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Demersal fish assemblages off São Sebastião, southeastern Brazil: structure and environmental conditioning factors (summer 1994)

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• ***Abstract***: The demersal fish community of the Channel and shelf of São Sebastião (SP), on the southeastern Brazilian coast, was investigated during the summer of 1994. The sampling was carried out using a bottom otter trawl at 26 stations located between 8 m and 65 m in depth. Ninety-three species of 40 families were identified in the area. Sciaenids were the most prominent in number of species, abundance, and weight. *Ctenosciaena gracilicirrhus*, *Paralonchurus brasiliensis*, and *Cynoscion jamaicensis* dominated in the catches. Cluster analysis showed three major groups of species and three groups of sites. The first group was composed of species found in the Channel and shallower areas of the inner shelf, the second of species associated with the inner shelf (<50 m depth), and the third group of species from the outer shelf (> 50 m depth). Environmental variables considered in Canonical Correspondence Analysis (CCA) explained 51% of the variation in the species data. Bottom water temperature was the most important variable selected by CCA, accounting for 21% of the explainable variance. The results revealed that structure of the ichthyofauna was associated with water mass distribution. During the period studied, the area was occupied by the warm Coastal Water (CW), but cold South Atlantic Central Water (SACW) was detected over the bottom of the outer shelf, influencing the distribution and abundance of the main species.

• ***Resumo***: A comunidade de peixes demersais do canal e plataforma de São Sebastião (SP), costa sudeste do Brasil, foi investigada no verão de 1994. A amostragem foi realizada com rede de arrasto de fundo, em 26 estações localizadas entre 8 e 65 m de profundidade. Foram identificadas 93 espécies pertencentes a 40 famílias. Os cienídeos foram os mais representativos em número de espécies, abundância e peso, sendo *Ctenosciaena gracilicirrhus*, *Paralonchurus brasiliensis* e *Cynoscion jamaicensis* as espécies dominantes. A análise de agrupamento revelou três grandes grupos de espécies e três grupos de estações. O primeiro grupo caracterizou-se pela presença de espécies com ocorrência no canal e regiões costeiras da plataforma interna; o segundo por espécies associadas à plataforma interna (<50 m de profundidade) e o terceiro grupo por espécies relacionadas à plataforma externa (>50 m). As variáveis ambientais selecionadas pela CCA explicaram 51% da variação dos dados das espécies, sendo a temperatura da água de fundo a mais importante, representando 21% da variância. Verificou-se a importância da distribuição das massas d'água na estruturação da comunidade de peixes demersais. Durante o período de amostragem a área foi ocupada pela massa d'água quente da Água Costeira (AC). No entanto, a presença da Água Central do Atlântico Sul (ACAS), mais fria, foi detectada na camada de fundo da plataforma externa, influenciando a distribuição e abundância das espécies dominantes.

• ***Descriptors:*** Marine ecosystem, Demersal fish, Assemblages, Channel, Continental shelf, São Sebastião, Southeastern Brazil.

• ***Descritores***: Ecossistema marinho, Peixes demersais, Associações, Canal, Plataforma continental, São Sebastião, Sudeste do Brasil.

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Introduction

The understanding of processes governing the distribution and abundance of organisms is fundamental for the management of living resources and environmental conservation. The distribution of the demersal ichthyofauna over the continental shelf is greatly affected by the shelf width, nature of the bottom sediments, oceanographic conditions, history of the oceans and possibilities of colonization from neighboring areas (Lowe-McConnell, 1987; Longhurst & Pauly, 1987). Depth and thermal gradients (Roel, 1987; Bianchi, 1991; Bianchi, 1992a; Mariscal-Romero *et al.*, 1998), in addition to oxygen (Bianchi, 1992b; Smale *et al.*, 1993), have been cited as the most important abiotic factors influencing the structure of soft bottom fish communities. Within each depth stratum, bottom type and latitudinal gradients affect species distributions (Bianchi. 1992a).

The structure and dynamic of the demersal ichthyofauna of the southeastern Brazilian shelf have been widely investigated in recent years. This area belongs to the Argentinean marine zoogeographical province which corresponds to a broad zone of faunistic transition with many endemic species (Figueiredo, 1981). Cabo Frio (Rio de Janeiro, Brazil) marks the southern limit of tropical species distribution and the Peninsula Valdés (Argentine) the northern limit of temperate species. Many studies have been carried out in this region in order to detect the pattern of distribution of demersal fish assemblages and understand the conditioning oceanographic processes involved (Benvegnu-Lé, 1978; Fagundes Netto & Gaelzer, 1991; Haimovici *et al.*, 1994; Natali Neto, 1994; Facchini, 1995; Paes, 1996; Rocha & Rossi-Wongtschowski, 1998).

The present study was developed within the framework of a multidisciplinary project entitled "Oceanography of the Inner Shelf of São Sebastião-OPISS", with a view to obtaining a thorough knowledge of the structure and function of the São Sebastião Channel and shelf and investigate evolutionary processes. In this context, the study of the ichthyofauna was carried out for the purpose of characterizing the structure of the demersal fish community and relate the species distribution pattern to the oceanographic conditions of the area.

Study Area

The area under study is located along the southeastern Brazilian coast, between 23°30'-24°30'S and 44°45'- 46° W (Fig. 1). The Channel is bordered on the west side by the continent and on the east side by São Sebastião Island. It is 24 km long and 5.8 km and 6.4 km wide at its northern and southern entrances, respectively, being 2 km in width at its central part. The deepest area is along its central axis (50 m), while the northern and southern entrances are 25 m and 20 m deep, respectively (Furtado, 1995). A paleo river valley, which extends from the southern entrance of São Sebastião Channel to depths greater than 100 m, developed during the last sea regression, representing the main route for the intrusion of the sea onto the inner shelf (Furtado *et al.*, 1996). The area suffers strong impact from sewage discharges, commercial activities of the harbor, and frequent oil spills from the "Dutos e Terminais Centro Sul" oil terminal (CETESB, 1996).

The continental shelf of the area is 100 km wide with the shelf break at 140 m depth (Zembruscki, 1979). The shelf can be hydrographically divided into an inner domain, bounded by the coast and the 40-50 m isobath, and an outer domain which extends from the 40-50 m isobath to the shelf slope. Water movements over the inner shelf are controlled by the wind, while both wind and the Brazil Current influence water dynamic of the outer shelf (Castro Filho *et al.*, 1987). Three water masses converge in this area: South Atlantic Central Water (SACW) characterized by low temperature (<20°C) and high salinity (S>36.4); Tropical Water (TW) with high temperature (>20°C) and salinity (S>36.4) (Miranda, 1982); and Coastal Water (CW), associated with high temperature (>24°C) and low salinity resulting from the combined effect of small to medium-size estuaries (Castro & Miranda, 1999). During summer, the water column of the inner shelf is stratified. The upper layer (down to 20 m) is occupied by the Coastal Water, which mixes with Tropical Water offshore. Cold SACW predominates over the bottom, and interacts with CW near the coast. During winter, the SACW retreats towards the shelf break, and is replaced by CW, disrupting the thermocline (Castro Filho *et al.*, 1987). Seasonal upwards movements of SACW into the euphotic zone promote natural enrichment of the area (Aidar *et al.*, 1993).

Material and methods

Sampling. Bottom trawl surveys were carried out during summer 1994 in the Channel (5 sites) and on the shelf (21 sites) (Fig. 1). Channel samples were obtained by the R/B Veliger II using a 9.7 m otter trawl with 40 mm stretch mesh in the body and sleeve, and 25 mm in the codend bar mesh, doors weighing 20 kg each. On the shelf, samples were taken by the R/V Prof. W. Besnard using a 17 m otter trawl with 60 mm stretch mesh in the body and sleeve and 25 mm in the codend bar mesh, each door weighing 100 kg. Thirty-minute standard tows were made during daylight hours at a speed of 2 knots. The total swept area was 55,590 m^2 in the Channel and 350,007 m^2 on the shelf. Temperature, salinity, and oxygen were measured from water samples collected with Nansen bottles. Sediment samples were obtained with a 0.1 m^2 van Veen grab and were analyzed by the Laboratory of Geology of the Instituto Oceanográfico, Universidade de São Paulo (IOUSP). Biological data were obtained at Centro de Biologia Marinha (CEBIMAR-USP) and IOUSP laboratories.

