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HYDROGRAPHY, PHYTOPLANKTON BIOMASS AND PHOTOSYNTHESIS IN SHELF AND OCEANIC WATERS OFF SOUTHEASTERN BRAZIL DURING AUTUMN (MAY/JUNE, 1983)

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Abstract

Spatial distribution of chlorophyll-a, phytoplankton photosynthesis and nutrients were studied in relation to the hydrographic environment of the southeastern Brazil from May 3 to June 31 of 1983 during an oceanographic cruise conducted by the R/V "Almirante Saldanha" of the Brazilian Navy. Temperature and salinity at 5 meters depth ranged from 21 to 25°C and from 33.00 to 37.11, respectively. The concentration of nutrients varied, nitrate + nitrite-N from 1.0-3.0 µg-at/l, phosphate-P 0.1-0.9 µg-at/l and silicate-Si 5-25 µg-at/l. The chlorophyll-a concentrations along the coast varied from 0.35 to 1.48 mg/m³ with maxima in front of Paranaguá Bay (PR) and over the southern shelf of Santa Catarina State. Low concentrations around 0.20 mg/m³ of uniform distribution were observed in shelf and off-shelf areas. Comparatively high concentrations were measured over the shelf break zone in front of Paranaguá Bay indicationg the occurrence of shelf break upwelling of deep nutrient rich waters. The pattern of vertical distribution was stratified and irregular in coastal stations and uniform in shelf and oceanic waters although some sub-surface peaks were sometimes detected. The integrated chlorophyll values within the euphotic layer varied between 2.70 and 28.06 mg/m². The surface photosynthetic capacity varied from 0.4 to 7.7 mgC/mgChl.a/hr with higher values obtained in coastal areas. The vertical distributions were variable in coastal areas and more uniform in mid-shelf stations. Sub-surface maxima of photosynthesis were detected in both nearshore and off-shore stations, and surface inhibition was not observed.

Descriptors: Hydrography, Chlorophyll-a, Photosynthesis, Nutrients (mineral), Geographical distribution, Southeastern Brazilian coast.
Descritores: Hidrografia, Clorofila-a, Fotossíntese, Nutrientes minerais, Distribuição geográfica, Brasil: costa sueste.

Introduction

The physical oceanographic structure of the southeastern Brazil has been studied during the last 30 years since the original work of Emilsson (1961). Chemical studies have also been carried out but they are mostly restricted to the southernmost areas of the Brazilian coast (Hubold, 1980*a*, *b*; Magliocca, 1973; Magliocca *et al.*, 1980; Magliocca *et al.*, 1982). 1980*a*). Phytoplankton studies over mid-shelf waters off southeastern Brazil started very recently (Aidar-Aragão *et al.*, 1980; Vieira & Teixeira, 1981; Soares, 1983; Brandini, 1986, 1988; Brandini & Moraes, 1986). However very little information has been reported about photosynthetic activity in offshore areas (Vieira & Teixeira, 1981).

During the seasonal oceanographic surveys conducted by the R/V "Almirante Saldanha" (Brazilian Navy) in the southeastern Brazil (DHN 1985; 1986*a*, *b*) phytoplankton samples were collected for studying the spatial distribution of chlorophyll-*a* and photosynthesis in relation to the hydrographic regime. The winter and summer cruises data have shown diverse hydrographic conditions (Brandini, 1986) which must be taken

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into account for explaining the seasonal differences in the spatial distribution and taxonomic structure of the phytoplankton population. In order to compensate the lack of information during an intermediate situation, the present paper reports data for the autumn period in the same region.

Material and methods

The survey area is located between Lat. 29°36' - 24°06'S and Long. 43°36' - 48°45'W covering coastal, mid-shelf and oceanic areas off Santa Catarina, Paranã and São Paulo States (Fig. 1). The sampling grid was formed by 91 stations distributed in 12 transects perpendicular to the coastline and located 30 miles apart. The stations were

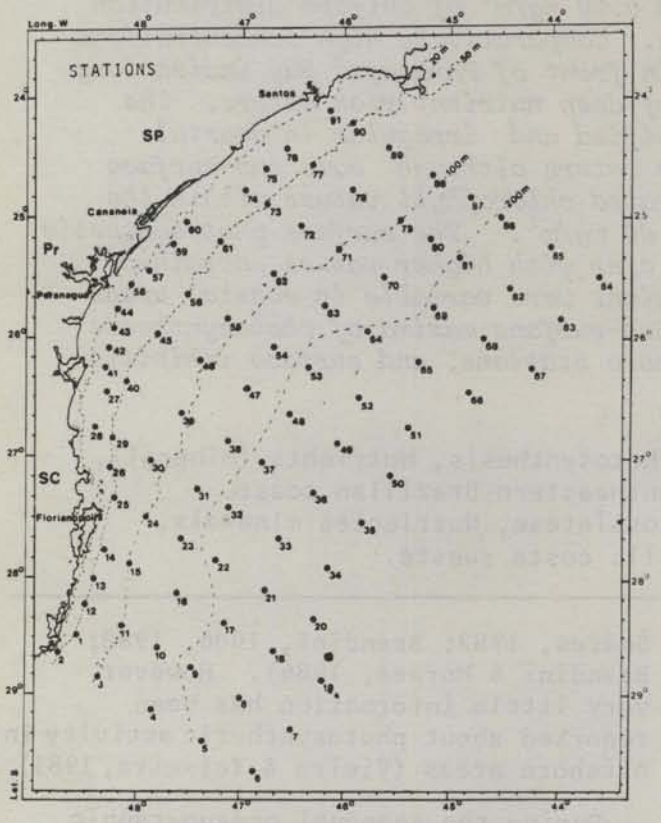

Fig. 1. Map of the survey areas and station positions off São Paulo (SP), Paranã (PR) and Santa Catarina (SC) States.

