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STUDIES ON ZOOPLANKTON AND ICHTHYOPLANKTON COMMUNITIES OFF THE RIO DE JANEIRO COASTLINE

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Resumo

Estudos sobre as comunidades de zooplâncton e ictioplâncton do litoral do Rio de Janeiro foram realizados a partir de 141 amostras coletadas pelo N.Oc. "Almirante Saldanha", em junho de 1977 e maio-junho de 1980. Foram realizados arrastos verticais de 5 m do fundo até a superfície nas regiões neríticas e até 200 m nas regiões oceânicas. Através de diagrama T/S foram identificadas as massas d'água e feitas as associações com as densidades de zooplâncton e ictioplâncton. O padrão de distribuição espacial esteve associado ao gradiente nerítico-oceânico e a ascenção da Água Central do Atlântico Sul na região nerítica. As maiores abundâncias de zooplâncton foram observadas na plataforma interna (<100 m), variando de 1.000-5.000 ind.m^{-3}. O grupo dos copépodes foi dominante com 60 espécies identificadas. Os maiores valores de diversidade específica entre os copépodes (>3,5 bits.ind^{-1}) foram encontrados em frente a Ponta Negra, tanto em Água de Plataforma quanto em Água Tropical. As larvas de peixes encontradas na Água de Plataforma apresentaram valores superiores a 200 larvas.100m^{-3}. No ictioplâncton foram identificadas 32 famílias. As larvas de Clupeidae, Engraulidae, Bothidae e Paralichthyidae foram dominantes nas estações até a isóbata de 100 m, enquanto Phycidae, Gonostomatidae e Myctophidae foram as mais abundantes nas áreas oceânicas. Foram observadas altas concentrações de espécies herbívoras no zooplâncton, sugerindo condições favoráveis a desova de **Engraulis anchoita** nas áreas de plataforma.

Palavras-chave: zooplâncton, ictioplâncton, estrutura da comunidade, Rio de Janeiro, Brasil.

Abstract

Zooplankton and ichthyoplankton studies were carried out off Rio de Janeiro in June 1977 and May-June 1980. Their were collected 141 samples by R/V "Almirante Saldanha". Vertical hauls were taken from 5 m above the bottom to surface in the neritic region and from 200 m depth in oceanic stations. Through T/S diagrams water masses were identified and associations with zooplankton and ichthyoplankton density were made. The main pattern of spatial differentiation observed in density and among zooplankton groups was related to neritic/oceanic gradients and intrusions of the South Atlantic Central Water in the neritic region. The greatest abundance of zooplankton was observed in the inner shelf (< 100 m) ranging from 1,000-5,000ind.m^{-3}. Copepods was the dominant group with 60 species identified. The highest values of specific diversity among the copepods (>3.5 bits.ind^{-1}) were found in front of Ponta Negra, as much in Shelf Water as in Tropical Water. The fish larvae present in Shelf Water showed values up to 200 larvae.100m^{-3}. In the ichthyoplankton 32 families were identified. Larvae of Clupeidae, Engraulidae, Bothidae and Paralichthyidae were more dominant in stations located shoreward from the 100 m isobath, while Phycidae, Gonostomatidae and Myctophidae were most abundant offshore. Highest concentrations of herbivorous zooplankton were observed, suggesting favorable conditions for the spawning of **Engraulis anchoita** in shelf waters.

Key-words: zooplankton, ichthyoplankton, community structure, Rio de Janeiro, Brazil.

Introduction

The concentration and diversity of zooplankton and ichthyoplankton in the Rio de Janeiro shelf show great seasonal variability (Valentin *et al.*, 1987; Bonecker *et al.*, 1990). In austral summer, the predominance of E-NE winds induces upwelling of South Atlantic Central Water (SACW), decreasing surface temperature and increasing nutrient concentration and primary productivity (Valentin, 1984a). Matsuura (1990) suggests that the formation of a spawning area for the Brazilian sardine is related to the presence of a frontal eddy, associated to this upwelling conditions.

Coastal waters off Rio de Janeiro (21° to 24°S) support roughly 21% of the national fishery, and Clupeidae (sardines) and Scombridae (tuna) comprise more than 70% of the regional total catch (IBGE, 1989). The fishery potential of a water mass depends on the development of the planktonic food-chain (Russel, 1952). One of the most important biological factors is the composition of the plankton community during spawning and larval fish development (Russel, *op. cit.*). Competition for food, predation, starvation or other dietary deficiencies and deleterious oceanographic conditions that may advect eggs or larvae into unsuitable environments are also important factors determining the size of fish stocks (Ali Khan & Hempel, 1974; Ciechomski & Sanchez, 1983; Hunter, 1984; Houde, 1987).

So far, plankton studies off Rio de Janeiro were conducted around Cabo Frio, where upwelling is stronger (Valentin, 1984a and b). In this work we broaden the knowledge about the spatial distribution of the plankton community in this region. This study will contribute to a better understanding of the influence of abiotic factors on the abundance and diversity of zooplankton, and to the identification of zooplankton as a potential food source on ichthyoplankton off Rio de Janeiro during fall/winter conditions.

Material and Methods

Zooplankton samples were collected from 141 oceanographic stations during two cruises conducted with the R/V "Almirante Saldanha" (Fig. 1). The "Rio de Janeiro I" (RJI) program surveyed the area between Ponta de Juatinga and Ponta Negra in June of 1977, and the "Rio de Janeiro II" (RJII) program covered the region between Ponta de Juatinga and Cabo Frio during May and June of 1980.

At each oceanographic station, temperature and salinity were measured using a bathythermograph, reversing thermometers and an inductance salinometer. Water samples were taken from the surface to 10 m of the bottom. For the RJII cruise, concentration of nutrients (nitrate, phosphate and silicate) were measured spectrophotometrically according to Strickland and Parsons (1972). Nutrient concentrations are expressed as vertically averaged values from surface to the depth of plankton tows (Tab. I). Further details about the cruises and all oceanographic data are available at the "Diretoria de Hidrografia e Navegação Data Center", Rio de Janeiro, Brazil. Water masses were identified according to Matsuura (1986).

Zooplankton and ichthyoplankton were sampled using conical plankton nets with 250 μm mesh size and 80 cm mouth diameter, equipped with a calibrated flowmeter. Vertical hauls were taken from 5 m above the bottom to surface in the neritic region and from 200 m depth in oceanic stations. The samples were preserved and stored in a borax buffered 4% formaldehyde-seawater solution.

The quantitative and qualitative analyses of zooplankton were made by subsampling with a Folsom splitter. Eggs and fish larvae were counted for the whole sample.

The feeding habits of organisms were classified according to Gauld (1966), Fraser (1969), Björnberg (1972), Esnal (1981a and b) and Ramirez (1981).

Distributional patterns were investigated and Shannon Index of diversity and evenness (Shannon, 1948) was used to obtain information about the maturity of the copepod community during the RJI cruise.

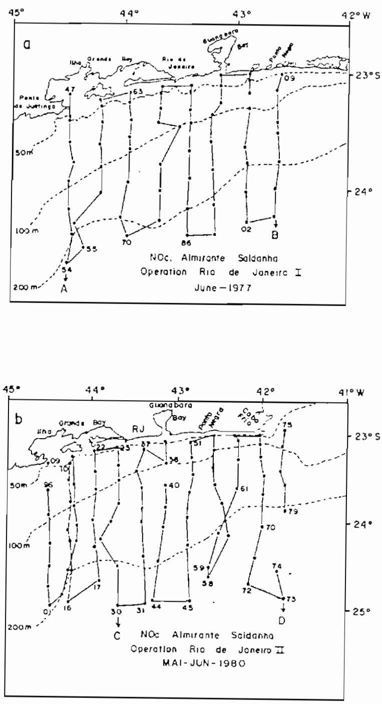


Figure 1. The study area and sampling stations during "Rio de Janeiro I" (A) and "Rio de Janeiro II" (B). Transect marked at A, B, C, and D were chosen to represent the vertical structure of temperature (see Fig. 4).