Data analysis. In order to obtain an overview of the hydrographic conditions of the area, 130 data pairs of temperature and salinity of the water column were used to construct a TS diagram. Differences of temperature and salinity among the three groups of sites obtained from cluster analysis were tested using a nonparametric Kruskal-Wallis test and Dunn's

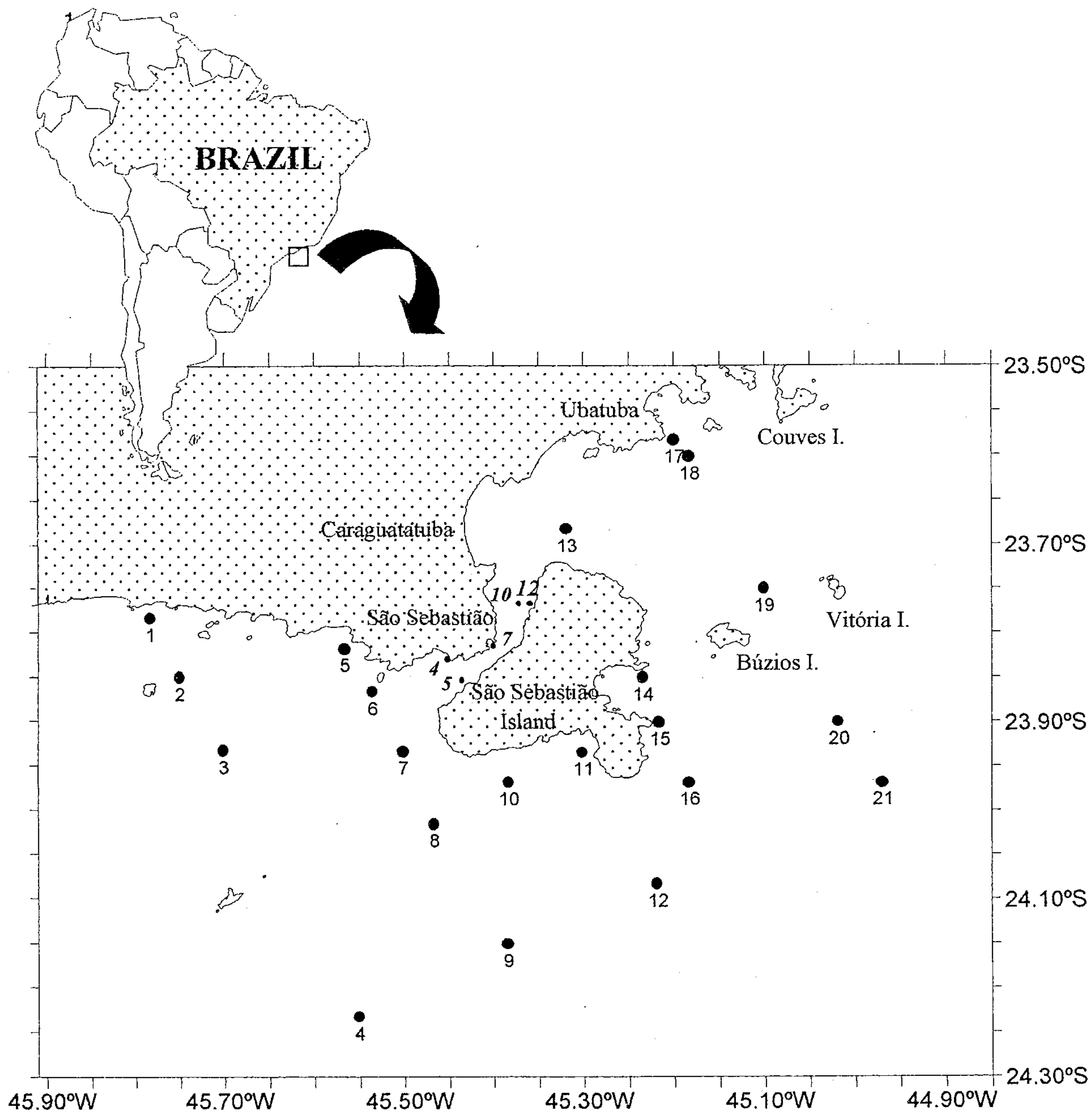


Fig. 1. Map of the area with the sampled sites (Channel sites in italic).

multiple comparison test (Sokal & Rohlf, 1998). The importance of species in the system was evaluated using an index of importance (I.I.), based on the contribution of each species in terms of number (N), weight (W) and occurrence (O). This index is expressed as I.I. = %N × %W × %O (Rocha & Rossi-Wongtschowski, 1998) and was calculated for the Channel and shelf ichthyofauna separately because total capture was higher on the shelf due to the larger swept area. Species were ranked by the index and the first 23 species of the Channel and 29 species of the shelf, a total of 42 species, were selected to be used in multivariate analysis.

Biomass (g m^{-2}) and density (number m^{-2}) were estimated by the swept area method. The swept area of each site was 11,118 m^2 and 16,667 m^2, respectively, for the Channel and the shelf. In order to standardize the catches between the two areas, Channel samples were multiplied by 1.4991. This correction factor was obtained by dividing the swept area of the shelf by that of the Channel. The following diversity indexes were calculated: Margalef's *richness* (d) (Margalef, 1974), Shannon-Wiener *Information Index* (H') (Shannon & Weaver, 1949), Pielou's *eveness* (J) (Pielou, 1966), and Berger and Parker's *dominance* (Da, Db and Dc) (Berger & Parker, 1970).

Cluster analysis was carried out to identify the structure of the community and to detect specific patterns of distribution. Analysis was performed on ln(x+1) transformed abundance data. The Percentage of Similarity index was used to measure the similarity between samples, and the UPGMA linkage method (Krebs, 1989) was employed to build dendograms. Sites and species dendograms were represented together with a trellis diagram representing classes of abundance. Nodal analysis (Lambert & Williams, 1962) was carried out using fidelity (F) and constancy (C) indexes (Boesch, 1977). The constancy index has the value of 1 when all species occur at all sites in the group and 0 when none of the species occur at those sites. Values of the fidelity index greater than 2 suggest a strong "preference" of the species in a group for a particular groups of sites. Values less than 1 suggest "avoidance" of the habitats represented by the group of sites.

Canonical Correspondence Analysis (CCA) using the computer program CANOCO (ter Braak, 1988, 1990) was applied to catch data to produce a gradient analysis and identify the most important environmental variables affecting the structure of the fish assemblages. Data were [log(x+1)] transformed prior to analysis. The environmental variables considered in the model were depth, bottom water temperature and salinity, organic matter, and substratum composition as % gravel, coarse + very coarse sand, medium sand, fine sand, very fine sand, and silt + clay. These data were standardized by: **(x - average x) . sd^{-1}** where x = raw datum and sd = standard deviation. Since depth was the first variable selected by the *forward selection of variables* procedure, temperature dropped out of the analysis due to the strong correlation between the two variables. The result was the same regardless of whether depth or temperature was used so we opted to use temperature in the model so as to better understand the relationship between water masses and the patterns of species distribution.

Results

Physical characteristics of the sampling area

Channel sites were 9 -10 m deep, except for C5 (23 m) which was located at the southern entrance of the Channel (Tab. 1, Fig. 1). On the shelf, the sampling was carried out at depths between 12 and 74 m. The lowest temperatures and highest salinity in the area studied occurred at sites located on the outer shelf, with average values of 17°C and 35.73. On the inner shelf and in the Channel, average values were 25.4°C / 34.76 and 27.6°C / 34.92, respectively. The Kruskal-Wallis test showed that temperature and salinity differed significantly (P=0.0004) among the three groups of sites identified by cluster analysis. According to Dunn's multiple comparison test, temperature and salinity were the same in the Channel and on the inner shelf (P>0.05), both differing from those of the outer shelf (P<0.05) (Tab. 2). The T-S diagram corroborated this result (Fig. 2). Channel and inner shelf were occupied by a warmer and less saline water mass (Coastal Water) and the outer shelf by a colder and more saline water (South Atlantic Central Water). The substratum at most sites consisted mainly of very fine sand. However, major proportions of medium sand, coarse + very coarse sand, and gravel occurred at sites C12 (Channel) and S13 (shelf) (Tab. 1).

Spatial patterns of density, biomass, and diversity

The ichthyofauna showed spatial differences in density and biomass (Figs 3A and 3B). Density was lowest in the Channel (except for site C5) and the deepest area of the shelf. Biomass was lowest in the Channel and the shallowest area of the shelf. High biomass was observed especially around São Sebastião Island. The outer shelf fauna had the greatest diversity, the lowest dominance, and highest evenness. Diversity of fauna was very similar in the Channel and on the inner shelf, though evenness was greater in the former and dominance on the later. Richness was highest on the inner shelf and lowest in the Channel (Tab. 3).

Table 1. Depth, bottom water temperature (T°C), salinity (S), dissolved oxygen (O_2), organic matter, and sediment characteristics of Channel (C) and shelf (S) sites.