sampled with Nansen bottles from May 3 to June 31 of 1983 in order to collect basic hydrographic data including temperature (reversing thermometers), salinity (Grundy 6230N salinometer) and nutrients, in superficial layers (5 m depth) of all stations and at standard depths from surface down to 350 m in three selected profiles perpendicular to the coast of Santa Catarina (Stns 7-12), Paranã (Stns 51-57) and São Paulo States (Stns 76-83). Nitrate, nitrite, phosphate and silicate were analysed on board immediately after sampling according to Strickland & Parsons (1972). Van Dorn bottles were also used to collect water samples for measuring chlorophyll-*a* (SCOR-UNESCO, 1966) in the surface at all the stations and vertically in those stations where photosynthetic experiments were performed. In this case, a Secchi disk was used to estimate the thickness of the euphotic layer and the depths corresponding to 60, 30, 16 and 1% of surface light intensity. Water samples were collected at these light levels for measuring phytoplankton photosynthesis using the C-14 technique (Steemann-Nielsen, 1952). Water volumes of 125 (coastal areas) or 300 ml (offshore areas), were inoculated with 10 µCi of $Na_2\ ^{14}CO_3$ and incubated for 5 hours under artificial fluorescent light (approximately 5 watts/cm^2). The *in situ* temperature was simulated by a constant flow of surface water into the incubator. At the end of the incubation period the samples were carefully filtered through Millipore AA filters (0.8 µm) and placed in 5 ml Bray's solution for liquid scintillation counting (Vollenweider, 1974). The photosynthetic rates were calculated with the equations of Strickland & Parsons (1972).

Results and discussion

1) Hydrography

The temperature and salinity at 5 meters depth (Figs 2 and 3) ranged from 21 to 25°C and from 33.00 to 37.11, respectively. The temperature horizontal distribution was nearly homogeneous. No large differences were found between coastal and oceanic waters. However, the horizontal distribution of salinity showed increasing gradients seaward. Analysis of the watermasses was based on T-S diagrams as reported previously (Emilsson, 1961; Miranda, 1982). The surface layers on the survey area was occupied by three types of water:

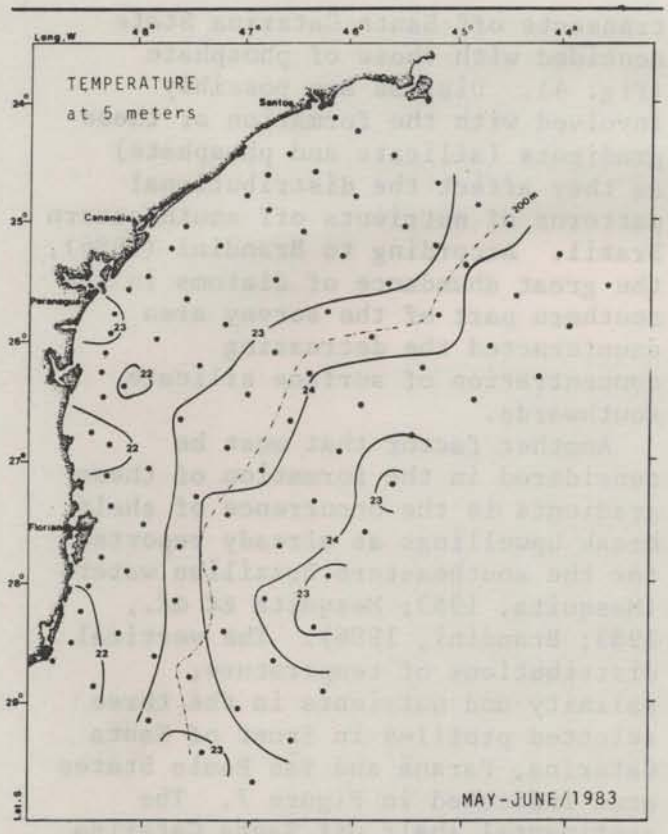

Fig. 2. Horizontal distribution of temperature at 5 meters depth in May-June 1983.

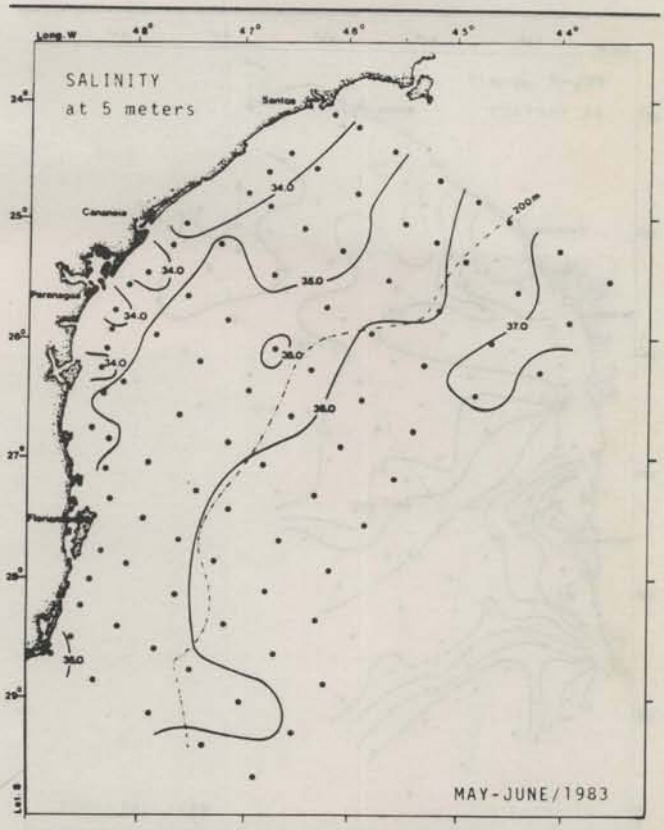

Fig. 3. Horizontal distribution of salinity at 5 meters depth in May-June 1983.

Tropical Water (TW), Shelf Water (SW) and Coastal Water (CW).