Results

Hydrography

The T/S diagrams (Fig. 2A-2B) permitted the identification of the following water masses: Tropical Water (TW) - temperature above 20°C and salinity >36.0; South Atlantic Central Water (SACW) with temperatures from 5° to 18°C and salinity between 35.0-36.0; and, Coastal Water (CW) with temperature higher than 20°C and salinity lower than 35.4. TW was dominant at the surface (Fig. 3) in both cruises. A Shelf Water (SW), resulting from the mixing of TW and CW (35.5<S<36.0), was frequent present on the continental shelf (<100 m). CW was present only in those stations located near Ilha Grande and Guanabara Bays. The SACW was detected over the shelf, below 50 m, and above this depth near Ilha Grande Bay and Ponta Negra during RJI (Fig. 4A-4B) and near the Ilha Grande Bay and off Cabo Frio during RJII (Fig. 4C-4D).

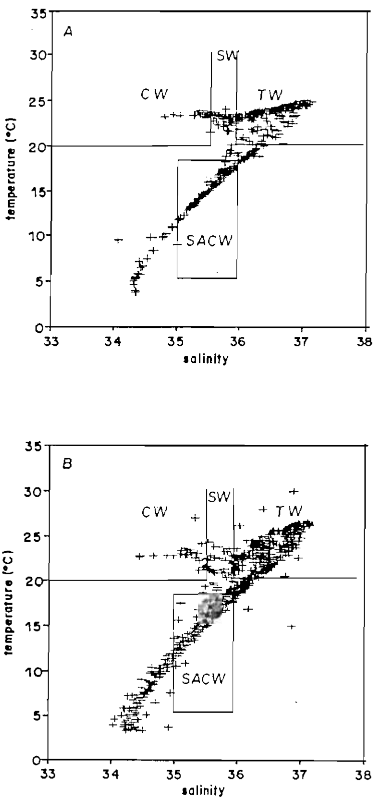
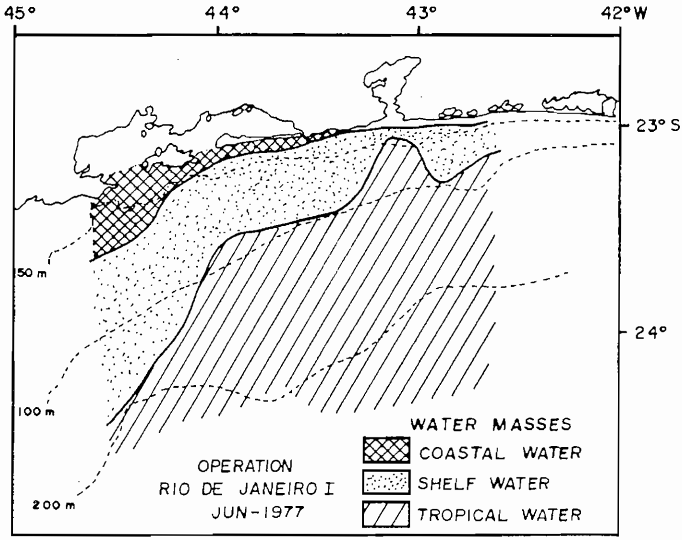


Figure 2. Surface T/S diagrams of "Rio de Janeiro I" (A) and "Rio de Janeiro II" 0(B). (TW) Tropical Water, (SACW) South Atlantic Central Water, (CW) Coastal Water and (SW) Shelf Water.



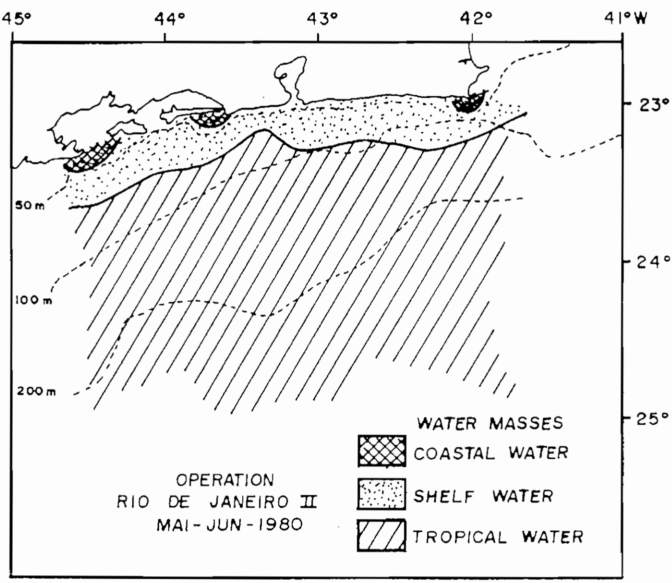


Figure 3. Horizontal distribution of water masses at surface in the "Rio de Janeiro I" (A) and "Rio de Janeiro II" (B).

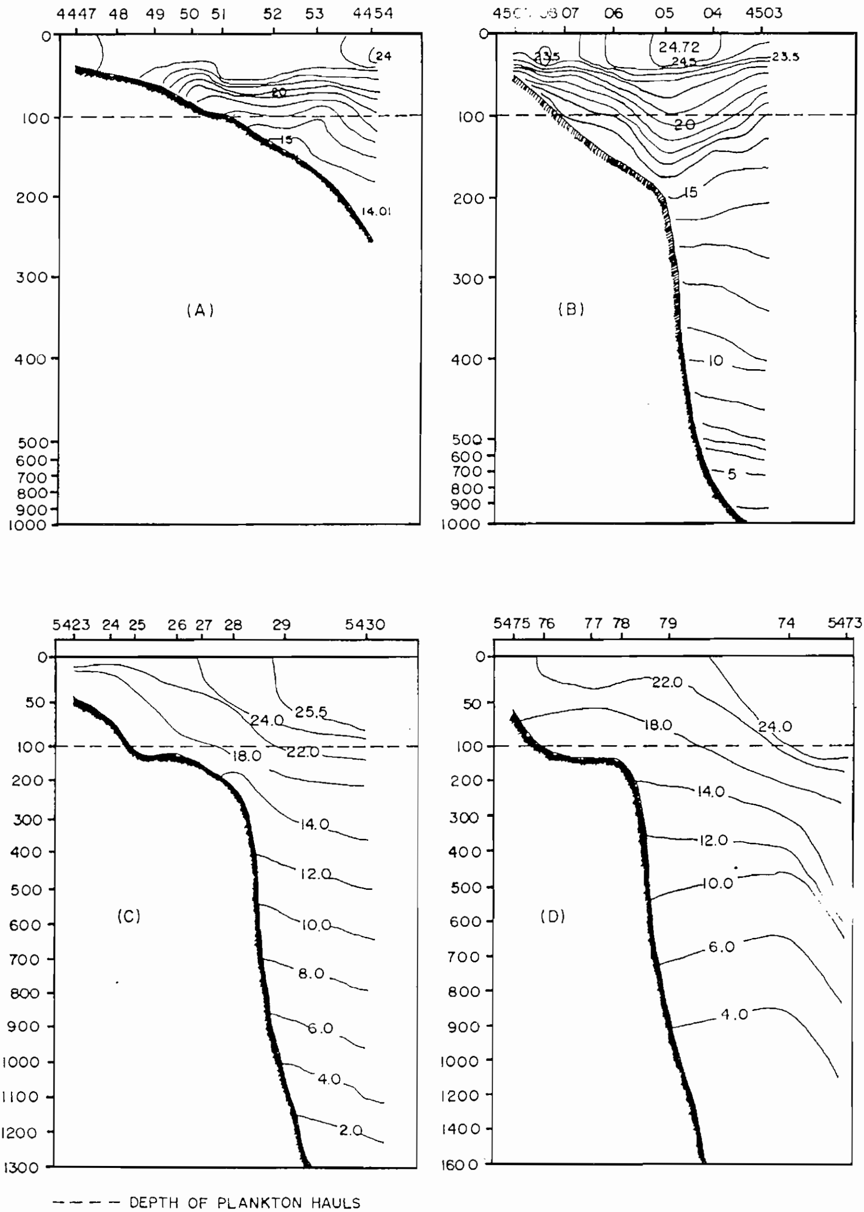


Figure 4. Vertical section of temperature profiles in front of Ilha Grande (A) and Ponta Negra (B) during the "Rio de Janeiro I" cruise and in front of Ilha Grande (C) and Cabo Frio (D) during the "Rio de Janeiro II" cruise (see Fig. 1).