Sites	Depth (m)	T °C	S	O2	% Organic Matter	% Gravel	% Coarse+ Very Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	% Silt + Clay
C4	10	27.37	35.008	4.75	0.605	0.13	0.18	0.19	1.02	92.82	5.66
C5	24	24.60	35.342	3.81	1.147	0.00	0.19	0.49	12.41	77.07	9.84
C7	8	27.90	34.764	4.65	2.268	0.00	0.22	0.36	1.26	36.31	61.85
C10	10	28.27	35.075	4.87	2.722	0.00	0.00	0.09	0.77	28.73	70.41
C12	8	26.89	34.842	4.59	0.862	3.48	38.43	12.38	8.81	7.16	29.74
S1	15	27.30	33.617	3.28	0.439	0.00	0.00	0.22	5.09	93.59	1.10
S2	22	26.79	34.282	3.09	1.204	0.00	0.59	2.13	8.08	76.57	12.63
S3	30	26.43	35.429	3.32	0.500	0.00	0.15	0.75	26.46	68.31	4.33
S4	60	16.66	35.578	3.47	0.909	0.00	0.00	0.56	16.99	73.12	9.33
S5	20	26.94	34.336	3.24	0.625	0.00	0.00	0.11	1.05	86.70	12.14
S6	25	26.64	35.035	3.89	0.391	0.00	0.00	0.10	0.83	92.83	6.24
S7	41	26.30	35.035	3.69	0.731	0.00	0.83	2.08	25.70	61.99	9.40
S8	50	18.50	35.732	3.42	0.889	0.00	0.15	0.40	2.44	83.62	13.39
S9	60	16.83	35.653	3.05	0.466	0.00	0.00	0.46	16.44	76.60	6.50
S10	50	17.39	35.673	2.90	1.672	0.00	2.48	3.26	7.46	32.23	54.57
S11	34	26.20	35.047	3.63	2.263	0.00	1.04	2.48	8.40	69.41	18.67
S12	69	16.51	35.661	2.96	0.626	0.10	1.76	2.67	58.80	21.58	15.09
S13	13	27.59	33.691	3.23	0.313	9.66	21.35	27.51	18.77	7.99	14.72
S14	24	16.51	35.094	3.39	1.694	0.00	0.00	0.00	0.00	8.17	91.83
S15	39	21.79	35.700	2.85	3.910	0.00	0.00	0.00	0.00	5.44	94.56
S16	53	16.83	35.735	2.77	3.195	0.00	0.21	0.30	1.44	25.89	72.16
S17	12	28.42	33.608	3.68	0.490	0.00	0.00	0.26	0.97	28.72	70.05
S18	18	26.20	35.031	2.71	0.569	0.00	3.15	3.51	4.49	48.16	40.69
S19	37	23.44	35.428	4.12	0.698	0.00	0.00	0.11	0.93	84.37	14.59
S20	62	16.80	35.957	3.00	2.221	0.00	0.26	0.85	9.97	54.81	34.11
S21	74	16.67	35.815	3.50	0.631	0.00	0.10	0.78	18.45	71.28	9.39

Table 2. Results of Kruskal-Wallis (H) and Dunn's multiple comparison test comparing temperature (T) and salinity (S) among groups resulting from cluster analysis.

		Temperature		**Salinity**	
	N	Mean	sd	Mean	sd
Channel	4	27.61	0.60	34.92	0.14
Inner Shelf	14	25.37	3.08	34.76	0.72
Outer Shelf	8	17.02	0.65	35.73	0.04
H		15.44		14.41	
		P=0.0004		P=0.0007	
Multiple comparisons					
Channel x Inner Shelf		P>0.05	ns	P>0.05	ns
Channel x Outer Shelf		P<0.001		P<0.05	
Inner Shelf x Outer Shelf		P<0.01		P<0.01	

sd = standard deviation , ns = not significant

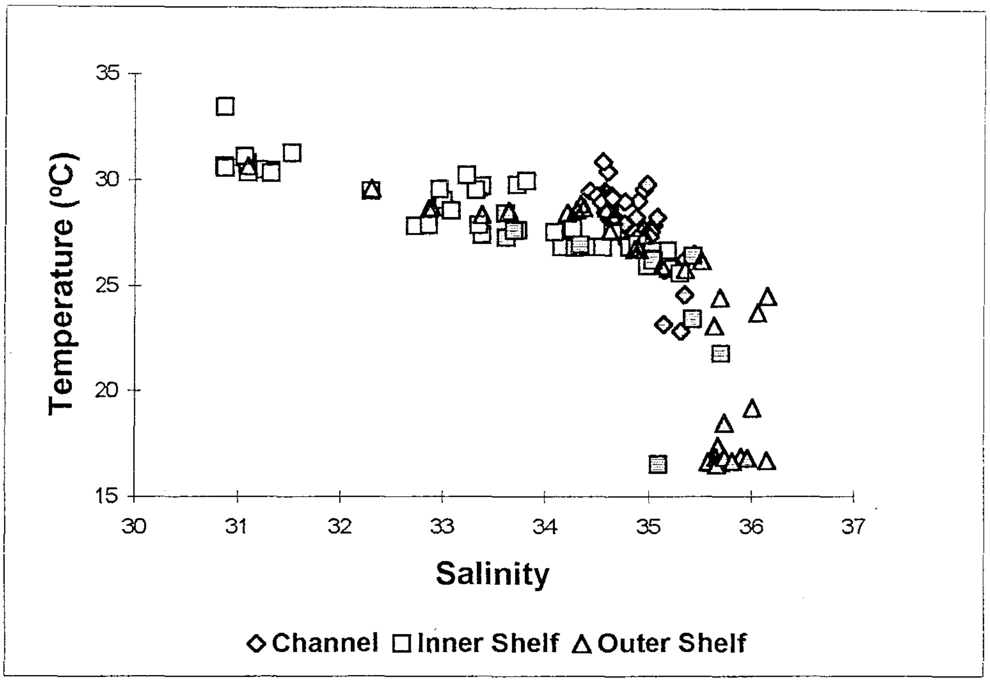
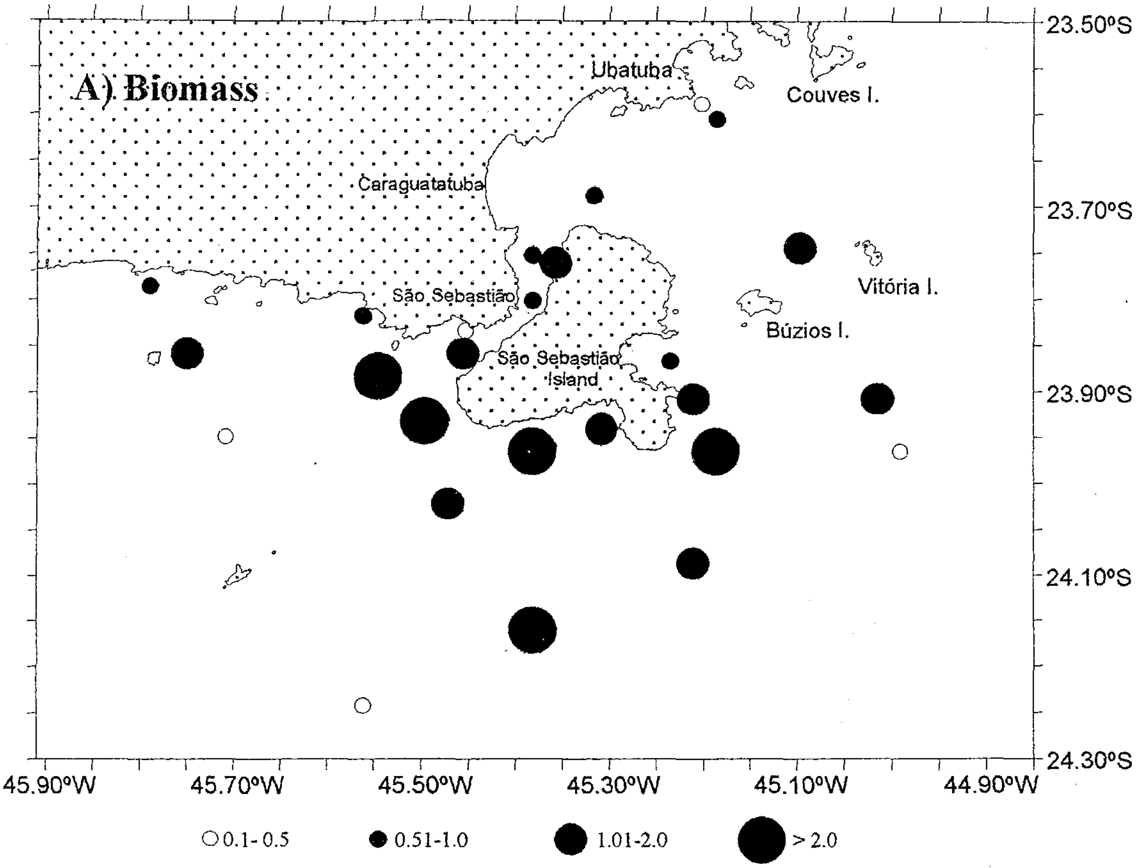


Fig. 2. Scattered *T-S* diagram for the São Sebastião system, during summer. Water column (empty symbols), bottom (full symbols), Channel (N=43), inner shelf (N=50) and outer shelf (N=37).

