 : 6 : 4 : 0	0.45	0.03	6.25	6.73	997.11	1003.84
	C	83	0 : 0 : 2 : 8 : 0	31.40	4.00	830.15	865.55	2032.84	2898.39
	D	116	0 : 0 : 3 : 7 : 0	0.77	1.00	65.09	66.86	321.61	388.47
	E	141	0 : 2 : 0 : 5 : 3	0.11	-	41.03	41.14	171.87	213.01
Dec.'75	II A	21		-	-	-	-	1039.49	1039.49
	B	42	NO	0.03	-	0.49	0.52	264.43	264.95
	C	60	DATA	0.23	0.08	3.11	3.42	187.20	190.62
	D	97	AVAILABLE	2.40	0.39	4.06	6.85	152.00	158.85
	E	127		0.36	0.16	6.79	7.31	68.64	75.95
Jan.'76	I A	19	0 : 0 : 10 : 0 : 0	-	-	-	-	362.75	362.75
	B	72	0 : 0 : 5 : 5 : 0	14.08	2.34	13.05	29.47	679.62	709.09
	C	81	0 : 4 : 0 : 6 : 0	0.12	0.18	22.79	23.09	69.85	92.94
	D	120	0 : 3 : 0 : 4 : 3	0.04	-	2.22	2.26	135.46	137.72
	E	280	0 : 2 : 0 : 6 : 2	0.09	0.01	1.94	2.04	98.89	100.93
Jan.'76	II A	22	0 : 0 : 10 : 0 : 0	-	-	0.03	0.03	185.56	185.59
	B	44	0 : 0 : 10 : 0 : 0	0.20	0.04	0.40	0.64	85.13	85.77
	C	64	0 : 0 : 4 : 6 : 0	0.02	-	0.60	0.62	87.95	88.57
	D	95	0 : 0 : 3 : 7 : 0	0.10	-	6.34	6.44	77.50	83.94
	E	135	0 : 0 : 3 : 7 : 0	-	-	0.05	0.05	53.56	53.61
May'76	I A	16	0 : 0 : 10 : 0 : 0	-	-	-	-	310.60	310.60
	B	71	0 : 0 : 10 : 0 : 0	-	-	-	-	235.64	235.64
	C	77	0 : 0 : 7 : 3 : 0	0.04	-	0.08	0.12	139.80	139.92
	D	117	0 : 0 : 4 : 6 : 0	0.10	-	0.18	0.28	84.09	84.37
	E	127	0 : 4 : 0 : 3 : 3	-	-	-	-	27.41	27.41
May'76	II A	20	10 : 0 : 0 : 0 : 0	-	-	-	-	179.52	179.52
	B	45	0 : 0 : 10 : 0 : 0	-	-	-	-	64.00	64.00
	C	64	0 : 0 : 10 : 0 : 0	-	-	-	-	54.46	54.46
	D	95	0 : 0 : 5 : 5 : 0	-	-	0.02	0.02	70.76	70.78
	E	134	0 : 0 : 4 : 6 : 0	-	-	-	-	36.15	36.15

cont.

Table 1. Cont.