Nutrient distribution (Tab. I) showed that phosphate concentration higher than 2 μM was observed near Ilha Grande Bay (station 5416). Nitrate ranged from 0 to 6.6 μM with maximum values observed off Ilha Grande Bay and Cabo Frio (stations 5401, 5404, 5416). Silicate varied from 1.8 to 11.5 μM, with values above 5 μM in the stations between Ilha Grande and Guanabara Bays.

Table I. "Rio de Janeiro II" chemical data: station number and nutrient concentrations.

STATION	PHOSPHATE (μM)	NITRATE (μm)	SILICATE (μM)	STATION	PHOSPHATE (μM)	NITRATE (μM)	SILICATE (μM)
5396	0.48	4.0	6.0	5440	0.22	2.2	5.1
5397	0.49	4.4	7.1	5441	0.23	2.8	4.2
5398	0.64	4.9	4.8	5440	0.22	2.2	5.1
5399	0.00	0.0	0.0	5441	0.23	2.8	4.2
5400	0.32	3.1	6.6	5442	0.28	3.5	6.7
5401	0.58	6.0	5.6	5443	NA	1.3	3.3
5402	0.46	3.9	5.0	5444	0.08	NA	2.7
5403	NA	3.6	5.5	5445	NA	0.7	2.0
5404	0.33	6.6	5.4	5446	0.25	3.6	2.8
5405	0.24	5.2	4.6	5447	0.36	4.5	4.3
5406	0.41	3.8	6.4	5448	0.22	2.4	4.1
5407	0.22	3.5	3.5	5449	0.26	3.0	2.9
5408	0.45	4.3	5.7	5450	0.30	3.6	2.0
5409	0.34	4.2	9.5	5451	0.33	2.8	4.7
5410	0.53	5.0	9.0	5452	0.26	2.8	5.3
5411	NA	3.7	6.1	5453	0.51	4.3	3.5
5412	NA	5.8	8.3	5454	0.28	2.9	2.4
5413	NA	4.4.	5.4	5455	0.21	2.3	3.5
5414	NA	4.0	6.8	5456	0.44	6.2	4.6
5415	NA	4.6	9.2	5457	0.37	5.1	3.5
5416	2.12	3.9	10.5	5458	0.13	0.8	4.7
5417	NA	4.1	6.5	5459	0.20	2.2	2.6
5418	NA	4.3	5.3	5460	0.38	5.2	4.5
5419	0.10	4.4	2.4	5461	0.46	4.7	2.7
5420	NA	5.1	3.1	5462	0.29	3.4	3.4
5421	NA	5.9	6.4	5463	0.37	3.9	3.1
5422	0.12	3.2	4.3	5464	0.29	2.7	3.2
5423	0.24	4.2	5.2	5465	0.31	0.8	5.0
5424	NA	5.0	7.0	5466	0.44	3.5	5.6
5425	0.11	4.7	4.0	5467	0.24	2.7	4.9
5426	0.17	3.7	3.1	5468	0.31	4.3	4.9
5427	NA	3.7	6.9	5469	0.50	5.6	5.7
5428	NA	4.2	6.4	5470	NA	2.0	4.1
5429	NA	3.3	3.3	5471	0.00	0.0	0.0
5430	NA	0.8	6.3	5472	NA	0.9	11.5
5431	NA	1.0	2.1	5473	0.00	0.0	0.0
5432	0.13	0.8	4.7	5474	NA	NA	3.4
5433	0.13	3.0	5.5	5475	0.35	0.3	5.0
5434	0.16	2.2	1.8	5476	0.25	0.2	3.0
5435	0.15	2.2	2.7	5477	0.30	2.0	2.9
5436	NA	2.2	6.7	5478	0.25	2.1	4.9
5437	0.18	1.6	4.6	5479	NA	2.7	6.8
5438	0.24	2.6	3.3				
5439	0.08	1.0	8.4				

NA = not analyzed

Zooplankton

The greatest abundance of zooplankton was observed in the inner shelf (< 100 m) ranging from 1,000-5,000 ind.m^{-3} (Fig. 5). Values above 5,000 ind.m^{-3} were observed in nearshore stations of less than 50 m, where the SACW was present, near Ilha Grande during RJI and Ilha Grande and Cabo Frio during RJII. Lowest zooplankton abundances characterized the offshore region, where TW was dominant. Approximately 50% of these stations had less then 500 ind.m^{-3}. Samples with more than 1,000 ind.m^{-3} were observed in some stations located between 50 and 100 m isobath, contributing to mean values of 970 ind.m^{-3} obtained during RJI and 2,916 ind.m^{-3} during RJII, in the Tropical Water.

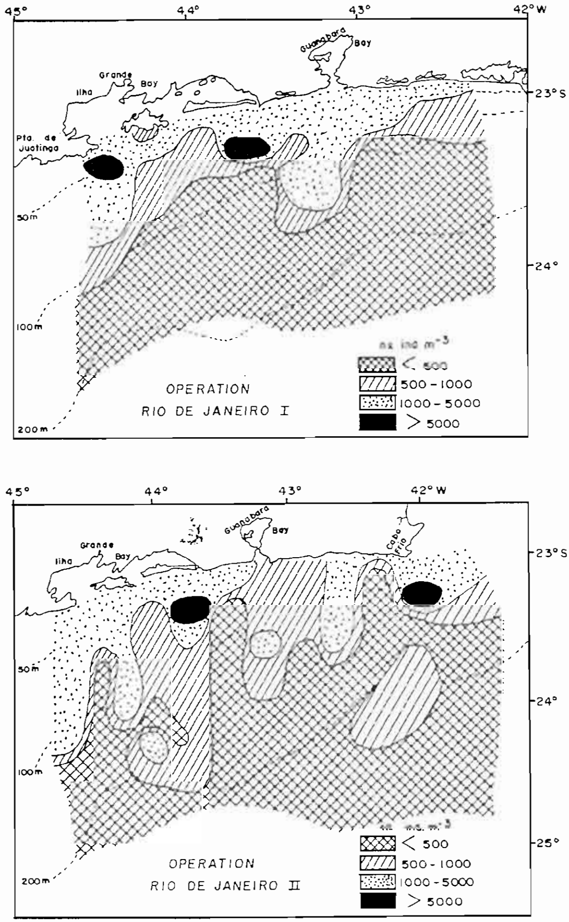


Figure 5. Distribution and abundance of zooplankton concentration (ind.m^{-3}) during "Rio de Janeiro I" (A) and "Rio de Janeiro II" (B).

Main zooplanktonic groups in both cruises were represented by: Foraminifera, Hydromedusae, Siphonophorae, Chaetognatha, Mollusca and Crustacea larvae, Cladocera, Copepoda, Ostracoda, Amphipoda, Sergestidae, Euphausiacea, Mysidacea, Appendicularia and Thaliacea (Tab. II).