The temperatures above 20°C and salinities higher than 36.00 observed in the present investigation indicate the great influence of TW which is tranported southwards by the Brazil Current. In Figure 3, the 36.00 isohaline extended along the shelf break line represented by the isobath of 200 m. This means that the Brazil Current was maintained away from the continental shelf. The shelf areas were dominated by the Shelf Water as defined by Emilsson (1961) with temperatures also above 20°C, but salinities between 35.00 and 36.00. The SW is formed by the mixing of TW, CW and the deep South Atlantic Central Waters (SACW) (Sverdrup *et al.*, 1942). From an oceanographic point of view the Coastal Water cannot be considered as a "true" watermass because the regional character of this investigation did not allow the definition of its thermo-haline intervals (Miranda, person. commun.*). However, temperatures above 15°C and salinities below 35.00 characterize the nearshore waters of the survey area (Emilsson, 1961; Miranda, 1982).

The concentration of phosphate at the surface (Fig. 4) varied from less than 0.1 µg-at/l in shelf and off-shelf areas of Paraná and São Paulo States, to 0.9 µg-at/l (Stn 26) in coastal waters off Santa Catarina State. In the southernmost part of the survey area marked gradients of phosphate were detected with isopleths of concentration perpendicular to the shoreline. In the majority of coastal and mid-shelf waters off Santa Catarina, the concentrations exceded 0.4 µg-at/l. According to Brandini (1986) the phosphate behaved conservatively like temperature and salinity during winter in the same study area, as the pattern of horizontal distribution of all three parameters were very similar. The sharp gradient observed in the southern part during the present work indicates either mixing processes, which were not clearly observed in the distributional patterns of temperature and salinity, or biological uptake. Phytoplankton biomass in terms of chlorophyll-*a* were

(*) Miranda, L. B. de, Instituto Oceanográfico da Universidade de São Paulo, 1988. (Personal communication).

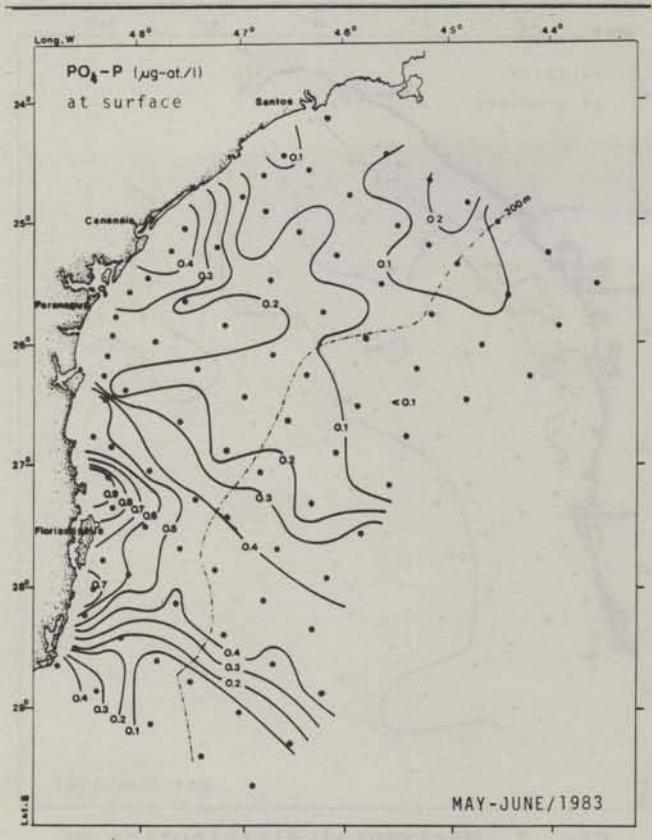

Fig. 4. Horizontal distribution of phosphate at surface (1 m) in May-June 1983.

only obtained at few stations in the southern part of the sampling area and, therefore, the gradients of phosphate observed cannot be explained based on the set of data reported in this work.

The nitrate+nitrite at the surface did not show the same gradients (as phosphate) in front of Santa Catarina State (Fig. 5), with concentrations ranging from 1.0 to 3.0 µg-at/1. The isopleths were perpendicular to the shoreline and slight spatial variations were detected only in a north-south direction. In general the concentrations were higher than 2.0 µg-at/1 in the northern half of the survey area. The silicate at the surface (Fig. 6) showed higher concentrations in the southern part with maximum of 25 µg-at/1 at Stn 17 in contrast to observations during winter (DHN, 1985) when the highest concentrations were in the northern part. In the north, the concentrations were homogeneously distributed fluctuating between 5 and 10 µg-at/1. The increasing gradients of silicate observed between the second and third transects off Santa Catarina State concided with those of phosphate (Fig. 4). Diatoms are possibly involved with the formation of these gradients (silicate and phosphate) as they affect the distributional patterns of nutrients off southeastern Brazil. According to Brandini (1986), the great abundance of diatoms in the southern part of the survey area counteracted the decreasing concentration of surface silicate southwards.

Another factor that must be considered in the formation of these gradients is the occurrence of shelf break upwellings as already reported for the southeastern Brazilian waters (Mesquita, 1983; Mesquita *et al.*, 1983; Brandini, 1986). The vertical distributions of temperature, salinity and nutrients in the three selected profiles in front of Santa Catarina, Paraná and São Paulo States area indicated in Figure 7. The continental shelf off Santa Catarina is less extensive than in the northern

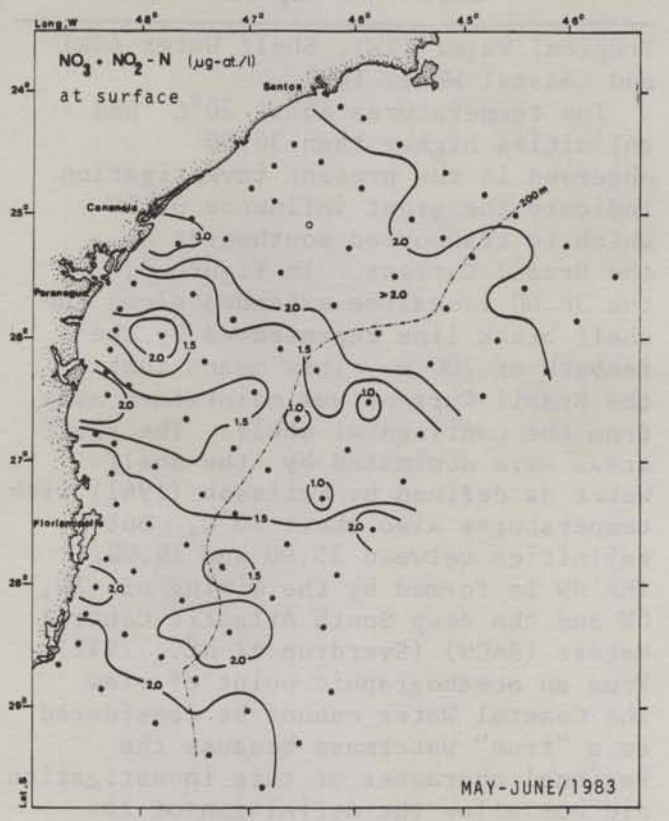

Fig. 5. Horizontal distribution of nitrate + nitrite at surface (1 m) in May-June 1983.