Species composition – Ninety-three fish species belonging to 40 families were collected during the sampling period. Twenty-four species occurred in both areas, 12 were exclusive to the Channel and 58 to the shelf (Tab. 4). In the Channel, the most abundant families were sciaenids, paralichthyds, gerreids, cynoglossids, haemulids, serranids, triglids, and muraenids. They were also important in terms of weight (Fig. 4). Channel samples included 971 specimens of 36 species belonging to 18 families (Tabs 4 and 5). *Ctenosciaena gracilicirrhus, Prionotus punctatus, Diplectrum radiale, Symphurus tesselatus*, and *Syacium papillosum* accounted for 79% of total number and 61% of total weight. On the shelf, 13,607 specimens belonging to 39 families and 81 species were collected (Tabs 4 and 5). Sciaenids were greatest in abundance and weight, while rajids and batrachoidids were important in weight only (Fig. 4). *Ctenosciaena gracilicirrhus, Paralonchurus brasiliensis*, and *Cynoscion jamaicensis* comprised 61% of the catch in number. Despite low abundance, *Porichthys porosissimus, Raja castelnaui*, and *R. cyclophora* were important in weight (Tab. 5).

Assemblages - Cluster analysis showed three major groups of species and sites (Fig. 5). Species **Group A** was composed of 11 species, dominated by *C. gracilicirrhus, C. jamaicensis*, and *P. brasiliensis*, which occurred mainly on the inner shelf (depth below 50 m). This group accounted for 72% and 46% of the total number and weight, respectively. Some of these species occurred in the Channel as well, though in low abundance. **Group B** was composed of 13 species, which occurred in the Channel and shallow areas of the inner shelf, five of them exclusively in the Channel. These species accounted for only 2.6% of the total number and 4% of the total weight. **Group C** was composed of 17 species associated with sites on the outer shelf (depth greater than 50 m). This group represented 21.5% of the total catch in number and 44.5% in weight. Although the subgroup composed of *C. guatucupa, S. hispidus*, and *P. porosissimus* also occurred on the inner shelf, their abundances were higher in the outer domain (Fig. 5). The nodal constancy and fidelity indexes corroborate the association of species groups with the three areas (Tab. 6). Despite the high biomass of the guitar ray *Rhinobatos percellens*, only one specimen occurred in the area and was not associated with any group (Fig. 5).

Ichthyofauna pattern and environment - The eigenvalues of the first three CCA axes were 0.558, 0.343 and 0.181, respectively. The species-environmental correlation was high with environmental variables accounting for 51% of the variation in the species data (Tab. 7). Through the *forward selection procedure* ($P<0.05$ in the unrestricted Monte Carlo permutation test), temperature, oxygen, coarse + very coarse sand, fine sand, and organic matter were selected as the best combination of variables. The first three variables accounted for the major fraction of species variation. The fourth canonical axis did not pass in the Monte Carlo test. Although fine sand had been selected, this variable was mainly related to axis 4.



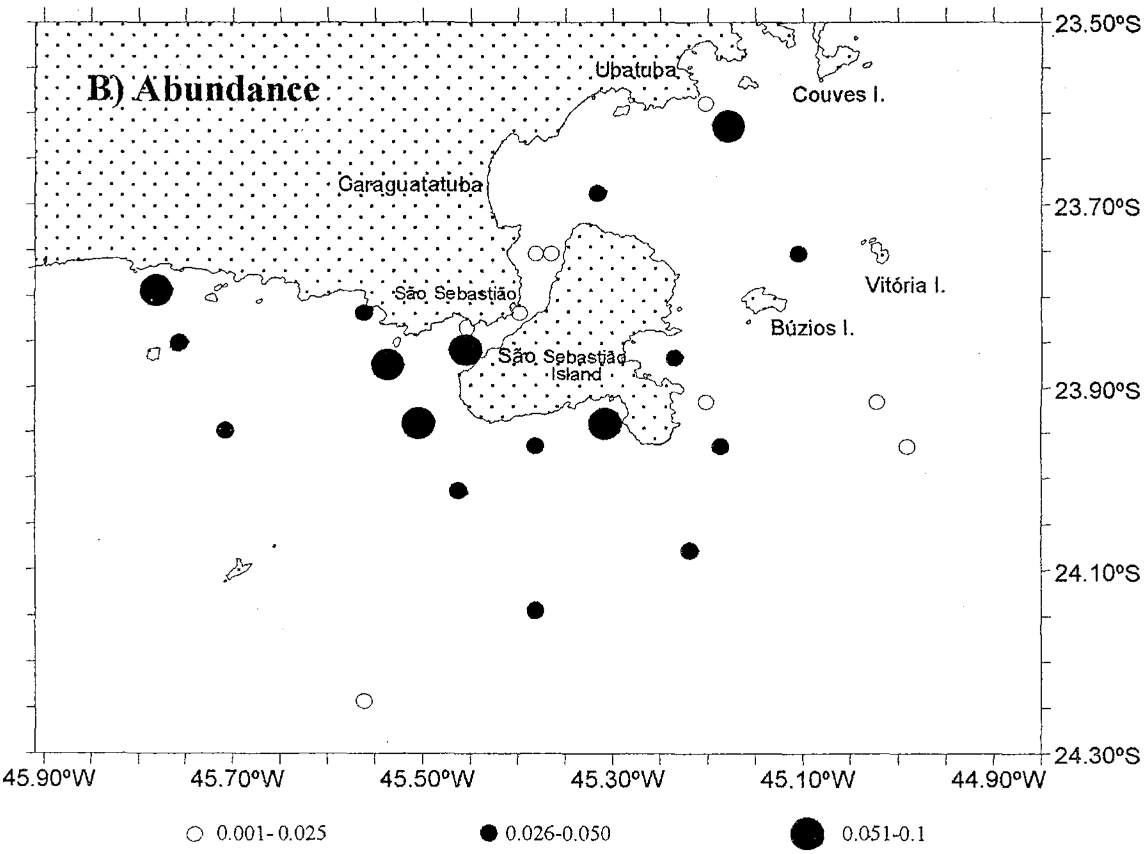


Fig. 3. Spatial distribution of (A) biomass (g m^{-2}) and (B) abundance (fish m^{-2}) of demersal fish off São Sebastião.

Table 3. Species richness (S), sample size (N), values of Berger & Parker (Da, Db, Dc), Shannon (H'), Margalef (d) and Pielou (J').

Area	S	N	Dominance			Diversity	Richness	Evenness
			Da	Db	Dc	H'*nits*	d	J'
Channel	36	971	0.547	0.646	0.696	1.930	5.088	0.539
Inner Shelf	65	9,849	0.321	0.591	0.784	1.939	6.960	0.470
Outer Shelf	48	3,758	0.148	0.279	0.399	2.672	5.710	0.700
Shelf (Total)	81	17,607	0.236	0.469	0.609	2.546	8.400	0.579

Table 4. Demersal fish species collected in the Channel and on the shelf of São Sebastião, in summer 1994. X = occurence.

	SPECIES	KEY*	CHANNEL	SHELF
CHONDRICHTHYES				
Squatinidae	*Squatina gugenhein*			X
Narcinidae	*Narcine brasiliensis*			X
Rajidae	*Psammobatis glansdissimilis*	PSGL		X
	Raja agassizii	RAAG		X
	Raja castelnaui	RACA		X
	Raja cyclophora	RACY		X
Rhinobatidae	*Rhinobatos horkelii*	RHHO		X
	Rhinobatos percellens	RHPE	X	
	Zapteryx brevirostris			X
Dasyatidae	*Dasyatis say*			X
OSTEICHTHYES				
Muraenidae	*Gymnothorax ocellatus*	GYOC	X	X
Congridae	*Ariosoma* sp			X
Ophchthidae	*Ophichthus gomesii*			X
Ariidae	*Cathorops spixii*			X
	Genidens genidens			X
	Netuma barba			X
	Sciadeichthys luniscutis			X
Synodontidae	*Saurida brasiliensis*			X
	Synodus foetens	SYFO	X	
Gadidae	*Urophycis brasiliensis*	URBR		X
Merlucciidae	*Merluccius hubbsi*	MEHU		X
Ophidiidae	*Ophidion holbrooki*			X
	Raneya fluminensis			X
Batrachoididae	*Porichthys porosissimus*	POPO	X	X
Lophiidae	*Lophius gastrophysus*	LOGA		X
Antennariidae	*Phrynelox scaber*		X	X
Ogcocephalidae	*Ogcocephalus vespertilio*			X
Fistularidae	*Fistularia petimba*			X
Syngnathidae	*Hippocampus erectus*			X
Triglidae	*Bellator brachychir*			X
	Prionotus nudigula	PRNU		X
	Prionotus punctatus	PRPU	X	X
Dactylopteridae	*Dactylopterus volitans*	DAVO	X	X
Serranidae	*Diplectrum formosum*	DIFO	X	
	Diplectrum radiale	DIRA	X	
	Dules auriga	DUAU		X
	Epinephelus morio			
	Epinephelus niveatus		X	X
Priacanthidae	*Priacanthus arenatus*			X