Table II. Zooplankton taxa collected in "Rio de Janeiro I" and "Rio de Janeiro II"

FORAMINIFERA	OSTRACODA	**Miracia efferata**
		Oculosetella gracilis
HYDROMEDUSAE	COPEPODA	**Clytemnestra scutellatta**
Liriope tetraphyla	**Nannocalanus minor**	**Oithona atlantica**
Phialidium sp.	**Undinula vulgaris**	**O. similis**
	Eucalanus pileatus	**O. plumifera**
SIPHONOPHORAE	**E. crassus**	**O. robusta**
Muggiaea kochi	**E. subtenuis**	**O. setigera**
Diphyes bojani	**E. sewelli**	**O. tenuis**
D. dispar	**Rhincalanus cornutus**	**Oncaea conifera**
Bassia bassensis	**Paracalanus aculeatus**	**O. media**
Abylopsis eschecholtzi	**P. parvus**	**O. venusta**
A. tetragona	**P. nanus**	**Lubbockia squillimana**
Eudoxoides spiralis	**P. quasimodo**	**Corycaeus (Corycaeus)**
		speciosus
Enneagonum hyalinum	**Acrocalanus longicornis**	**C. (Agetus) typicus**
Agalma elegans	**Calocalanus styliremis**	**C. (Agetus) limbatus**
Chelophyes eppendiculata	**C. contractus**	**C. (Onychocorycaeus)**
		giesbrechti
Nanomia bijuga	**C. pavo**	**C. (Urocorycaeus) lautus**
Sulculeolaria chuni	**C. pavonicus**	**Farranula gracilis**
	Mecynocera clausi	**Farranula rostrata**
CHAETOGNATHA	**Clausocalanus furcatus**	
Sagitta enflata	**C. mastigophorus**	AMPHIPODA
S. hispida	**Ctenocalanus vanus**	
S. bipunctata	**C. citer**	SERGESTIDAE
S. minima	**Euaetideus giesbrechti**	
S. lyra	**Euchaeta acuta**	EUPHAUSIACEA
S. hexaptera	**E. marina**	
S. friderici	**Temora stylifera**	MYSIDACEA
S. serratodentata	**Pleuromamma piseki**	
Krohnitta subtilis	**P. gracilis**	THALIACEA
K. pacifica	**P. xiphias**	**Salpa fusiformis**
Pterosagitta draco	**Centropages velificatus**	**Thalia democratica**
	C. violaceus	**Thalia cicar**
MOLLUSCA LARVAE	**Lucicutia flavicornis**	**Doliolum nationalis**
	Candacia bipinnata	**D. gegenbauri**
CRUSTACEA LARVAE	**C. pachydactyla**	**Pyrosoma atlanticum**
	Paracandacia simplex	
CLADOCERA	**Labidocera fluviatilis**	APPENDICULARIA
Penilia avirostris	**Pontellopsis villosa**	**Oikopleura dioica**
Podon polyphemoides	**Calanopia americana**	**O. rufescens**
Evadne tergestina	**Acartia danae**	**O. fusiformis**
	A. lilljeborgi	
	Macrosetella gracilis	

The copepods made up 78% of the total zooplankton during RJI and 58% during RJII. Samples with more than 2,000 ind.m^{-3} were frequent in SW (Tab. III). Sixty species of copepods were identified in the RJI samples, being **Clausocalanus furcatus, Oithona plumifera, Oncaea venusta** and **Corycaeus giesbrechti** the most abundant (Tab. IV). Specific diversity was always inferior to 3 bits.ind^{-1} in the inner stations (Tab. III), due to the proliferation of **C. furcatus, O. venusta** and **Paracalanus parvus**. Copepods were also the most numerous plankters in TW, with specific diversity superior to 3 bits.ind^{-1} (Tab. III). **Clausocalanus citer, Farranula gracilis, Oncaea media** and **Macrosetella gracilis** were the species characteristic of this water mass. Some stations in front of Ponta Negra, as much in SW as in TW, were present high values of specific diversity (>3.50 bits.ind^{-1}) (Tab. III). **O. plumifera, O. venusta, C. furcatus, C. giesbrechti, F. gracilis, P. parvus, Temora stylifera** and **Paracalanus aculeatus** had a percentual of occurrence more than 80% in the stations (Tab. IV).

Table III. Date of Copepods that occurred during "Rio de Janeiro I": density, Shannon index diversity and evenness.

STATION	DENSITY (ind.m^{-3})	DIVERSITY (bits.ind^{-1})	EVENNESS	STATION	DENSITY (ind.m^{-3})	DIVERSITY (bits.ind^{-1})	EVENNESS
4447	2662.25	3.02	0.87	4480	1003.32	3.01	0.79
4448	4157.77	2.97	0.80	4481	126.44	3.24	0.83
4449	2105.96	3.28	0.84	4482	307.97	3.21	0.82
4450	1413.22	3.38	0.87	4483	741.04	3.42	0.78
4451	645.57	3.52	0.81	4484	529.88	3.19	0.75
4452	427.56	3.26	0.84	4485	29.75	3.33	0.74
4453	594.52	3.73	0.85	4486	139.24	3.59	0.85
4454	521.91	3.61	0.79	4487	81.34	3.58	0.75
4455	362.22	3.43	0.79	4488	177.46	3.81	0.84
4456	446.95	3.55	0.79	4489	406.25	3.41	0.79
4457	168.75	3.65	0.82	4490	1617.94	2.40	0.56
4458	104.30	3.29	0.79	4491	566.37	3.58	0.86
4459	536.93	3.41	0.90	4492	906.25	2.99	0.75
4460	705.18	3.32	0.81	4493	945.65	3.48	0.83
4461	1398.23	3.28	0.84	4494	1222.51	3.42	0.81
4462	845.13	2.51	0.72	4495	1826.09	3.27	0.84
4463	2413.98	2.71	0.78	4496	1206.52	3.23	0.76
4464	840.64	3.03	0.80	4497	724.43	3.09	0.73
4465	446.48	3.39	0.89	4498	353.98	2.54	0.61
4466	425.89	3.22	0.81	4499	215.95	2.66	0.68
4467	516.61	2.60	0.64	4500	134.47	3.55	0.84
4468	280.88	3.61	0.82	4501	264.42	3.30	0.78
4469	263.68	3.40	0.76	4502	92.45	3.13	0.72
4470	96.82	3.75	0.85	4503	370.52	3.53	0.79
4471	113.40	3.62	0.81	4504	282.02	3.20	0.74
4472	288.56	2.97	0.73	4505	58.99	3.52	0.81
4473	105.10	2.81	0.74	4506	245.02	3.05	0.75
4474	462.15	2.85	0.68	4507	294.02	3.55	0.80
4475	266.17	3.25	0.79	4508	374.50	3.51	0.80
4476	440.35	3.26	0.86	4509	1067.73	3.45	0.83
4477	594.68	3.11	0.78				
4478	1273.63	3.12	0.90				
4479	1258.96	3.10	0.79				

Table IV: Percentual and presence of Copepoda collected during "Rio de Janeiro I".