Transect Season	Station	Local depth (m)	Predominant relationship of water masses C : T : S : A : M	C o p e p o d d e n s i t i e s					(No. m ⁻³) Copepod Total
				Calanoides carinatus			other		
				ad. ♀	ad. ♂	juv.	Total	spp	
I Dec. '76	A	24	0 : 0 : 10 : 0 : 0	0.19	2.04	4.80	7.03	618.81	625.84
	B	74	0 : 0 : 4 : 6 : 0	0.84	1.40	10.87	13.11	1048.44	1061.55
	C	81	0 : 6 : 0 : 4 : 0	0.05	0.10	8.95	9.10	245.34	254.44
	D	124	0 : 6 : 0 : 4 : 0	0.09	-	3.50	3.59	97.14	100.73
	E	144	0 : 8 : 0 : 2 : 0	-	-	0.12	0.12	58.67	58.79
II Dec. '76	A	19	10 : 0 : 0 : 0 : 0	-	-	-	-	565.29	565.29
	B	44	0 : 0 : 10 : 0 : 0	-	-	-	-	534.84	534.84
	C	64	0 : 0 : 7 : 3 : 0	-	-	-	-	354.04	354.04
	D	94	0 : 4 : 2 : 4 : 0	0.06	-	0.06	0.12	178.33	178.45
	E	127	0 : 3 : 3 : 6 : 0	0.03	-	0.05	0.08	88.28	88.36
I Jan./Feb. '77	A	20	0 : 0 : 10 : 0 : 0	0.52	-	0.10	0.62	510.55	511.17
	B	70	0 : 0 : 2 : 8 : 0	35.56	1.82	10.30	44.68	1201.24	1245.92
	C	81	0 : 0 : 1 : 9 : 0	5.20	2.53	202.35	210.08	151.69	361.77
	D	120	0 : 3 : 2 : 5 : 0	0.34	0.41	10.82	11.57	98.46	110.03
	E	136	0 : 6 : 0 : 2 : 2	0.09	0.04	6.07	6.20	81.13	87.33
II Jan./Feb. '77	A	22	4 : 0 : 6 : 0 : 0	-	-	-	-	914.28	914.28
	B	44	0 : 0 : 5 : 5 : 0	-	-	0.19	0.19	691.44	691.63
	C	65	0 : 0 : 3 : 5 : 2	0.80	0.48	7.55	8.83	623.83	632.66
	D	96	0 : 0 : 2 : 7 : 1	0.19	0.09	1.27	1.55	196.57	198.42
	E	131	0 : 2 : 2 : 4 : 2	0.07	0.11	8.71	8.89	153.87	162.76

According to Björnberg (1963), the above water masses on the Brazilian shelf should be ranked as follows, relative to the decreasing mean plankton volume: Coastal, SA Central (Deep Shelf), Shelf (Surface Shelf), and Tropical waters. Consequently, their distribution should influence the qualitative and quantitative copepod composition greatly, as can be deduced from some results (see Table 1); e.g., the copepod densities were relatively high in St. A off Paranaguá where coastal waters were present. On the other hand, densities were generally low in stations where tropical waters predominated over SA Central waters.

Calanoides carinatus was present on the shelf during late spring and early summer (Dec./Jan./Feb.) and practically absent in autumn (May) (Campaner, 1985; present data) clearly showing its seasonal occurrence. The stocks from early summer were predominantly juveniles (Table 1). The reduction of the species over the shelf during autumn has also been observed in the SE Atlantic off Africa (Courties, 1978;

Petit & Courties, 1976) and attributed to the migration of the summer copepodite stock to deeper waters. The development growth of *C. carinatus* and its quick reproduction are not only favoured by the cooling of the surface waters (Binet & Suisse de Sainte Claire, 1975) but also by the phytoplankton growth (Smith, 1982). The more superficial occurrence of the SA Central waters on the Brazilian shelf from December to February (Table 1) should contribute with nutrients for the proliferation of the phytoplankton. This water mass did not reach depths below 50 m in May. Contrary to observations from São Sebastião-Ubatuba, the SA Central waters seemed to have little influence on the increase of copepod abundance in Paranaguá, where the greatest number occurred in the St. A (see Table 1: Transect II, Dec.'75) in shallow coastal water. In this station *C. carinatus* did not occur, it only appeared significantly in January, when the SA Central waters were more superficially situated on the shelf. Generally, this species represented

approximately 20% and 5% of the mean copepod density in São Sebastião-Ubatuba and Paranaguá, respectively.

The spawning season and the greatest abundance of *Sardinella brasiliensis* larvae over the shelf occur from late spring to late summer, whereas in autumn no eggs and a few larvae were recorded (Matsuura, 1983). This seasonal occurrence pattern is similar to that observed for *C. carinatus*, but the density distribution of these two species are not coincident: considerable numbers of *C. carinatus* are found in areas of absence or low numbers of sardine larvae during Dec./Jan. (Fig. 2).

Nakatani (1982) found that spawning of *Engraulis anchoita* occurs in two seasons, viz. late spring-early summer and late winter-early spring. The former episode is restricted to upwelling areas near the coast while the latter is scattered throughout the shelf. In the former season greater concentrations of larvae are found in areas of Transect I where *C. carinatus* also occurs abundantly, especially its young forms (Fig. 3, Table I).