Table 4. (Continued)

	SPECIES	KEY*	CHANNEL	SHELF
	Priacanthus cruentatus			X
Acropomatidae	*Synagrops spinosus*			X
Gerreidae	*Diapterus rhombeus*			X
	Eucinostomus argenteus	EUAR	X	X
	Eucinostomus gula	EUGU	X	
Haemulidae	*Conodon nobilis*			X
	Haemulon aurolineatum			X
	Haemulon steindachneri	HAST	X	X
	Orthopristis ruber	ORRU	X	X
	Pomadasys corvinaeformis			X
Sparidae	*Calamus penna*		X	X
	Pagrus pagrus			X
Sciaenidae	*Ctenosciaena gracilicirrhus*	CTGR	X	X
	Cynoscion guatucupa	CYGU	X	X
	Cynoscion jamaicensis	CYJA	X	X
	Cynoscion leiarchus			X
	Isopisthus parvipinnis			X
	Larimus breviceps	LABR		X
	Macrodon ancylodon		X	X
	Menticirrhus americanus	MEAM	X	X
	Micropogonias furnieri	MIFU	X	X
	Paralonchurus brasiliensis	PABR	X	X
	Stellifer brasiliensis			X
	Stellifer rastrifer	STRA		X
	Umbrina canosai	UMCA		X
	Umbrina coroides			X
Mullidae	*Mullus argentinae*			X
	Upeneus parvus		X	
Percophidae	*Percophis brasilienis*	PEBR		X
Ephippididae	*Chaetodipterus faber*			X
Scorpaenidae	*Scorpaena brasiliensis*		X	
Balistidae	*Balistes capriscus*			X
Monacanthidae	*Stephanolepis hispidus*	STHI	X	X
Tetraodontidae	*Lagocephalus laevigatus*			X
Diodontidae	*Ciclichthys spinosus*	CICSP	X	X
Bothidae	*Bothus ocellatus*		X	
	Bothus robinsi			X
Paralichthyidae	*Citharichtys arenaceus*		X	
	Citharichtys macrops		X	
	Citharichtys spilopterus	CISP	X	
	Cyclopsetta chittendeni	CYCH	X	
	Etropus crossotus	ETCR	X	X
	Etropus longimanus	ETLO		X
	Paralichthys isosceles	PAIS		X
	Paralichthys patagonicus	PAPAT	X	X
	Paralichthys triocellatus			X
	Syacium papillosum	SYPA	X	X
	Verecundum rasile			X
Soleidae	*Gymnachirus nudus*			X
Cynoglossidae	*Symphurus diomedianus*		X	
	Symphurus plagusia			X
	Symphurus tesselatus	SYTE	X	X
	Symphurus trewavasae			X

*KEY used to represent species on CCA diagram

Table 5. Abundance (%N), weight (%W), and frequency of occurrence (%O) of demersal fish sampled on the shelf and in the Channel of São Sebastião, during summer 1994.

		SHELF			CHANNEL		
	SPECIES	%N	%W	%O	%N	%W	%O
1	*Ctenosciaena gracilicirrhus*	23.60	14.18	71	54.69	34.22	20
2	*Paralonchurus brasiliensis*	23.29	14.85	62	0.41	0.11	40
3	*Cynoscion jamaicensis*	13.99	4.73	67	3.19	2.80	20
4	*Porichthys porosissimus*	3.98	8.89	86	0.62	1.98	80
5	*Dules auriga*	3.69	2.70	48			
6	*Cynoscion guatucupa*	3.45	2.41	24	0.62	0.03	20
7	*Prionotus punctatus*	3.39	3.23	76	9.89	5.94	100
8	*Stellifer rastrifer*	3.36	0.53	19			
9	*Stephanolepis hispidus*	3.35	0.91	52	0.10	0.02	20
10	*Etropus longimanus*	2.62	0.53	62			
11	*Prionotus nudigula*	2.36	0.64	38			
12	*Micropogonias furnieri*	1.78	4.11	57	0.51	5.46	60
13	*Menticirrhus americanus*	1.72	1.55	52	0.41	2.43	60
14	*Urophycis brasiliensis*	0.62	2.67	38			
15	*Larimus breviceps*	0.62	0.69	38			
16	*Umbrina canosai*	0.52	1.20	24			
17	*Raja cyclophora*	0.50	6.24	33			
18	*Merluccius hubbsi*	0.41	0.54	33			
19	*Dactylopterus volitans*	0.40	0.06	67	0.31	1.75	20
20	*Raja agassizii*	0.36	3.45	19			
21	*Eucinostomus argenteus*	0.34	0.11	29	0.62	0.11	20
22	*Psammobatis glansdissimilis*	0.32	0.71	24			
23	*Paralichthys patagonicus*	0.29	2.25	33	0.41	1.14	20
24	*Upeneus parvus*	0.19	0.13	43	1.13	0.54	80
25	*Orthopristis ruber*	0.19	0.68	29	2.27	1.57	60
26	*Paralichthys isosceles*	0.15	0.40	29			
27	*Ciclichthys spinosus*	0.12	0.14	48	0.21	0.28	40
28	*Rhinobatos horkelii*	0.10	0.88	24			
29	*Lophius gastrophysus*	0.10	0.91	29			
30	*Raja castelnaui*	0.07	11.86	24			
31	*Percophis brasiliensis*	0.07	0.99	19			
32	*Gymnothorax ocellatus*	0.05	0.20	29	1.13	4.00	80
33	*Syacium papillosum*	0.04	0.02	14	5.05	4.42	60
34	*Symphurus tessellatus*	0.03	0.03	14	4.63	7.51	80
35	*Haemulon steindachneri*	0.02	0.16	10	2.16	7.76	20
36	*Etropus crossotus*	0.02	0.02	10	1.03	0.35	20
37	*Synodus foetens*				0.41	1.76	60
38	*Rhinobatos percellens*				0.10	2.06	20
39	*Diplectrum radiale*				4.74	8.73	80
40	*Diplectrum formosum*				0.51	1.28	20
41	*Cyclopsetta chittendeni*				0.31	0.17	60
42	*Citharichthys spilopterus*				2.88	2.55	60
	Other Species	3.87	6.41		1.66	1.03	
	Total Abundance	**13,607**			**971**		
	Total Weight		**447,029 g**			**32,270 g**	
	Number of Sites			**21 sites**			**5 sites**