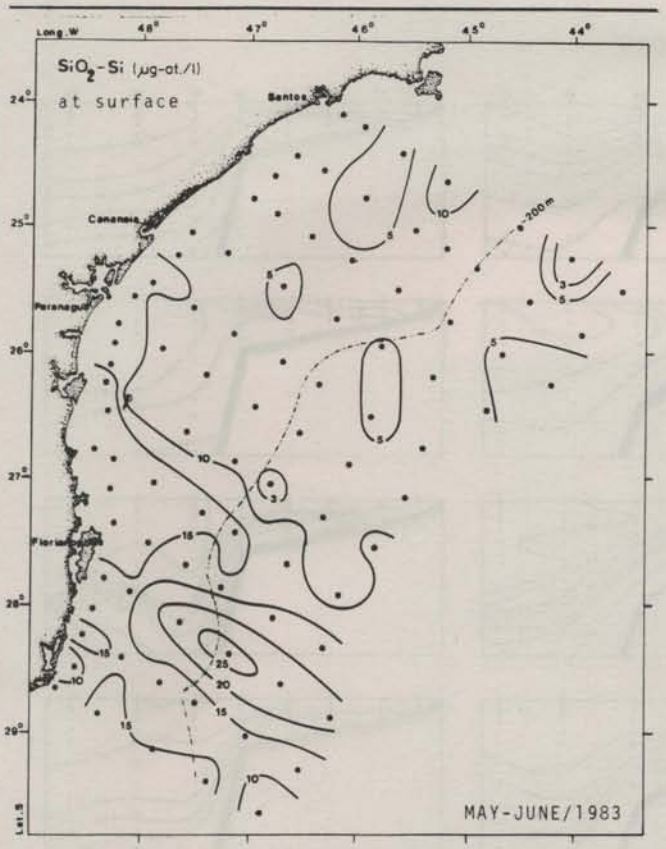

Fig. 6. Horizontal distribution of silicate at surface (1 m) in May-June 1983.

areas making easier the intrusion of nutrient rich SACW along the bottom of the shelf, and then reaching superficial layers. In the profiles off Paraná and São Paulo upward motions of deep SACW in the shelf break zone were more evident but did not reach the surface, except at Stn 55 off Paraná State (Fig. 7B). In this same transect Mesquita (1983) and Mesquita *et al.* (1983) reported upward movements of deep waters and Brandini (1986) detected a very strong upwelling over the shelf break zone during winter and showed their importance for autotrophic processes within the euphotic zone of oceanic waters.

2) Chlorophyll-*a*

The concentrations of surface chlorophyll-*a* (Fig. 8) were comparatively high along the coast ranging from 0.35 to 1.48 mg/m^3 (Stns 13 and 44, respectively) with maxima in front of Paranaguá Bay and in the southern coast of Santa Catatina State. This is obviously related to higher concentrations of nutrients carried from land. A similar range of surface chlorophyll-*a* was obtained by Aidar-Aragão *et al.* (1980) in May 1976 (0.4-2.0 mg/m^3) in this same area. Low concentrations around 0.2 mg/m^3 and uniform distribution was observed in shelf and off-shelf areas although higher concentrations were detected at Stn 31 over the shelf break off Florianópolis City and also at the offshore Stn 34 on the same transect. Highly productive zones at the shelf break were also observed during the winter and summer cruises (Brandini, 1986) as a consequence of shelf break upwelling of deep nutrient rich waters. In the Brazilian oligotrophic waters of the Equatorial Atlantic, Teixeira *et al.* (1981) measured surface concentrations between 0.04 and 0.30 mg/m^3.

In most of the nearshore stations (Fig. 9A and B) the pattern of vertical distribution was totally irregular and stratified except at Stn 90. Maxima concentrations were observed at the surface of Stns 41, 13 and 27; at the base of the euphotic zone of Stns 42 and 72, and at intermediate layers of Stns 14, 43, 58 and 91. In shelf stations at 100 m depth (Fig. 9C) the vertical distributions were more uniform although small sub-surface peaks were present at Stns 71 and 79. In shelf break (Fig. 9D) and off-shelf stations (Fig. 9E) the vertical distributions were totally uniform throughout the euphotic layer. Subsurface chlorophyll maxima are closely related to thermal stratification of the water column and they were not detected as frequently as during summer in mid-shelf waters (Brandini, 1986). It is relevant to mention that the pattern of vertical distribution of any parameter based on discrete sampling must be interpreted carefully as the water bottle samplers may lose the "true" peaks within the water column.

