Use of GIS for the analysis of ecological variables distribution at Bacia de Campos (RJ) during winter

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Abstract. The phytoplankton biomass distribution and related physical and chemical variables were studied at Bacia de Campos (RJ), during winter (June and July/ 1992) through Geographic Information Systems (GIS). Thematic maps of chlorophyll-a, water masses, nitrate and cluster analysis, were matched spatially for the depths of 0, 20, 50 and 100 m. The spatial distribution of the groups, individualized by cluster analysis, was strongly associated to chlorophyll-a distribution, more evidently than those of water masses or nutrients.

Key words: GIS, thematic maps, phytoplankton biomass, chlorophyll-a, hidrography, Bacia de Campos.

Introduction

Geographic Information Systems (GIS) are spatial database management programs. As such, they lend themselves well to the managment, analysis, and display of large, multivariate data sets. Studies focusing the spatial distribution of oceanographic parameters are essential to the development of projects and studies of coastal occupation, utilization and environmental changes.

Once the GIS data layers are recorded and stored electronically they are also available for analysis on the periodicity, evolution and biological effects of oceanographic phenomena as upwellings, eddies or coastal eutrophication, which can be easily updated. The overlay of oceanographic parameter charts through boolean operation or fuzzy in studies of productivity and other environmental variables, coastal management with integrated planning of marine and estuarine ecosystems are easily performed by a GIS.

In the present work, the phytoplankton biomass, spatial distribution during winter, is analyzed through a meso scale survey, between the coast and the 100 m isobath, using a Geographic Information System (GIS). The tridimentional clustering of the similar points via cluster analysis allowed a better comprehension of the hydrographical factors influence over the phytoplankton biomass distribution at Bacia de Campos (RJ).

Methodology

Vertical samplings (0 to 150 m depth) were carried out in 39 stations along 6 transects, during winter (06/27/92 to 07/15/92). The study area is located between latitudes 21° 40 S and 23° 40 S and longitudes 42° 00 W and 40° 10 W (**Figure 1**). The following parameters were analyzed: chlorophyll-a and phaeophitin (Lorenzen, 1967), organic (OSM) and inorganic (ISM) suspended matter (APHA, 1965), phosphate and silicate (Grasshoff *et al.*, 1983), nitrate and nitrite (Aminot & Chaussepied, 1983), temperature and salinity (CTD SeaBird mod. SeaCat, cod. 808), euphotic zone (Z_{eu}) (determined using a Secchi disc) and mixing zone (Z_m) (calculated according to Aidar *et al.*, 1993).