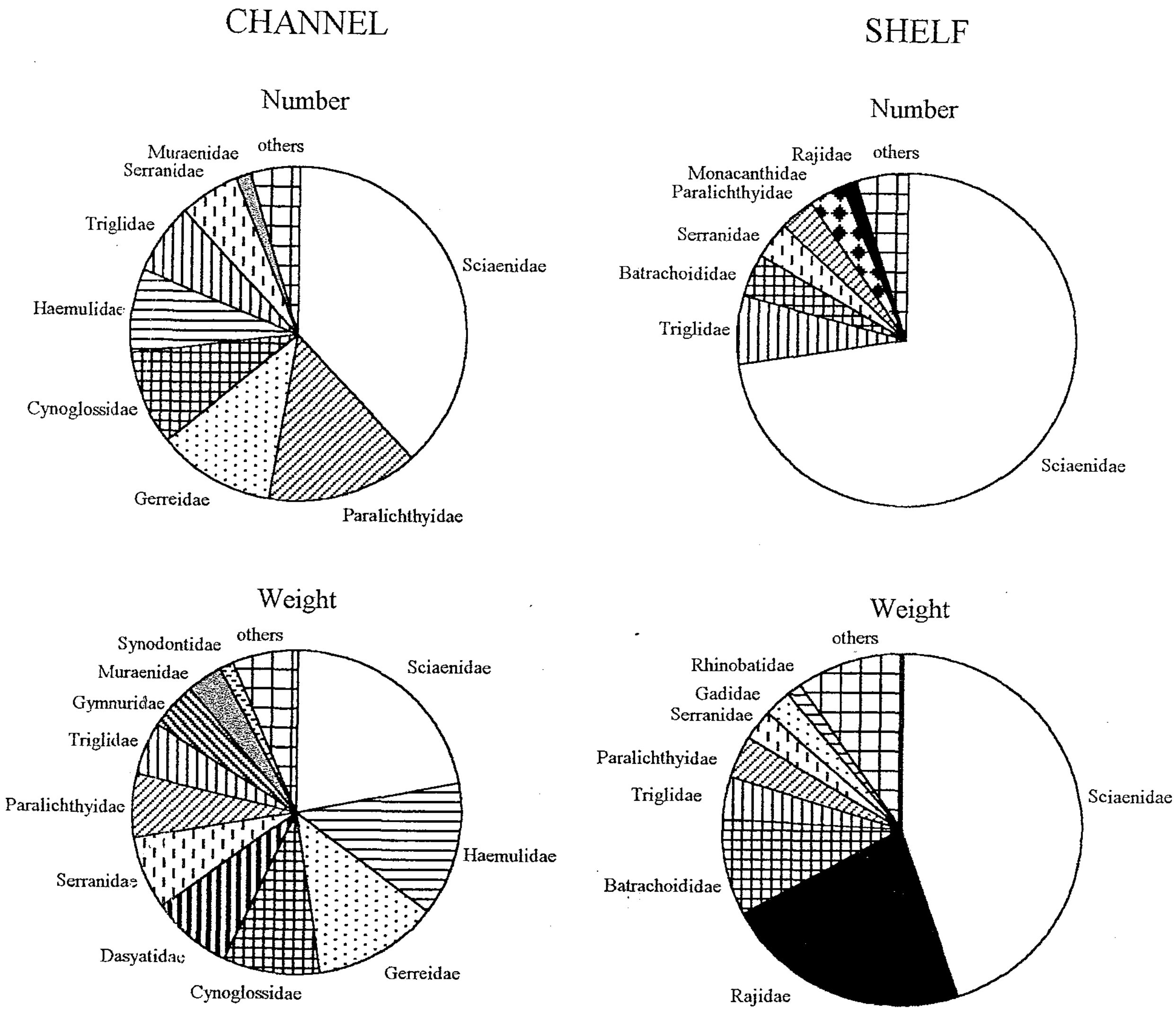


Fig. 4. Relative abundance and weight of demersal fish families sampled in Channel and shelf habitats of the São Sebastião area.

Table 6. Nodal constancy (C) and fidelity (F) of species groups to sites groups resulting from cluster analysis.

		Sites		
Species		Group I	Group II	Group III
Group A	C	0.23	0.71	0.22
	F	0.70	2.15	0.67
Group B	C	0.58	0.17	0.01
	F	1.75	0.52	0.03
Group C	C	0.06	0.15	0.77
	F	0.18	0.45	2.33

The first two CCA axes accounted for 23% and 14% of the total variance, respectively (Fig. 6A and 6B). Axis 1 was mainly represented by temperature while axis 2 by oxygen and coarse + very coarse sand. The three well defined groups of species and sites obtained by clustering were evident in the ordination diagrams (Figs 5, 6A, 6B). Sites and species were clearly separated along the temperature-depth gradient. Axis 1 separated sites and species associated with lower temperatures and deeper areas on the right side (Group III and Group A), from sites and species related to higher temperatures and shallower sites plotted on the left side (Groups A-B, Group I-II). Moreover, on the upper left side of the diagram are species associated with warmer waters, high dissolved oxygen, and high fraction of coarse sediments (Group B and Group I).

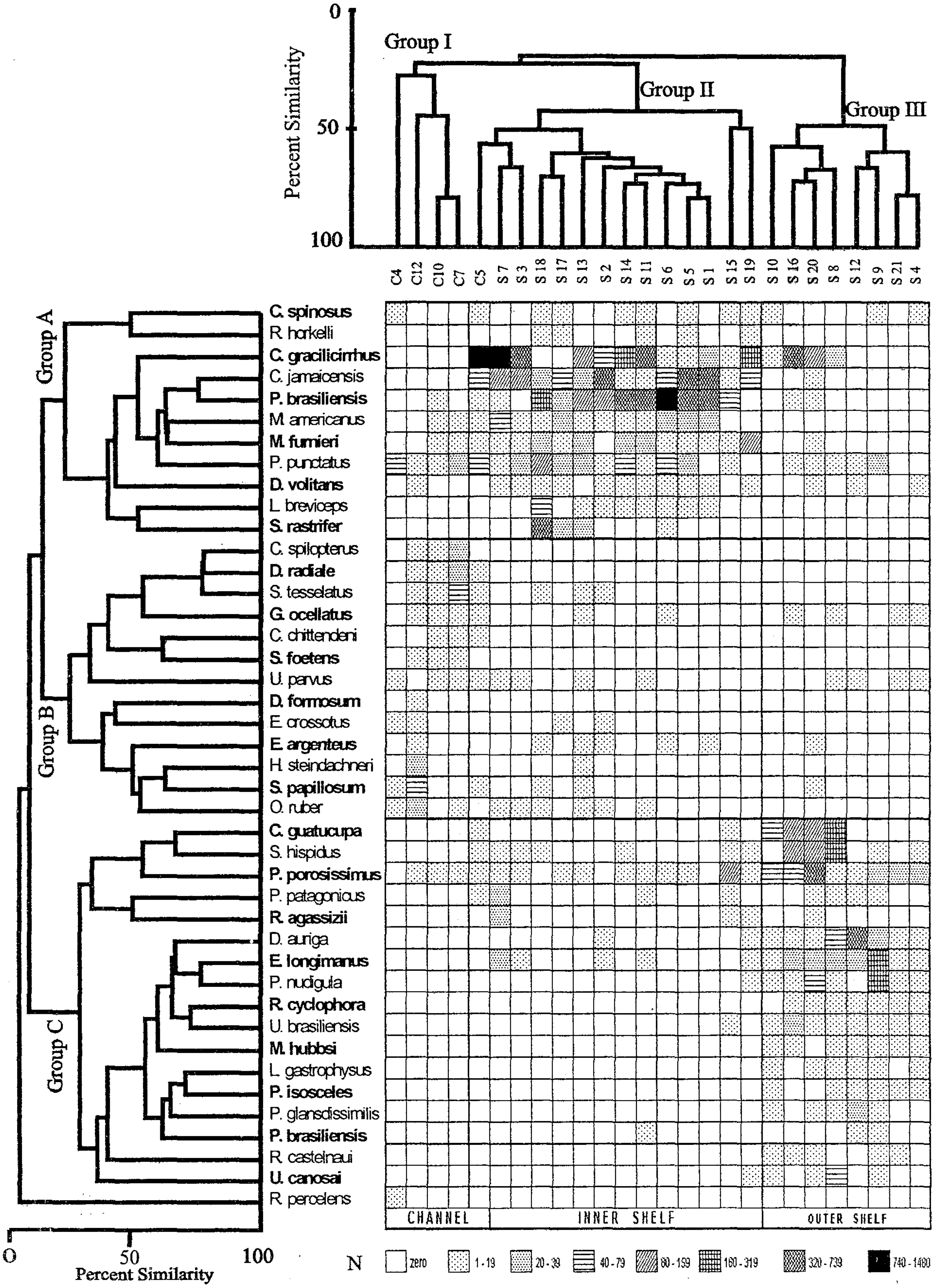


Fig. 5. Trellis diagram representing sites and species dendograms with abundance classe (N)

Table 7. Canonical Correspondence Analysis (CCA) for demersal fish community in São Sebastião region. Eigenvalues, extracted variance (%) and environmental correlation for the four axes.

Axis	1	2	3	4	Total [a]
Eigenvalues	0.558	0.181	0.343	0.115	1,244
Extracted variance (%)	22.9	14.0	7.4	4.7	51.0
Environmental correlation	93.8	88.3	90.0	86.1	

Forward selection	*Inertia*	*%*	*Added inertia*
Temperature	0.52	21.3	0.52
Salinity	0.39	16.0	
Oxygen	0.33	13.5	0.23
Coarse + very coarse sand	0.30	12.3	0.25
Fine sand	0.18	7.4	0.13
Medium sand	0.15	6.1	
Gravel	0.14	5.7	
Organic matter	0.13	5.3	0.11
Very fine sand	0.09	3.7	
Silt + clay	0.08	3.3	
Sum			1.24

[a] The total inertia of species data was 2.442. Inertia: Extracted variance attributable to each individual variable. Added inertia: added variance accounted for variables selected one by one in sequence. The variables significant ($p < 0.05$) on the Monte Carlos test are in bold type.