The integrated euphotic zone chlorophyll-*a* (Fig. 10) varied from 2.7 to 28.0 mg/m^2. The range is similar to those obtained by Brandini (1986) during the winter (8.8-36.7 mg/m^2) and summer (1.2-18.5 mg/m^2) and the geographical distribution was very irregular and greatly affected by the

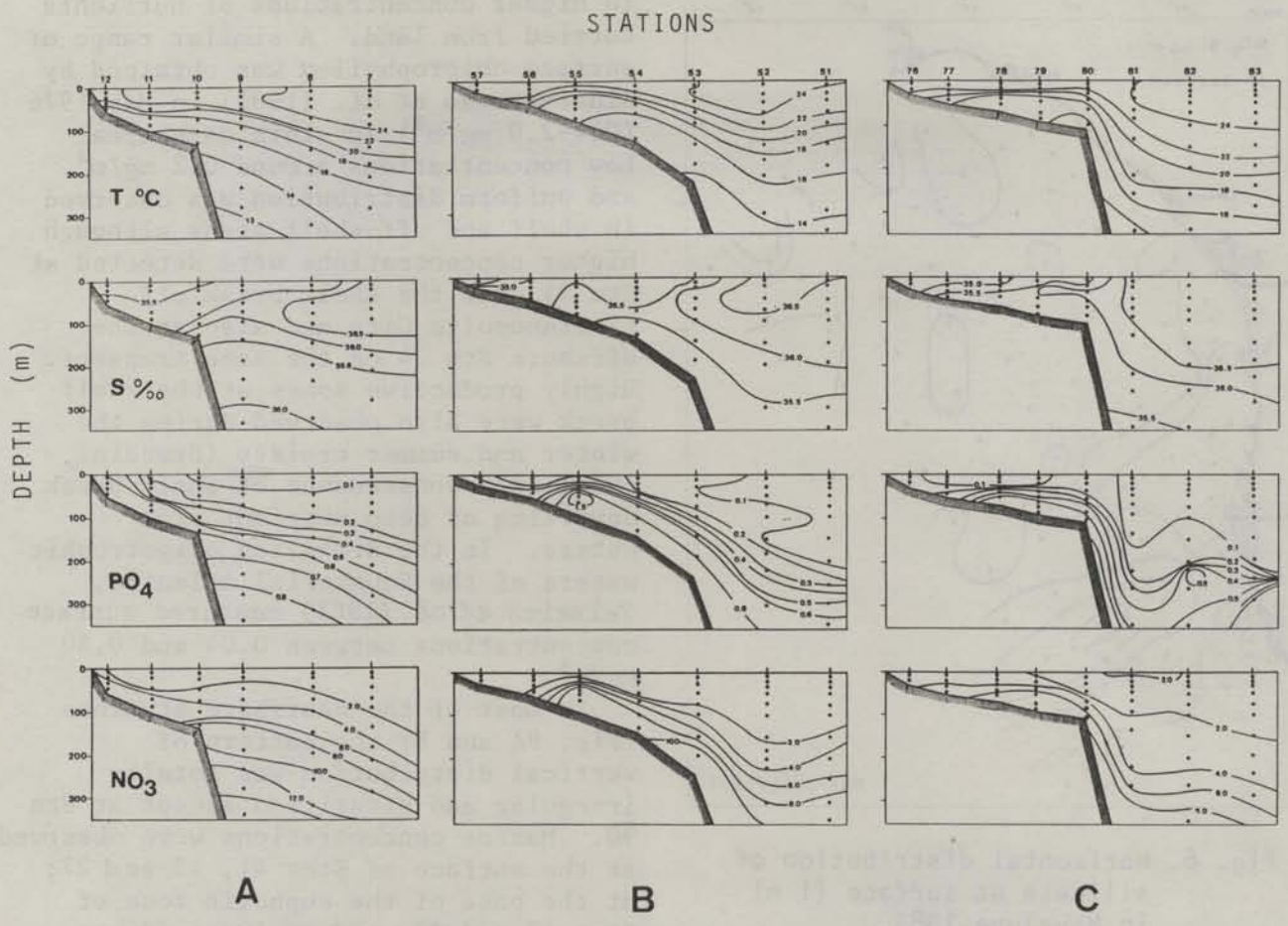

Fig. 7. Vertical distribution of temperature, salinity, phosphate and nitrate in selected profiles of Santa Catarina (A), Paranã (B) and São Paulo (C) States in May-June 1983.

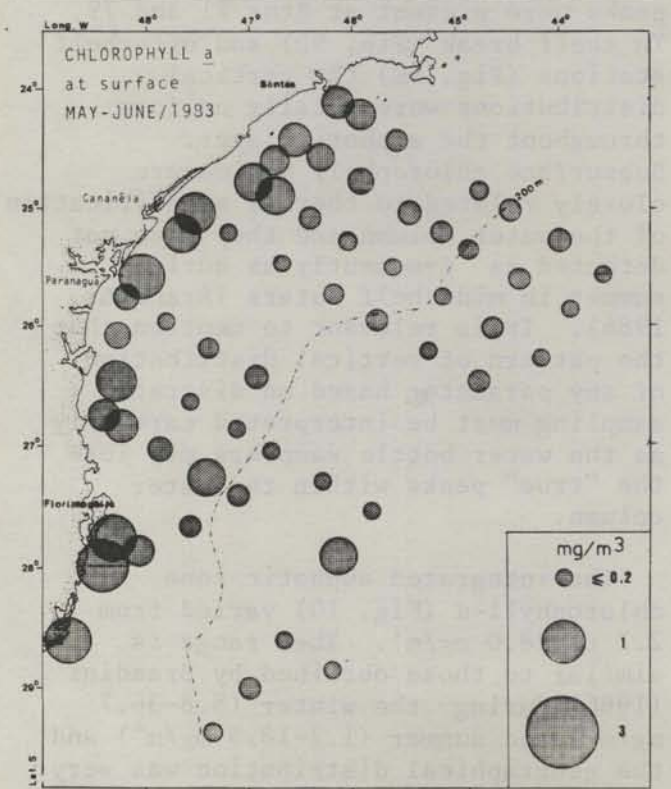

Fig. 8. Horizontal distribution of chlorophyll-*a* at surface in May-June 1983. (The circles shown in the legend are reference values).