Espécies	%	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	76	77
N. minor	48					+				+	+					+			+					+
U. vulgaris	41					+			+		+													
E. pileatus	70		+	+	+	+	+	+	+		+			+	+	+		+	+	+	+	+		+
E. crassus	6											+				+					+			
E. subtenuis	38					+		+		+			+	+	+		+				+	+	+	+
R. cornutus	2									+														
E. sewelli	2																							
P. aculeatus	85	+	+	+	+	+	+	+	+		+		+	+	+	+	+	+	+	+	+		+	+
P. nanus	2																							
P. parvus	92	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
P. quasimodo	5			+																				
A. longicornis	14																			+				
C. styliremis	2											+												
C. contratus	2											+												
C. pavo	19							+																
C. pavonicus	14																							
M. clausi	30									+		+										+		
C. furcatus	98	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+
C. vanus	41					+				+	+	+	+		+						+	+	+	+
C. citer	64		+	+	+	+	+	+	+	+	+	+	+								+	+	+	+
C. mastigophorus	2																							
D. giesbrechti	3																							
E. acuta	2										+													
E. marina	13																							
T. stylifera	87	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+
P. piseki	11								+															
P. gracilis	6								+															
P. xiphias	2																							
C. velificatus	64	+	+	+	+	+	+	+	+				+	+	+	+	+	+	+	+			+	+
C. violaceus	2									+														
L. flavicornis	21								+	+														
C. bipinnata	5																							
C. pachydactyla	8							+	+															
P. simplex	2																							
L. fluviatilis	2																							
P. villosa	11				+						+	+												
C. americana	60	+	+	+	+	+	+		+			+		+	+	+	+	+	+	+			+	+
A. danae	11							+				+												
A. lilljeborgi	5	+		+																				
O. atlantica	10									+		+	+											
O. similis	41								+	+	+	+	+		+							+		
O. plumifera	100	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
O. robusta	2								+															
O. setigera	46					+	+		+		+	+		+	+					+	+	+		
O. tenuis	19							+		+	+	+	+											
O. conifera	38					+		+		+	+		+	+						+	+			
O. media	64		+		+	+		+	+		+	+		+		+	+		+			+		+
O. venusta	100	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
L. squillimana	10																							
C. speciosus	37					+	+	+	+		+													
C. typicus	3								+			+												
C. giesbrechti	97	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. gracilis	94	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+
F. rostrata	41			+	+			+					+		+							+	+	+
C. limbatus	5																							
C. lautus	2																							
M. gracilis	59							+	+	+	+	+	+		+	+			+		+	+		
M. efferata	2																							
O. gracilis	3																							
C. scutellatta	25							+			+				+									

Cont.

Espécies	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
N. minor	+	+	+				+			+					+	+	+	+		+
U. vulgaris	+	+	+	+	+	+	+								+	+	+	+		+
E. pileatus		+			+	+	+	+		+	+	+	+	+	+	+			+	
E. crassus	+																			
E. subtenuis	+			+			+	+	+	+		+				+	+			
R. cornutus																				
E. sewelli																				
P. aculeatus	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+		
P. nanus																				
P. parvus	+	+				+	+	+	+	+	+	+	+	+	+	+	+	+	+	
P. quasimodo																				
A. longicornis					+													+		
C. styliremis																				
C. contratus																				
C. pavo			+			+												+	+	
C. pavonicus																				
M. clausi	+			+			+									+	+		+	
C. furcatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. vanus		+		+		+	+	+	+	+				+	+	+		+	+	
C. citer	+	+				+	+	+	+	+		+		+	+	+		+		+
C. mastigophorus																				
D. giesbrechti																				+
E. acuta																				
E. marina	+				+											+	+			+
T. stylifera	+	+	+	+	+			+	+	+	+	+	+	+			+	+	+	+
P. piseki				+	+															+
P. gracilis																		+		+
P. xiphias																				+
C. velificatus			+	+			+	+	+	+	+	+	+	+		+				
C. violaceus																				
L. flavicornis		+		+													+	+	+	+
C. bipinnata	+		+																	
C. pachydactyla	+																		+	
P. simplex		+																		
L. fluviatilis																				
P. villosa				+																
C. americana		+		+	+			+	+	+	+	+	+			+				
A. danae	+																			+
A. lilljeborgi																				
O. atlantica																				
O. similis			+	+											+			+	+	+
O. plumifera	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
O. robusta																				
O. setigera	+	+	+	+		+	+	+						+	+	+		+	+	+
O. tenuis		+															+	+	+	
O. conifera		+	+	+	+										+	+				+
O. media	+		+	+				+		+				+			+	+	+	+
O. venusta	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
L. squillimana			+	+														+	+	+
C. speciosus		+	+	+									+			+	+	+	+	+
C. typicus														+	+	+	+	+	+	+
C. giesbrechti	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
F. gracilis	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. rostrata			+				+	+	+	+		+				+	+			
C. limbatus																	+		+	+
C. lautus																		+		
M. gracilis	+	+	+	+	+	+								+		+	+	+	+	+
M. efferata																				+
O. gracilis																				+
C. scutellatta		+	+	+																

Cont.

Espécies	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
N. minor	+	+	+							+	+		+	+	+	+	+	+	+	+	+	
U. vulgaris		+	+								+	+	+		+	+	+		+	+	+	
E. pileatus			+	+	+	+	+	+	+	+	+				+	+	+		+	+	+	+
E. crassus																						
E. subtenuis				+		+	+		+											+		+
R. cornutus																						
E. sewelli		+																				
P. aculeatus	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+		+	+	+	+
P. nanus								+														
P. parvus		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
P. quasimodo							+															
A. longicornis	+	+	+									+	+		+							
C. styliremis																						
C. contratus																						
C. pavo	+												+	+		+	+	+	+			
C. pavonicus						+		+	+	+	+		+	+					+			+
M. clausi	+	+									+	+	+	+			+	+	+		+	
C. furcatus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. vanus				+	+		+			+	+										+	+
C. citer	+	+	+	+	+			+	+	+	+		+		+					+	+	+
C. mastigophorus													+									
D. giesbrechti	+																					
E. acuta																						
E. marina		+													+			+				
T. stylifera	+	+	+	+	+	+	+	+	+			+		+	+	+	+	+	+	+	+	+
P. piseki	+															+	+					
P. gracilis																+						
P. xiphias																						
C. velificatus			+	+	+	+	+	+	+	+				+						+	+	+
C. violaceus																						
L. flavicornis											+				+	+	+	+				
C. bipinnata																				+		
C. pachydactyla																	+					
P. simplex																						
L. fluviatilis							+															
P. villosa						+	+															
C. americana				+	+	+	+	+	+	+	+				+		+			+	+	+
A. danae										+								+			+	
A. lilljeborgi							+															
O. atlantica			+				+							+								
O. similis	+	+				+						+	+	+	+	+	+	+	+	+	+	
O. plumifera	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
O. robusta																						
O. setigera				+							+		+		+			+		+		
O. tenuis	+	+												+								
O. conifera	+	+		+					+	+	+					+		+		+		
O. media	+	+	+	+	+	+	+	+	+	+		+		+	+	+	+	+	+			+
O. venusta	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
L. squillimana																			+			
C. speciosus		+							+	+		+	+		+	+		+				+
C. typicus	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
C. giesbrechti	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. gracilis	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. rostrata			+		+	+	+		+			+	+	+		+	+			+	+	
C. limbatus																						
C. lautus																						
M. gracilis	+		+					+			+	+	+	+	+	+		+	+	+	+	+
M. efferata																						
O. gracilis	+																					
C. scutellatta	+		+	+	+			+							+			+		+		

In SW the predominance (>85%) of herbivorous or facultative herbivorous taxa were observed: **Penilia avirostris**, **Doliolum nationalis**, many copepod species (>40%) and group of appendicularians and ostracods. Carnivorous taxa such as **Sagitta enflata**, **S. bipunctata** and **S. hispida**, **Muggiaea kochi**, **Liriope tetraphyla** and **Phialidium** sp. were present in SW. Their abundance represented between 5 and 10% in all stations during RJI, and was always less than to 5% in RJII samples. Herbivorous copepods were also dominant in TW (Tab. IV). Carnivorous species of the families Euchaetidae, Candaciidae and Aetideidae, and omnivorous species such as Metridiidae and Lucicutidae have been observed exclusively in these waters. Cold water species such as **Rhincalanus cornutus**, **Ctenocalanus vanus**, **Euaetideus giesbrechti** and **Pleuromamma piseki** were present in some stations beyond 100 m depth where the penetration of SACW was observed.