Axis 3 accounted for 7.4% of the total variance and an additional diagram was built to plot axes 2 and 3. The most important variables were dissolved oxygen, coarse + very coarse sand, and organic matter (Figs 7A, 7B). Most of the species of Group A and C were distributed around the origin of the axis reflecting no relation to the variables considered or species were associated with average variable values. However, Group B (Channel) was influenced by these variables. All Channel sites were characterized by high oxygen concentration. Axis 3 separated on the upper right side of the diagram, sites rich in organic content, located on the axis of the Channel (C7 and C10). Species positively associated with these variables were *C. spilopterus*, *C. chittendeni*, *D. radiale*, and *S. tesselatus*. In the lower part of the diagram are represented sites located in the northern part of the Channel (C12 and S13), characterized by high proportions of coarse + very coarse sand. *H. steindachneri*, *D. formosum*, *E. argenteus*, and *S. papillosum* were related to this variable.

Discussion

Much of the knowledge about the structure and function of coastal ecosystems in subtropical regions of the Western Atlantic comes from interdisciplinary studies undertaken in the Ubatuba region, an area to the north of São Sebastião. Seasonal oceanographic events influence temporal variability of fish food sources and community structure, modifying the energy and matter path within the system (Pires-Vanin *et al.*, 1993).

The São Sebastião Channel is a very unstable environment, not only oceanographically but because it is an area of intense human activity. The complexity of the abiotic conditions of the area is reflected by the fish fauna, which was characterized by high dominance and low diversity, richness, and evenness. The highest density and biomass occurred on the inner shelf, especially around the eastern and southern parts of the island. Despite high density near the coast, biomass was low, probably due to the predominance of juveniles. The shallowest area of the São Sebastião shelf is dominated by juveniles, the deepest area by adults and the intermediate depths by equal proportions of juveniles and adults (Rossi-Wongtschowski *et al.*, 1997). During summer, sciaenid, triglid, gerreid, and pleuronectiform larvae were widely distributed throughout the region suggesting spawning activity (Katsuragawa & Dias, 1997). Diversity was similar to that observed in the Channel fauna, but richness was much higher. Fish biomass on the inner shelf of São Sebastião (1.181g m^{-2}) was lower than that of the Ubatuba shelf in summer (2.145g m^{-2}), where the same fishery effort was

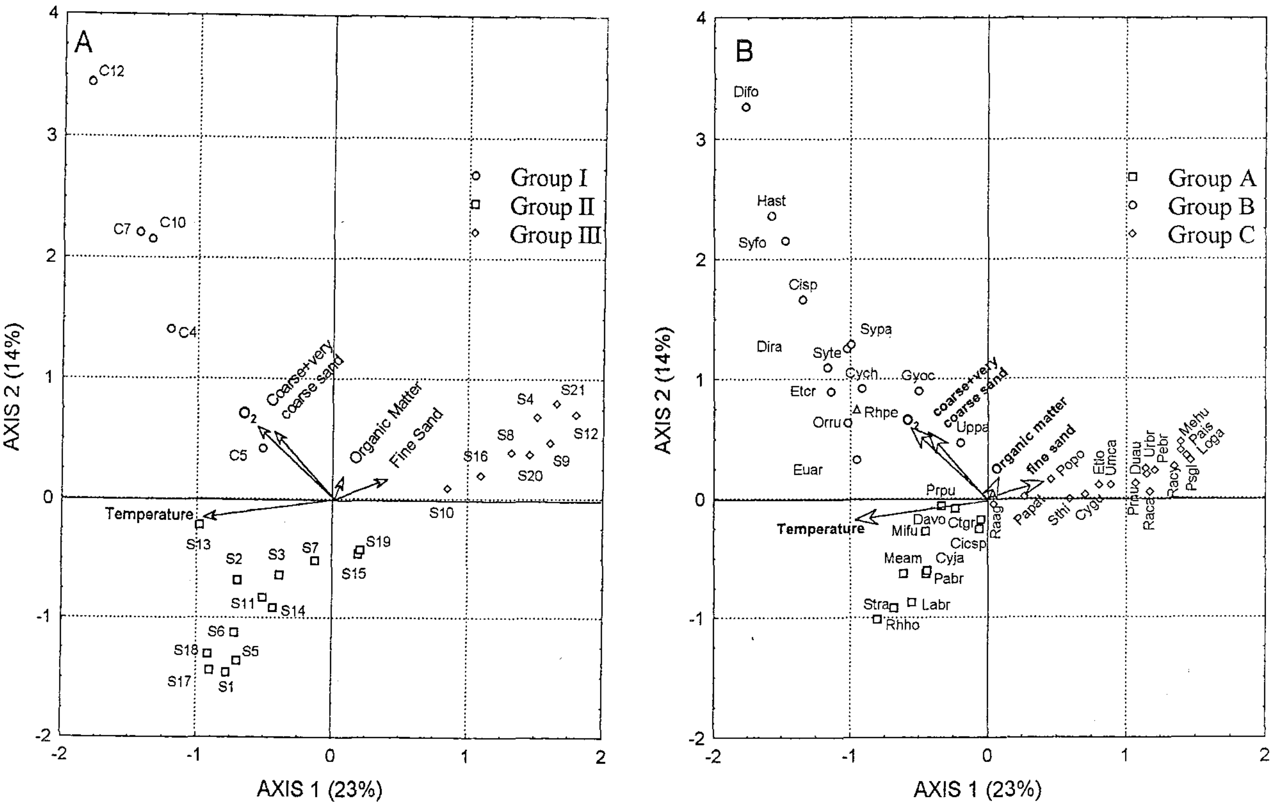


Fig. 6. CCA ordination diagram (*Axis 1* vs *Axis 2*) of demersal fish community. (A) Biplot of sites and environmental variables; (B) biplot of species and environmental variables. For the key of species see table 4. Groups of species and sites resulting from cluster analysis are represented by different symbols.

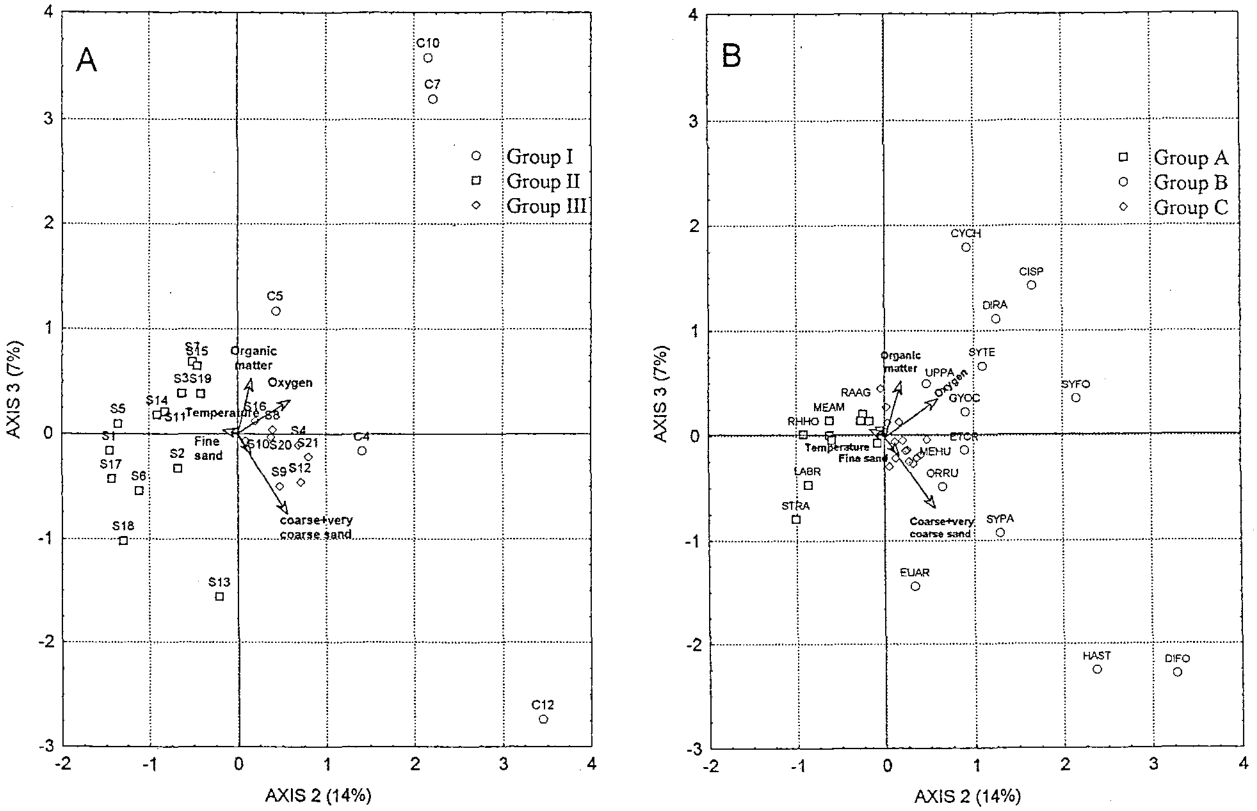


Fig. 7. CCA ordination diagram (*Axis 2* vs *Axis 3*) of demersal fish community. (A) Biplot of sites and environmental variables; (B) biplot of species and environmental variables. For the key of species see table 4. Groups of species and sites resulting from cluster analysis are represented by different symbols.

applied (Rossi-Wongtschowski, pers. comm.*). However, SACW intrusion was more intense in the Ubatuba shelf, allowing some species associated with this water mass to extend their distribution towards shallower areas. In general, demersal species associated with SACW were larger than those inhabiting the inner shelf. On the outer shelf of São Sebastião, where the environment seems to be more stable, diversity and evenness were the highest, and dominance the lowest. Despite low density, biomass was high due to the presence of larger species. In marine ecosystems, increasing size with depth is a general tendency for demersal bony species (MacPherson & Duarte, 1991).