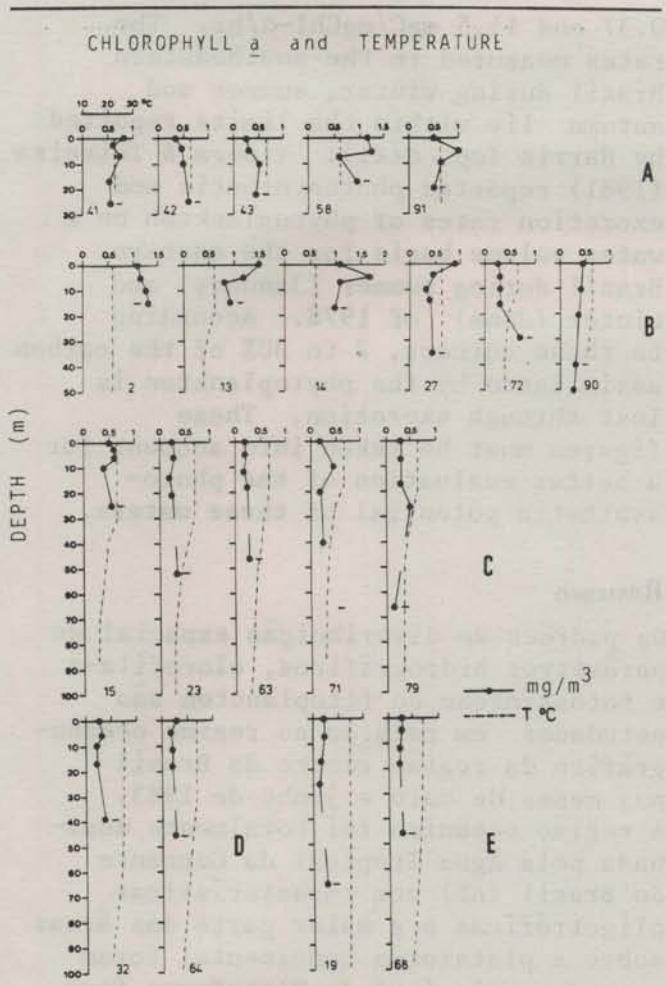

Fig. 9. Vertical distribution of chlorophyll-*a* and temperature within euphotic layers stations with 25 (A), 50 (B), 100 (C), 200 (D) and more than 200(E) meters depth in May-June 1983. The horizontal stroke indicates the depth of 1% surface light intensity.

depth of the euphotic zone. The problems of discrete sampling mentioned above also make it difficult to interpret the distributional patterns from the data observed in this investigation.

3) Photosynthesis

The surface photosynthetic rate (Fig. 11) varied from 0.4 to 7.7 mgC/mgChl-*a*/hr at Stns 8 and 43, respectively. The highest values were observed in coastal areas of Paraná and Santa Catarina States and at Stn 72 located in the mid-shelf waters off São Paulo State. The patterns of vertical distribution in nearshore area (Fig. 12A) were similar at Stns 42, 43, 58 and 27 with subsurface peaks between 5 and 10 meters, and a second peak at deeper euphotic layers. The photosynthetic rate varied from 0.95 to 10.4 mgC/mgChl-*a*/hr at Stn 27 (surface) and 58 (7 meters), respectively. The vertical distributions at Stns 15 and 23, located in shelf areas (Fig. 12B), were uniform fluctuating around 2.0 mgC/mgChl-*a*/hr. In off-shelf areas (Fig. 12C) the vertical distributions were homogeneous at Stns 6, 19 and 83, and stratified at Stn 32. A subsurface peak of 2.25 mgC/mgChl-*a*/hr was detected at Stn 8 (5 meters). The rates ranged from 0.3 (Stn 6, at 31 meters) to 4.3 mgC/mgChl-*a*/hr (Stn 32, between 10 and 17 meters). The photosynthetic rates reported by Brandini (1986) during winter and summer ranged respectively from 0.2 to 9.6 and 0.66 to 10.24 mgC/mgChl.*a*/hr. According to Harris (1978) the normal limits of photosynthetic rates observed for natural populations are within

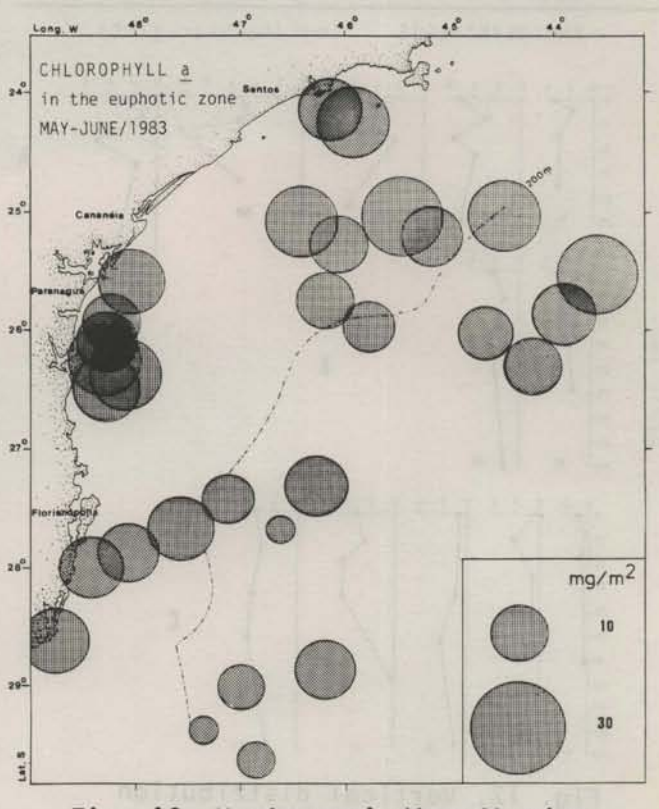

Fig. 10. Horizontal distribution of chlorophyll-*a* per m^2 of euphotic zone in May-June 1983.