Chaetognatha ranked second in dominance in tropical waters during RJI, and were substituted by Appendicularia in dominance during RJII.

Ichthyoplankton

The fish larvae present in SW showed values up to 200 larvae.100m^{-3} and were observed in both cruises (Figs. 6-7). Thirty-two families were identified from RJI and RJII samples, being that three families occurred only in RJI (Elopidae, Caproidae and Balistidae) and three only in RJII (Ophidiidae, Exocoetidae and Diodontidae) (Tab. V). Clupeidae, Bothidae (**Bothus ocellatus**), Paralichthyidae (**Syacium papillosum**) and Engraulidae (**Engraulis anchoita**) were more abundant in the stations located shoreward from the 100 m isobath (Fig. 8). Gobiidae and Trichiuridae (**Trichiurus lepturus**) were present both in the SW and in the TW, whereas Bregmacerotidae (**Bregmaceros** sp.) showed higher densities along the 100 m isobath (Fig. 9).

The larvae of the Phycidae (**Urophysis mystaceus** and **U. brasiliensis**), Myctophidae and Gonostomatidae (**Maurolicus muelleri**, **Vinciguerria nimbaria**, **V. attenuata** and **Pollichthys mauli**) were dominant above the 100 m isobath (Fig. 10).

Fish eggs were comparatively rare in the SW, observed more during the RJII cruise, with values inferior to 50 eggs.100m^{-3} (Fig. 7). Of the five families and one order identified, the Engraulidae (**Engraulis anchoita**) showed the most important spawning in samples. The other families and order were Clupeidae, Synodontidae, Gonostomatidae (**Maurolicus muelleri**), Trichiuridae (**Trichiurus lepturus**) and Anguilliformes.

Table V. Ichthyoplankton taxa observed in Operations "Rio de Janeiro I" and "Rio de Janeiro II".

Elopidae	
Anguilliformes	
Engraulidae	
	Engraulis anchoita
Clupeidae	
Gonostomatidae	
	Maurolicus muelleri
	Vinciguerria nimbaria
	V. attenuata
	Pollichthys mauli
	Cyclothone sp.
Synodontidae	
Paralepididae	
Myctophidae	
Ophidiidae	
Bregmacerotidae	
	Bregmaceros sp.
Phycidae	
	Urophysis mystaceus
	U. brasiliensis
Mugilidae	
	Mugil sp.
Exocoetidae	
Caproidae	
	Antigonia capros
Syngnathidae	
	Hippocampus sp.
Macrorhamphosidae	
Dactylopteridae	
	Dactylopterus volitans
Scorpaenidae	
Triglidae	
	Prionotus nudicola
Carangidae	
	Chloroscombrus chrysurus
Gerreidae	
Sciaenidae	
	Menticirrhus americanus
Scaridae	
Callionymidae	
Gobiidae	
	Gobionellus boleosoma
Trichiuridae	
	Trichiurus lepturus
Scombridae	
Bothidae	
	Bothus ocellatus
Paralichthyidae	
	Syacium pappilosum
Cynoglossidae	
	Symphurus sp.
Balistidae	
Monacanthidae	
Diodontidae	

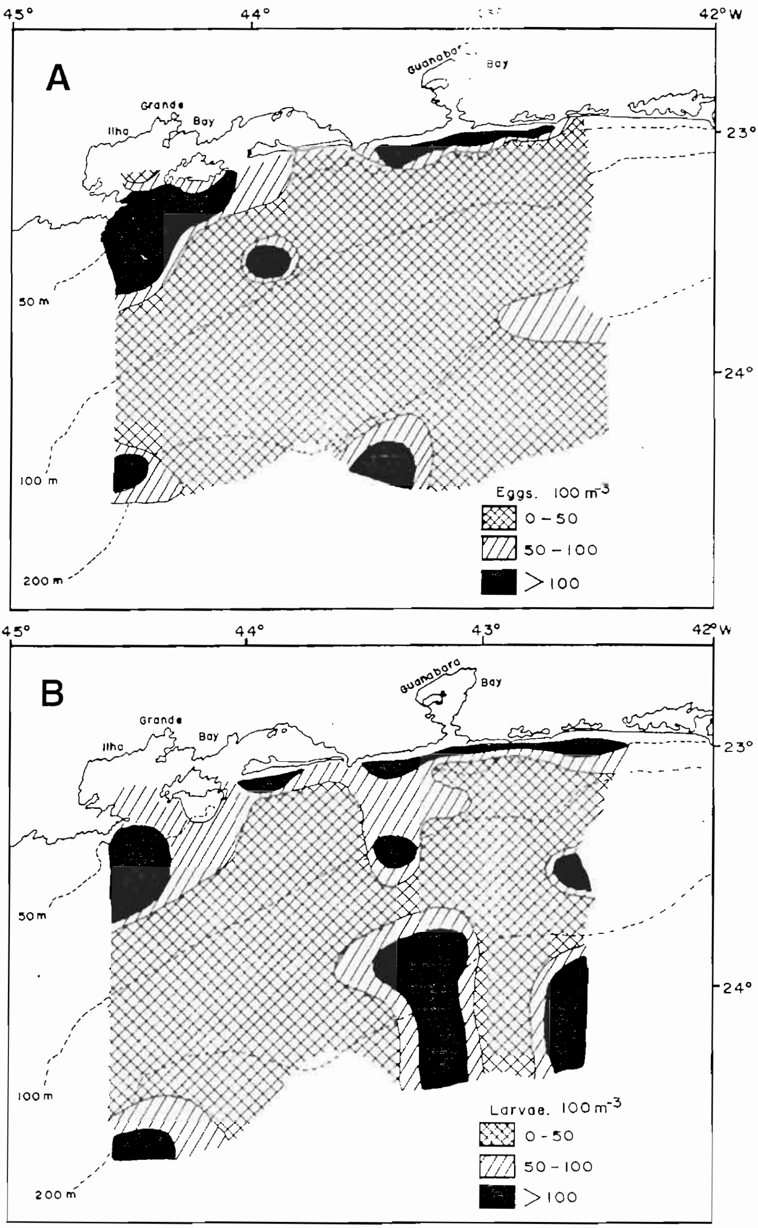


Figure 6. Distribution and abundance of fish eggs (eggs.$100m^{-3}$) (A) and larvae (larvae.$100m^{-3}$) (B) during "Rio de Janeiro I".