The main habitat of the sardine larvae and juveniles in the southern Brazil are the shelf waters with temperature ranging from 22 to 26°C and salinity from 34.5 to 36.0 ‰ (Matsuura 1979, 1983); these are practically the same characteristics of the habitat of *Sardinella aurita* off the Senegalese coast (Boely, 1982). The habitat of the anchovy larvae are the SA Central waters with temperature below 20°C (Matsuura, 1983; Matsuura *et al.*, 1985; Nakatani, 1982). In fact, areas of higher concentrations of anchovy larvae (Fig. 3) are generally coincident with stations of Transect I where the SA Central waters predominate over the other water masses in the water column (Table 1).

According to Goiten (1983), adults of *Sardinella brasiliensis* are predominantly phytoplanktivorous in the Cananéia region and zooplanktivorous off Ubatuba and Santos, the copepods representing respectively about 80 and 60% of the stomach contents of the sardines caught in the two areas. *Calanoides carinatus* was not found among the copepod species identified, these being commonly recorded in coastal and shelf waters. No information is

available about feeding habits of larvae and juveniles.

The feeding habit of larvae, juveniles, and adults of *Engraulis anchoita* has been studied in the Argentine waters (Angelescu, 1982; Ciechowski, 1967; Ciechowski & Weiss, 1974). According to these authors, all developmental stages feed exclusively on zooplankton, the larvae predominantly on eggs, nauplii, young copepodites, and adults of copepods, especially the Calanoida. The cryophile species of calanoid copepods, including *C. carinatus*, constitute the main item of the diet of juvenile and adult anchovies.

Angelescu (1982: 38) considered the quality and abundance of the main food (calanoid copepods) in the area under influence of the Malvinas Current, together with the environmental temperature and the thermocline formation, as the ecological factors important in influencing the anchovy's feeding and growth. Anchovies may encounter these conditions on the southern Brazilian shelf - the cool SA Central waters spread upwards over the shelf off São Sebastião/Ubatuba - during spring and summer when *Calanoides carinatus*, one of the dominant copepod species in this waters mass, is reproducing quickly. Consequently, large numbers of copepod eggs and larvae are available to the anchovy larvae and juveniles. During May, the anchovy larvae are more abundant far from the coast (Fig. 3) in areas where *C. carinatus* is practically absent; this copepod species is replaced in abundance by another herbivore, *Eucalanus pileatus*, (Campaner, 1985) which could be an important food item in the anchovy diet during this period.

To conclude, the distribution of *Calanoides carinatus* over the southern Brazilian continental shelf coincides with both that of the *Engraulis anchoita*'s larvae and the SA Central waters in the São Sebastião-Ubatuba area during late spring and early summer. With a seasonal occurrence similar to *C. carinatus*, *Sardinella brasiliensis*' larvae are locally abundant in different areas from December to February which might suggest the absence of trophic relationship between them.