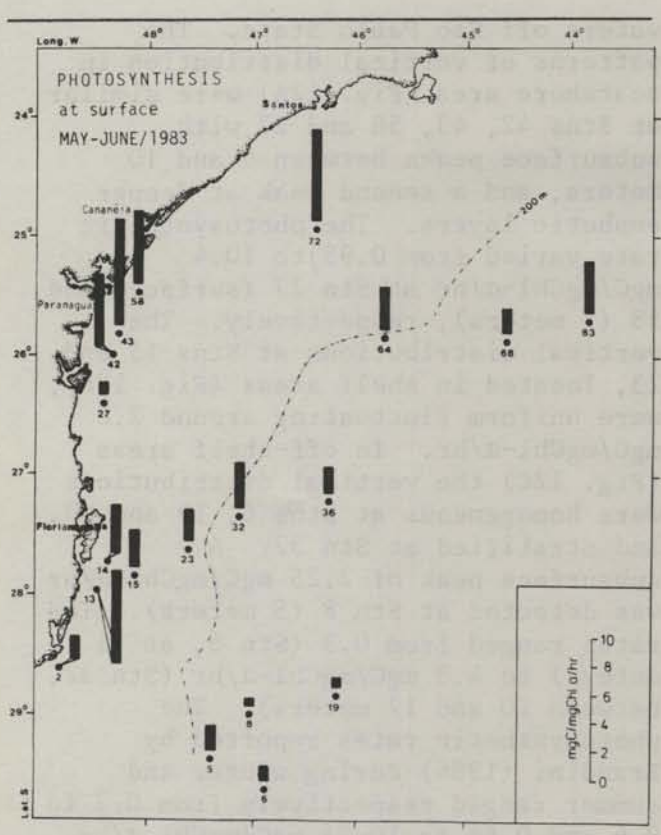

Fig. 11. Horizontal distribution of photosynthesis at surface in May-June 1983.

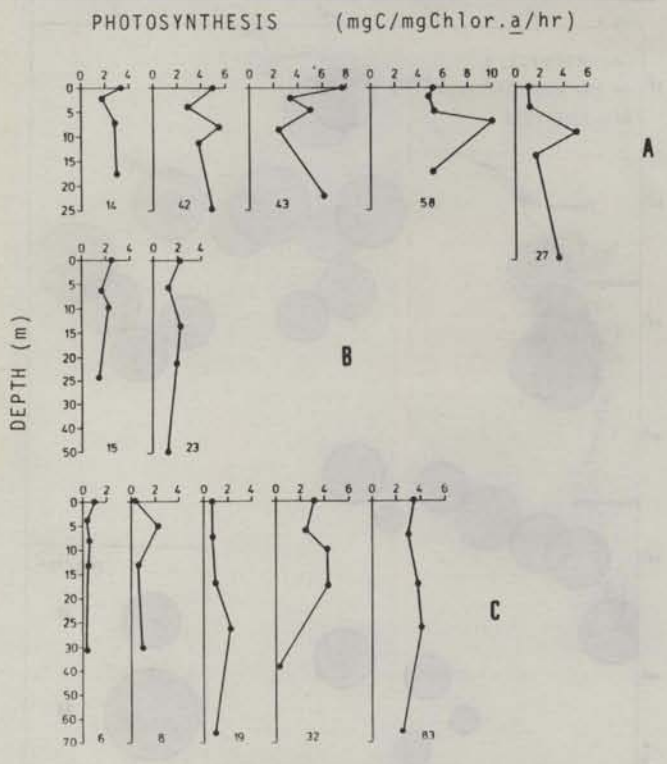

Fig. 12. Vertical distribution of photosynthesis in coastal (A), mid-shelf (B) and oceanic (C) areas in May-June 1983.

0.37 and 11.5 mgC/mgChl-*a*/hr. The rates measured in the southeastern Brazil during winter, summer and autumn lie within the limits reported by Harris (*op. cit.*). Vieira & Teixeira (1981) reported photosynthetic and excretion rates of phytoplankton on a water volume basis for the eastern Brazil during summer (January) and winter (June) of 1978. According to these authors, 2 to 30% of the carbon assimilated by the phytoplankton is lost through excretion. These figures must be taken into account for a better evaluation of the photosynthetic potential of these waters.

Resumo

Os padrões de distribuição espacial de parâmetros hidrográficos, clorofila-*a* e fotossíntese do fitoplâncton são estudados em relação ao regime oceanográfico da região sueste do Brasil nos meses de maio e junho de 1983. A região oceânica foi totalmente dominada pela Água Tropical da Corrente do Brasil (AT) com características oligotróficas e a maior parte das áreas sobre a plataforma continental foram ocupadas pela Água de Plataforma formada pela mistura da AT com águas costeiras.

A temperatura e a salinidade a 5 m de profundidade variaram de 21 a 25°C e de 33,00 a 37,11, respectivamente. Os nutrientes nitrato+nitrito, fosfato e silicato na superfície variaram de 1,0 - 3,0, 0,1 - 0,9 e 5 - 25 µg-at/l, respectivamente. As maiores concentrações foram obtidas nas áreas costeiras e nas camadas profundas da Água Central do Atlântico Sul (ACAS).

As concentrações de clorofila-*a* em águas de superfície na região costeira variaram de 0,35 a 1,48 mg/m^3 com máximos obtidos na Baía de Paranaguá (PR) e nas áreas costeiras ao sul de Santa Catarina. Baixas concentrações em torno de 0,20 mg/m^3 e uma distribuição horizontal uniforme foram observadas na maioria das áreas de plataforma e oceânicas adjacentes. Concentrações comparativamente mais altas foram detectadas sobre o talude continental em frente a Paranaguá, possivelmente relacionadas com a ocorrência de ressurgências de borda de plataforma. A distribuição ver-

tical foi estratificada nas estações costeiras e relativamente uniforme em estações afastadas da costa, apesar da ocorrência de alguns picos sub-superficiais em algumas estações de plataforma. A concentração de clorofila-*a* na zona eufótica variou de 2,70 a 28,06 mg/m^2.

A taxa fotossintética na superfície variou de 0,4 a 7,7 mgC/mgClor-*a*/hr, com máximos obtidos nas áreas costeiras. A distribuição vertical foi irregular e estratificada nas estações costeiras e homogênea nas estações oceânicas.

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References

AIDAR-ARAGÃO, E.; TEIXEIRA, C. & VIEIRA, A. A. H. 1980. Produção primária e concentração de clorofila-*a* na costa brasileira (Lat. 22°31'S - Long. 41°52'W a Lat. 28°43'S - Long. 47°57'W). Bolm Inst. oceanogr., S Paulo, *29*(2):9-14.