A large scale study on the demersal fish community of the inner (Rocha & Rossi-Wongtschowski, 1998) and outer shelf (Natali Neto, 1994) was carried out off Ubatuba. Both authors documented seasonal and annual fluctuations in species abundance associated with the dynamics of Coastal Water and South Atlantic Central Water over the shelf. According to Rossi-Wongtschowski & Paes (1993), fish assemblages of the inner and outer shelf of the Ubatuba system are composed of "structural species", that are related to sediment type, and "seasonal species" that are closely associated with the inshore and offshore movements of the cold SACW in summer and winter periods, respectively. On the Rio Grande shelf (southern Brazil), water temperature affects the abundance of demersal bony fish, while species composition is associated with depth (Haimovici *et al.*, 1996). The intrusion of upwelling waters over the coastal shelf of Cabo Frio (RJ) influences the bathimetric distribution of demersal fish (Fagundes Neto & Gaelzer, 1991).

Silva (1995) studied the oceanographic conditions of the Channel and adjacent area of São Sebastião and verified that Coastal Water (CW) filled the bottom from the coast to the 50 m isobath during summer. In this period the upper water layer of the outer shelf was occupied by Tropical Water (TW), while the bottom was occupied by the South Atlantic Central Water (SACW). This water mass was not detected in the Channel or on the inner shelf, but the author points out that since the intrusion of SACW is wind driven, the hydrodynamics of the region change very fast. Therefore, SACW could have been present in other periods of the summer. The spatial organization exhibited by the ichthyofauna along depth gradient in the São Sebastião system were closely related to the distribution of the water masses. Three major assemblages were identified, distributed in three distinct areas: Channel, inner shelf, and outer shelf. These assemblages correspond to those identified on the inner shelf (below 50 m depth) off Ubatuba: Tropical Sciaenid, Subtropical Sciaenid, and Gerreid-Haemulid (Rocha & Rossi-Wongtschowski, 1998).

The Channel assemblage, corresponding to the Gerreid-Haemulid assemblage, was characterized by *Eucinostomus argenteus*, *Orthopristis ruber*, *Haemulon steindachneri*, *Symphurus tesselatus*, *Syacium papillosum*, *Etropus crossotus*, *Citharichtys spilopterus*, *Cyclopsetta chittendeni*, *Diplectrum radiale*, and *D. formosum*. These species occurred mainly in the Channel and the shallower areas of the inner shelf and were associated with the presence of Coastal Water. Most of them occur throughout the year in the Channel, except for *C. chittendeni* and *U. parvus* that occur only in spring and summer (Rossi-Wongtschowski *et al.*, 1997). Although *Gymnothorax ocellatus* and *U. parvus* had been clustered to this group, both species showed broad distribution over the area occurring even on the outer shelf. In relation to the shelf, the Channel presented a higher oxygen concentration which could be related to the pattern of water circulation associated with depth. The sediment distributed along the Channel, predominantly poorly and moderately sorted sandy sediments, is heterogeneous as a result of the complex circulation in the area (Furtado *et al.*, 1998). The finest sediments occur along the axis of the Channel, especially in the southern portion, due to the direct action of the waves that rework the bottom material. The amount of sedimentary organic matter was highest along the axis of the Channel (sites C7 and C10). This is consistent with observations that mud deposition is more intense in the low energy environment along the axis and on the continental side of the Channel (Furtado *et al.*, 1998). Low macrofauna densities at sites C7 and C10 of the Channel may be explained by organic enrichment from municipal sewage discharges and harbor activities (Pires-Vanin *et al.*, 1997). Low fish abundance and biomass were also observed in this area and may be related to low food availability. Medium and coarse sand predominate in the insular region, especially in the northern portion (Furtado *et al.*, *op. cit.*). The distribution of *C. spilopterus*, *C. chittendeni*, and *D. radiale* seems to be associated with areas rich in organic matter and that of *H. steindachneri* and *D. formosum* with poorly selected sediment. The southernmost part of the Channel (site C5) differed greatly from the central and northern areas due to the occurrence of *Ctenosciaena gracilicirrhus* and *Cynoscion jamaicensis*. The existence of a paleo river valley southwest of São Sebastião Island suggests that the intrusion of the bottom oceanic water into the Channel occurs through its southern entrance (Furtado *et al.*, 1996). This fact would explain the high abundance and biomass at site C5, since the penetration of some species from the inner shelf may occur through that area.

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The assemblages found on the São Sebastião shelf were similar to those identified on that of Ubatuba, where the most important is the Tropical Sciaenid Community, characterized by the dominance of *C. gracilicirrhus*, *Paralonchurus brasiliensis*, and *C. jamaicensis* (Rocha & Rossi-Wongtschowski, 1997). Sciaenids were also the most dominant group in the study region, occurring mainly on the inner shelf, associated with Coastal Water. They were highly abundant (61% of total catch) and widely distributed, especially the three above-mentioned species. A great abundance of sciaenids is also characteristic of bays, islands, and surrounding coastal areas (Cunningham, 1983; Nonato *et al.*, 1983; Ribeiro Neto, 1989; Giannini, 1990; Maciel, 1995). Tropical sciaenids, pomadasyds, and gerreids also inhabit the shallowest area of the outer shelf of Ubatuba. *C. gracilicirrhus* and *C. jamaicensis* present a seasonal variation of distribution with peak abundance in winter, because the Coastal Water expands its distribution towards the deepest area with a corresponding retraction of SACW (Natali-Neto, 1994).

The assemblage of the deepest area of the São Sebastião shelf was characterized by species closely associated with the cold SACW. They correspond to the Subtropical Sciaenidae Community identified on the Ubatuba shelf, associated with the front of this water mass (Rocha & Wongtschowski, 1998; Natali-Neto, 1994). Some species of this community (e.g. *Dules auriga, Psammobatis glansdissimilis*, and *Etropus longimanus*) expand their distribution towards shallower waters, with the intrusion of the SACW during summer (Paes, 1996). A similar pattern was also observed for the subtropical sciaenids *Cynoscion guatucupa* and *Umbrina canosai* (Rocha & Rossi-Wongtschowski, *op. cit.*). Most of these species did not occur on the inner shelf of São Sebastião, because SACW was present only on the outer shelf. Although *Raja agassizii, Stephanoleps hispidus,* and *Paralichthys patagonicus* have been grouped with species of the outer shelf in our analysis, the first two species are associated with Coastal Water and the distribution of *P. patagonicus* is not affected by water masses (Rocha & Rossi-Wongtschowski, *op. cit.*, Natali-Neto, *op. cit.*). Despite the classification of *Porichthys porosissimus* and *Prionotus punctatus* into different groups on the cluster analysis, both species were widely distributed across the shelf and water masses seemed to affect their abundance rather than their distribution.

In the Ubatuba system, the region around the 50 m isobath undergoes a great seasonal variation of hydrographic conditions as well as of species composition (Natali-Neto, *op. cit.*). Although our study was carried out only in summer, this transitional zone can be observed near the 50 m depth as well and sites S15 and S19 of the inner shelf seem to be influenced by SACW. This area presented intermediate values of temperature, indicating some degree of mixing of CW and SACW. Moreover, both tropical sciaenids and subtropical species were present there.

The difficulty in establishing the main factors affecting the communities's organization lies in the constraint of measuring all the variables involved and in the complexity of the interrelations between species living in an environment that changes over time and space. However, the results show that environmental features, mainly temperature and depth, explain much of the distribution of the species. Within the Channel, type of sediment, organic matter, and dissolved oxygen played an important role in species distribution. Due to the complexity of the water circulation and the heterogeneity of sediment deposits in the Channel, a more detailed study must be undertaken in order to arrive at a better understanding of ichthyofauna organization. Although this study was carried out only during summer, species composition, fish assemblages, and oceanographic condition of the São Sebastião shelf were very similar to those observed off Ubatuba.

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