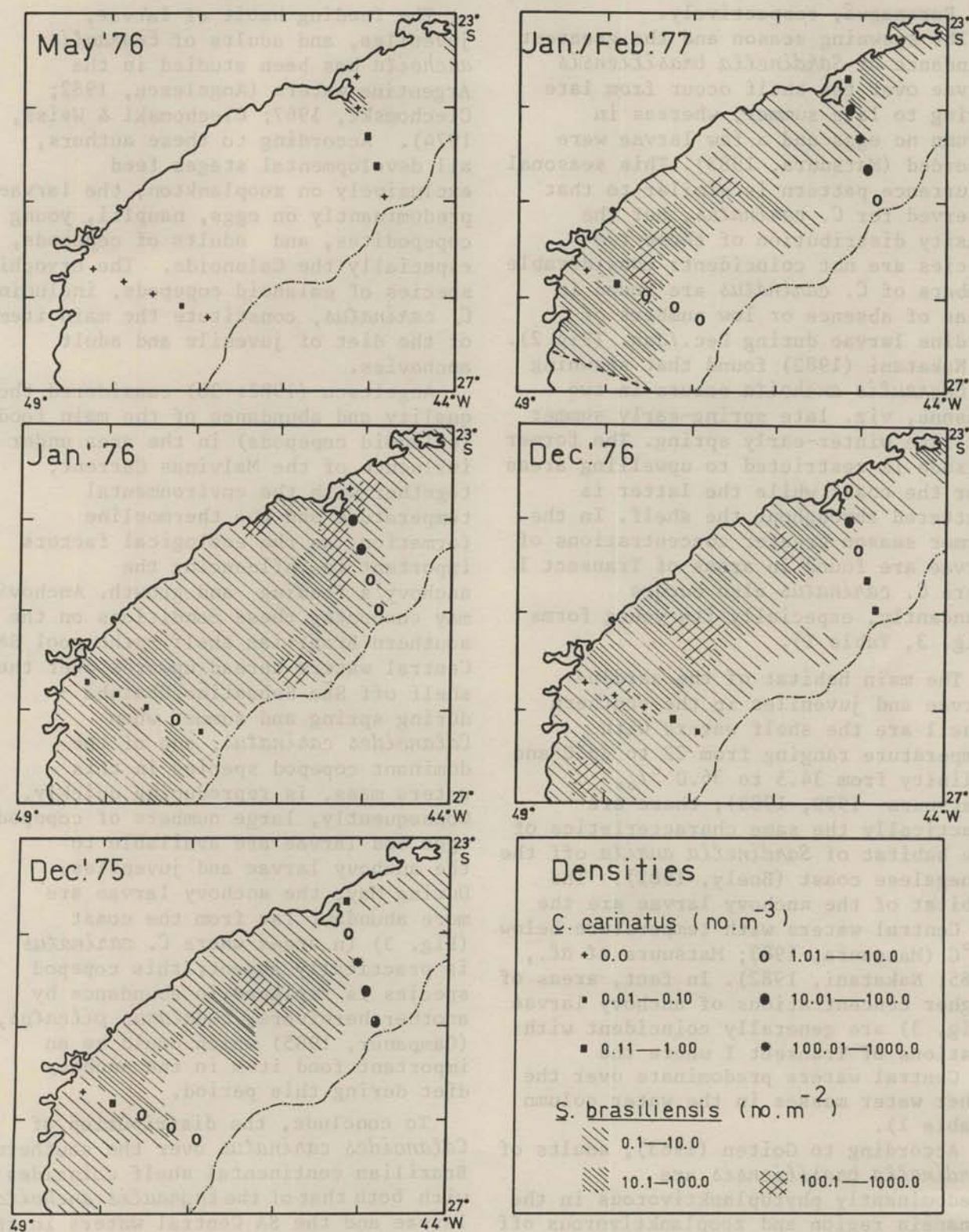


Fig. 2. Abundance of *Calanoides carinatus* in transects I and II plotted in distributional areas of larvae of *Sardinella brasiliensis* in the SE-S Brazilian continental shelf based on Matsuura's (1979, 1983) data.