BRANDINI, F. P. 1986. Hidrografia e características do fitoplâncton na região sudeste do Brasil: produção primária, biomassa e composição. Tese de doutorado. Universidade de São Paulo, Instituto Oceanográfico. 110p.

———— 1988. Composição e distribuição do fitoplâncton na região Sueste do Brasil e suas relações com as massas de água (Operação sueste - julho/agosto 1982). Ciênc. Cul., S Paulo, *40*(4):334-341.

———— & MORAES, C. L. B. 1986. Composição e distribuição do fitoplâncton em áreas costeiras e oceânicas da região sueste do Brasil. Nerítica, Pontal do Sul, *1*(3):9-19.

DHN. 1985. CI Comissão Oceanográfica/ Operação Sueste II, Costa Sueste - Oceanografia física, química e biológica. NOc. "Almirante Saldanha" (25/04 a 03/06/83). Ministério da Marinha. 31p.

—— 1986*a*. XCVIII Comissão Oceanográfica/Operação Sueste I, Costa Sueste - Oceanografia física, química e biológica. NOc. "Almirante Saldanha" (12/07 a 21/08/82). Ministério da Marinha. 33p.

—— 1986*b*. CV Comissão Oceanográfica/Operação Sueste III, Costa Sueste - Oceanografia física, química e biológica. NOc. "Almirante Saldanha" (13/02 a 01/04/84). Ministério da Marinha. 33p.

EMÍLSSON, I. 1961. The shelf and coastal waters of the southern Brazil. Bolm Inst. oceanogr., S Paulo, *11*(2):101-112.

HARRIS, G. P. 1978. Photosynthesis, productivity and growth: the physiological ecology of phytoplankton. Arch. Hydrobiol., Beih., Ergebn. Limnol., *10*(1/4):1-171.

HUBOLD, G. 1980*a*. Hydrography and plankton off southern Brazil and Rio de La Plata, August-November 1977. Atlântica, Rio Grande, *4*(único):1-22.

———— 1980*b*. Second report on hydrography and plankton off southern Brazil and Rio de La Plata; Autumn cruise: April-June 1978. Atlântica, Rio Grande, *4*(único):23-42.

MAGLIOCCA, A. 1973. Distribuição vertical de oxigênio dissolvido e alguns nutrientes. *In*: Relatório sobre a Segunda Pesquisa Oceanográfica e Pesqueira do Atlântico Sul entre Torres e Maldonado (Lat. 29°- 35°S). Publção esp. Inst. oceanogr., S Paulo, (3, pte 3):1-41.

MAGLIOCCA, A; MIRANDA, L. B. de & PINHEIRO, E. A. 1982. Variação sazonal de oxigênio dissolvido, temperatura e salinidade na costa sul brasileira (28°-35°S; 48°-54°W). Bolm Inst. oceanogr., S Paulo, 31(1):1-9.

————————; PINHEIRO, E. A.; SILVA, J. F. da; MIRANDA, L. B. de; ROBILOTTA, R. R. & RAVASINI, R. M. 1980. Condições oceanográficas entre Tramandaí (30°00'S - 05°08'W) e Cabo de Santa Marta Grande (28°37'S - 48°50'W), no período de 22 a 23/04/78. Relat. cruz., sér. N/Oc. "Prof. W. Besnard", Inst. oceanogr. Univ. S Paulo, (4):1-6.

MESQUITA, A. R. de 1983. Contribuição à oceanografia da região costeira sudeste do Brasil (Lat. 24°S) - Sub-projeto Hidrodinâmica Costeira: execução e resultados. Tese de livre-docência. Universidade de São Paulo, Instituto Oceanográfico. 187p.

————————; LEITE, J. B. de A. & RIZZO, R. 1983. Note on the shelf break upwelling off the southeastern coast of Brazil (Lat. 26°30'S). Bolm Inst. oceanogr., S Paulo, 32(2):193-198.

MIRANDA, L. B. de 1982. Análise de massas de água da plataforma continental e da região oceânica adjacente: Cabo de São Tomé (RJ) a Ilha de São Sebastião (SP). Tese de livre-docência. Universidade de São Paulo, Instituto Oceanográfico. 123p.

SCOR-UNESCO. 1966. Determination of photosynthetic pigments. Report of SCOR-UNESCO Working Group 17 which met from 4 to 6 June 1964, UNESCO, Paris. Monogr. oceanogr. Methodol., U.N., (1):9-18.

SOARES, F. S. 1983. Estudo do fitoplâncton de águas costeiras e oceânicas da região de Cabo Frio-RJ (23°31'S; 41°52'W) até o Cabo de Santa Marta Grande-SC (28°43'S; 47°57'W). Dissertação de mestrado. Universidade de São Paulo, Instituto Oceanográfico. 118p.

STEEMANN-NIELSEN, E. 1952. The use of radioactive carbon (C-14) for measuring organic production in the sea. J. Cons. int. perm. Explor. Mer, 18:117-140.

STRICKLAND, J. D. H. & PARSONS, T. R. 1972. A practical handbook of seawater analysis. 2nd ed. Bull. Fish. Res. Bd Can., (122): 1-172.

SVERDRUP, H. U.; JOHNSON, M. W. & FLEMING, R. H. 1942. The oceans; their physics, chemistry, and general biology. New York, Prentice-Hall. 1087p.

TEIXEIRA, C.; KUTNER, M. B. B. & AIDAR-ARAGÃO, E. 1981. Estudo preliminar sobre a produção primária e o fitoplâncton em águas do Atlântico Equatorial (Lat. 0°00'S - Long. 35°00'W). *In*: SEMINÁRIOS DE BIOLOGIA MARINHA, São Paulo, 1980. Trabalhos apresentados. Rio de Janeiro, Academia Brasileira de Ciências. p.173-178.

VIEIRA, A. A. H. & TEIXEIRA, C. 1981. Excreção de matéria orgânica dissolvida por populações fitoplanctônicas da costa leste e sudeste do Brasil. Bolm Inst. oceanogr., S Paulo, 30(1):9-25.

VOLLENWEIDER, R. A., ed. 1974. A manual on methods for measuring primary production in aquatic environment. Oxford, Blackwell. 225p.

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