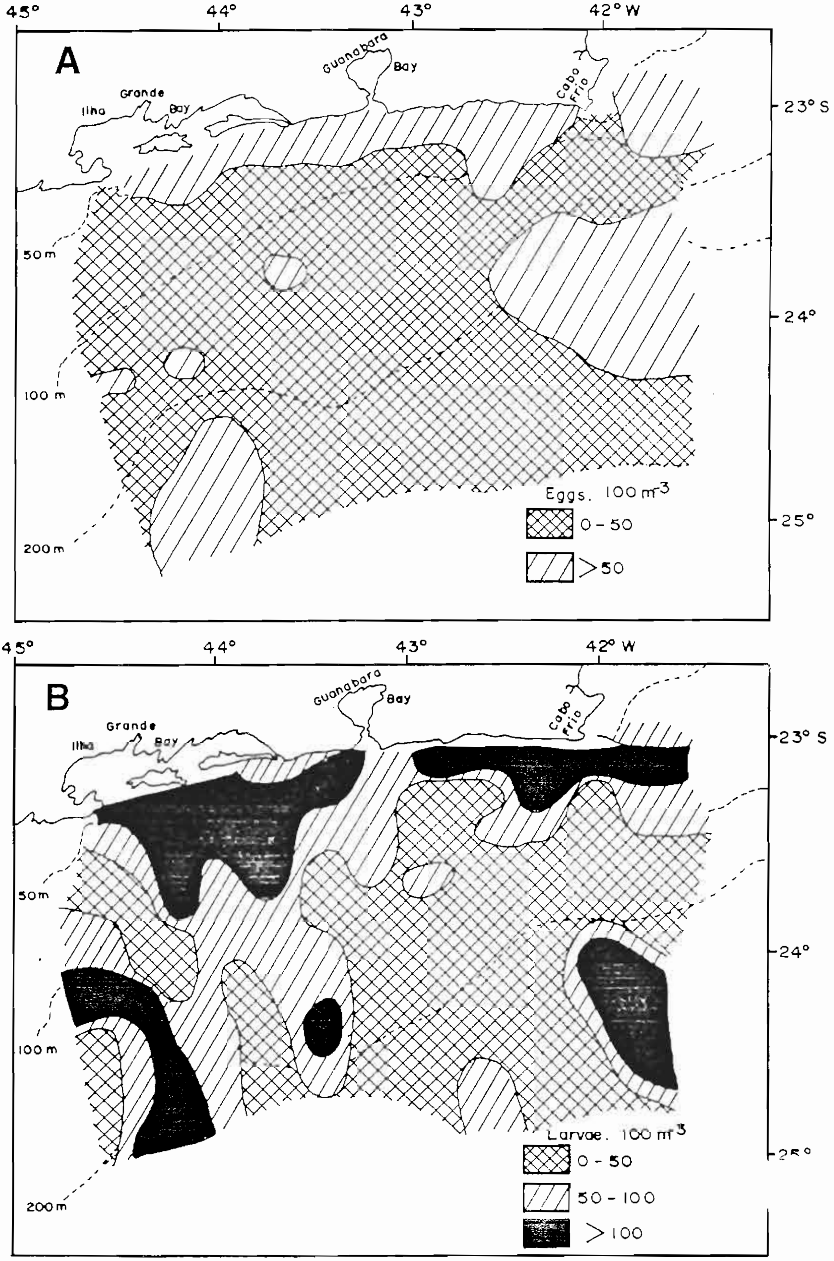


Figure 7. Distribution and abundance of fish eggs (eggs.100m^{-3}) (A) and larvae (larvae.100m^{-3}) (B) during "Rio de Janeiro II".

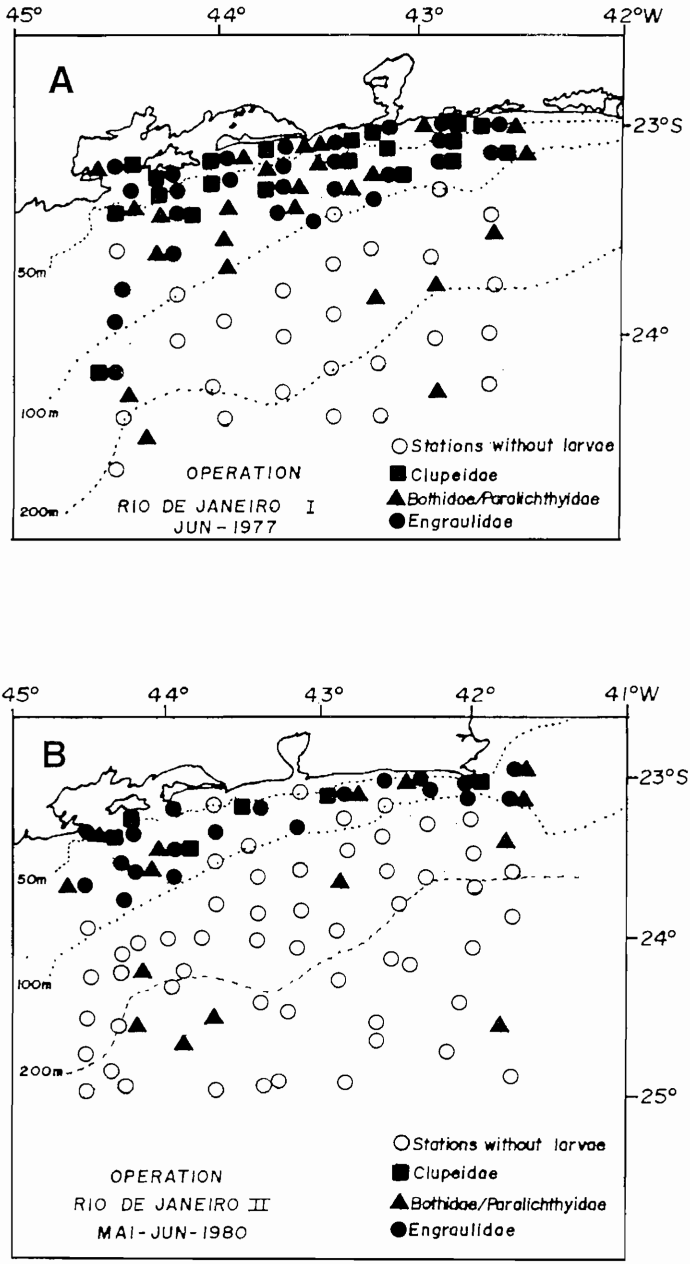
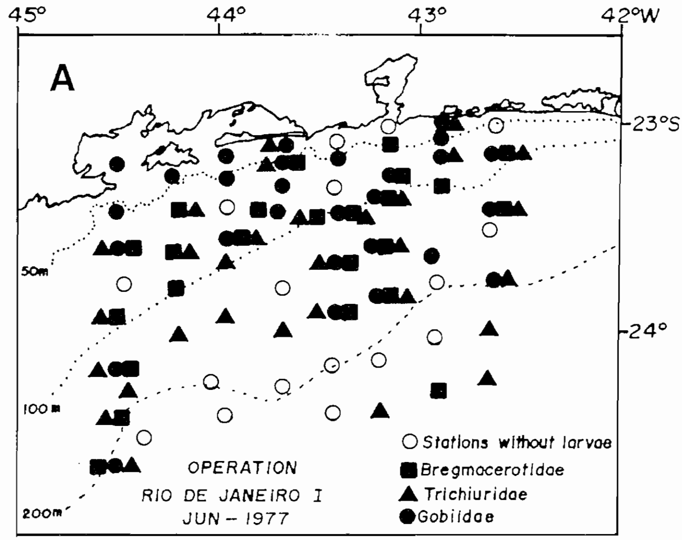


Figure 8. Occurrence of the larvae of Clupeidae, Engraulidae and Bothidae during "Rio de Janeiro I" (A) and "Rio de Janeiro II" (B).