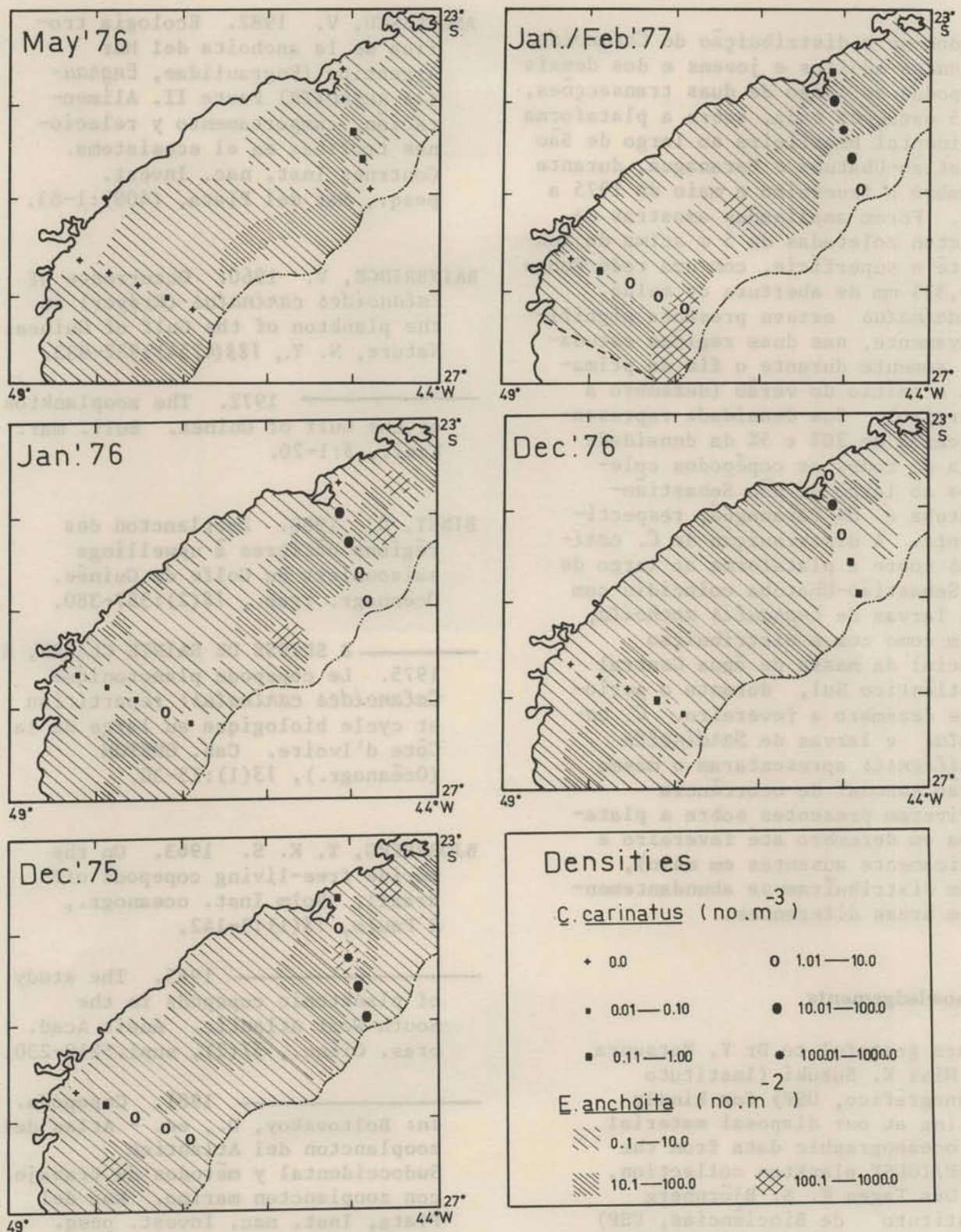


Fig. 3. Abundance of *Calanoides carinatus* in transects I and II plotted in distributional areas of larvae of *Engraulis anchoita* in the SE-S Brazilian continental shelf based on Nakatani's (1982) data.

Resumo

Estudou-se a distribuição de *Calanoides carinatus* adultos e jovens e dos demais copépodos ao longo de duas transecções, com 5 estações cada, sobre a plataforma continental brasileira ao largo de São Sebastião-Ubatuba e Paranaguá, durante dezembro a fevereiro e maio de 1975 a 1977. Foram analisadas amostras de plâncton coletadas de 5 m acima do fundo até a superfície, com uma rede Bongo de 0,333 mm de abertura de malha. *C. carinatus* esteve presente significativamente, nas duas regiões estudadas, somente durante o fim da primavera e início do verão (dezembro a fevereiro). Sua densidade representou cerca de 20% e 5% da densidade média de todos os copépodos coletados ao largo de São Sebastião-Ubatuba e de Paranaguá, respectivamente. A distribuição de *C. carinatus* sobre a plataforma ao largo de São Sebastião-Ubatuba coincidiu com a de larvas de *Engraulis anchoita*, assim como com a distribuição espacial da massa de água Central do Atlântico Sul, durante o período de dezembro a fevereiro. *C. carinatus* e larvas de *Sardinella brasiliensis* apresentaram o mesmo padrão sazonal de ocorrência (estiveram presentes sobre a plataforma em dezembro até fevereiro e praticamente ausentes em maio), porém distribuíram-se abundantemente em áreas diferentes.

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