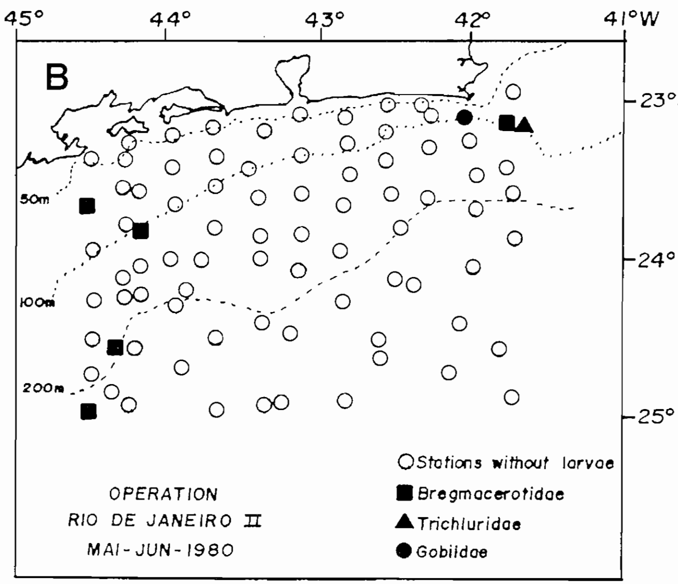
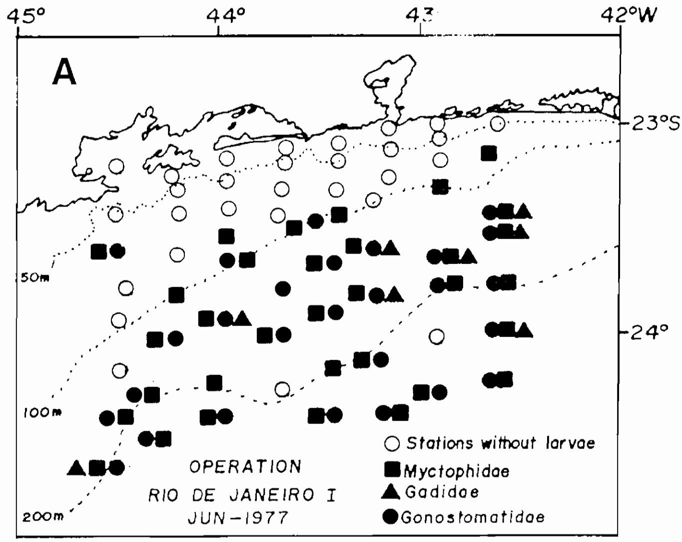


Figure 9. Occurrence of the larvae of Trichiuridae, Bregmacerotidae and Gobiidae during "Rio de Janeiro I" (A) and "Rio de Janeiro II" (B).



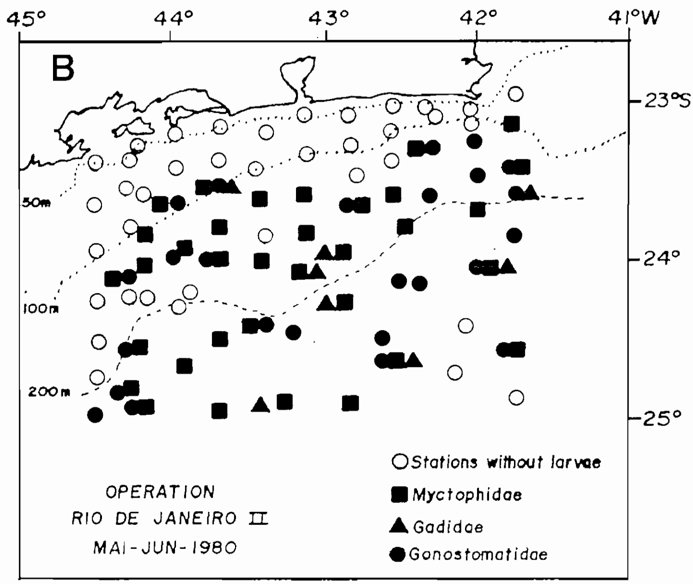


Figure 10. Occurrence of the larvae of Myctophidae, Gonostomatidae and Phycidae during "Rio de Janeiro I" (A) and "Rio de Janeiro II" (B).

Discussion

The hydrographic structure observed during the RJI and RJII cruises, performed during fall/winter conditions, showed the predominance of the TW down to 200 m depth and the presence of SACW in the bottom at the edge of the continental shelf, in the great part of the studied area. These observations confirmed earlier studies carried out in the Southern Brazilian shelves (23° to 25°S) by several authors (Emilsson, 1961; Miranda, 1985; Matsuura, 1986). The upwards movements of SACW, however was observed in some points mainly near Ilha Grande Bay and Cabo Frio. According Maglioca *et al.* (1979) this phenomenon may be associated with variations of the coastal flow, that transports cold and enriched waters upon the continental shelf, an effect similar to those produced by upwelling.

Nutrients values were influenced by this oceanographic conditions. Valentin (1984a) observed NO_3 and SiO_2 concentrations above 5.0 μM and 1.0μM of PO_4 in the Cabo Frio upwelling. During downwelling conditions, when TW dominates, these values were inferior to 0.30 μM of PO_4 and 1.0 μM of NO_3. Magliocca *et al.* (1979) recorded values higher than 0.6 μM of PO_4 in upwelling cold waters south of Cabo Frio. The distributional pattern of zooplankton and water masses were closely related, with an inshore-offshore gradient. A tendency of decline in zooplankton associated to TW (< 500 org.m^{-3}) and increase of densities in inshore and SACW (> 5,000 org.m^{-3}) were also observed by Valentin (1984b; 1986; 1987) during studies off Rio de Janeiro.

In the Shelf Water the principal source of specific diversity of the copepod populations observed during RJI cruise was probably the enrichment effect of mixing water masses. In this water, values of diversity nearly to 3 bits.ind^{-1} were observed previously in this region and in Cabo Frio, where the upwelling showed a maximum intensity during summer (Bonecker *et al.*, 1990; Valentin *et al.*, 1984b).

Copepod species have been used to identify water masses along the Southern Atlantic (Björnberg, 1963; Ramirez, 1969; 1970) and as indicators of SACW upwelling in Cabo Frio (Valentin *et al*, 1984; 1987).

The most abundant copepods observed in this study as **Clausocalanus furcatus**, **Oithona plumifera**, **Oncaea venusta** and **Paracalanus parvus** are common in tropical coastal waters all over the world. Gaudy (1967) and Binet & Dessier (1968), observed some of these species through horizontal hauls in the Madagascar coast influenced by the warm Mozambique Current, where deep waters were at surface during winter (July-August). Cold water species such as **Ctenocalanus vanus** and **Rhincalanus cornutus**, good indicators of SACW were also observed in those region.

Although the ichthyoplankton collected with vertical hauls does not account for an evaluation of eggs and larvae stocks, the results showed a great diversity of fish families inhabiting these waters. In our previous study of the zooplankton obtained by oblique hauls during RJI, the ichthyoplankton represented up to 10% of the zooplankton population in the samples, with 29 fish families identified (Bonecker *et al.*, 1990).

In the majority of teleostean fish with pelagic eggs the spawning happen more intense in the spring/summer months. The frequency was diminishing with the decrease of the temperature (Phonlor, 1984). **E. anchoita** spawning more intensively in the winter, because diminish the competitivity of disposable food for their larvae at least in the critical period of their planktonic phase (Phonlor, **op. cit.**). During the fall/winter, spawning of **Engraulis anchoita** was observed in both cruises. This is an important commercial fish that occurs along the southern coastline in shelf waters. Spawning conditions were also favorable in TW for **Maurolicus muelleri**. According to Nakatani (1982), spawning of **E. anchoita** can occur in two seasons during late winter-early spring scattered throughout the shelf and during late spring and early summer associated to upwelling of SACW in coastal waters. Our data showed high occurrence of **Engraulis anchoita** larvae near Ilha Grande Bay and in Cabo Frio probably associated with the lower temperature observed in these areas.

Engraulids exploring in the maximum a favorable environment, have short life cycle and high reproductive capacity, permitting a quite population expansion (Katsuragawa *et al.*, 1993). Larvae of **E. anchoita** are zooplanktivorous, eating predominantly eggs, larvae and adults of copepods (Ciechomski, 1967; Ciechomski & Weiss, 1974; Angelescu, 1982). These food items were abundant during winter, favoring the feeding and growth of the larvae. The result showed that waters off Rio de Janeiro are rich in zooplankton which could support the stocks of anchovy in coastal regions and mesopelagic fishes in oceanic waters during cold months.

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