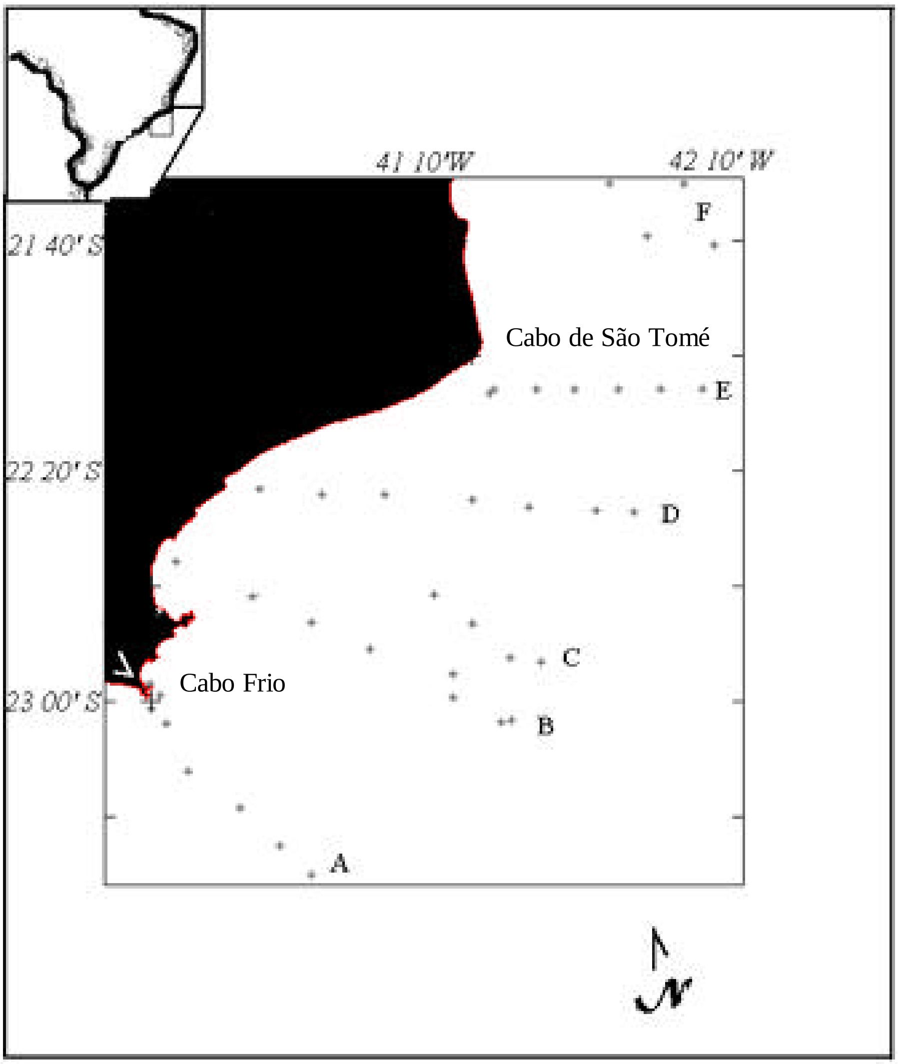

Figure 1: Study area and sampling points (*) along 6 transects, from A to F.

In order to understand the general tendency of the phytoplankton biomass distribution, stepwise regression analysis was applied to the data. The selected variables were nitrate, temperature and salinity represented as thematic maps, the last two were represented as water masses charts.

A cluster analysis combining Ward method and euclidian square distance (Legendre & Legendre, 1983) was applied to the whole set of analyzed variables. The cluster analysis is a mathematical method that is used to find out similarities among objects. Objects (sampling stations) with similar descriptions (attributes) are mathematically gathered into the same group, allowing a classification of these objects.

The maps of chlorophyll-a, nitrate concentrations, water masses and cluster analysis were represented to the surface (0 m), bottom of the mixing zone (Z_m) (20 and 50 m) and shelf bottom (100 m). The selection of the depth of Z_m for the variables thematic representation was determined through a frequency histogram of Z_m values obtained to the 39 sampling stations. Through this frequency histogram two Z_m depths were chosen: 20 m, the most frequent depth for coastal stations and 50 m the most frequent depth for offshore stations.

The nautical charts of the study area (Mercator projection, DHN 1500 and 1400) were digitized in the SGI program (Imagens Geossistemas, 1994). The following steps were executed in this program:

1) Over the digitized area the digital elevation models (DEMs) of chlorophyll-a, nitrate, temperature, salinity and cluster analysis were done for surface, bottom of the mixing zone (20 and 50 m) and shelf bottom (100 m). Regular grids of 400 x 400 pixels were produced for temperature and salinity, employing the interpolation method of average of the n closest neighbors (where n=8). These grids were overlaid through boolean operation, resulting in thematic maps of water masses distribution. The thermohaline intervals defined to the water masses present at Bacia de Campos area were choosen according to Aidar *et al*. (1993) and Miranda & Katsuragawa (1991). The boundary values for each water mass were: South Atlantic Central Water (SACW), temperatures $\leq 18^o$ C, salinities $\leq$ 36.0; Coastal Water (CW), temperatures $\geq 20^o$ C, salinities $\leq$ 35.4; Tropical Water (TW), temperatures $\geq 20^o$ C, salinities $\geq$ 36.0; mixture of SACW and CW, temperatures between $18\ ^o$ C and $20\ ^o$ C, salinities between 35.4 and 36.0; mixture of SACW and TW, temperatures between $18\ ^o$ C and $20\ ^o$ C, salinities $\geq$ 36.0; mixture of CW and TW, temperatures $\geq$ 20, salinities between 35.4 and 36.0.

For the input of the DEMs, a database was created on SPRING 2.0.1 (INPE, 1997). In this program, the DEMs were transformed in thematic maps by first making grids of 400 x 400 pixels employing the interpolation method of weighed average and then slicing numerical intervals into classes. Chlorophyll-a and nitrate were sliced into concentration intervals while the cluster groups were sliced into four intervals: group A, defined by an interval from 0 to 1.5, group B from 1.5 to 2.5, group C from 2.5 to 3.5 and group D from 3.5 to 4.

Chlorophyll-a, water masses, nitrate and cluster groups spatial distribution charts were produced in SCARTA (for SPRING 2.0.1), at a scale of 1:13250 m.

Results and Discussion:

The thematic representations of water masses showed the SACW upwelling close to Cabo Frio (**Figure 2 a, b**). This water mass upwelled through the south portion of the studied area, as is clearly apparent in the maps of the layers of 50 and 100 m (**Figure 2 c, d**). TW occupies the east and north region. CW is restricted to the surface of the area immediately north to Cabo Frio.

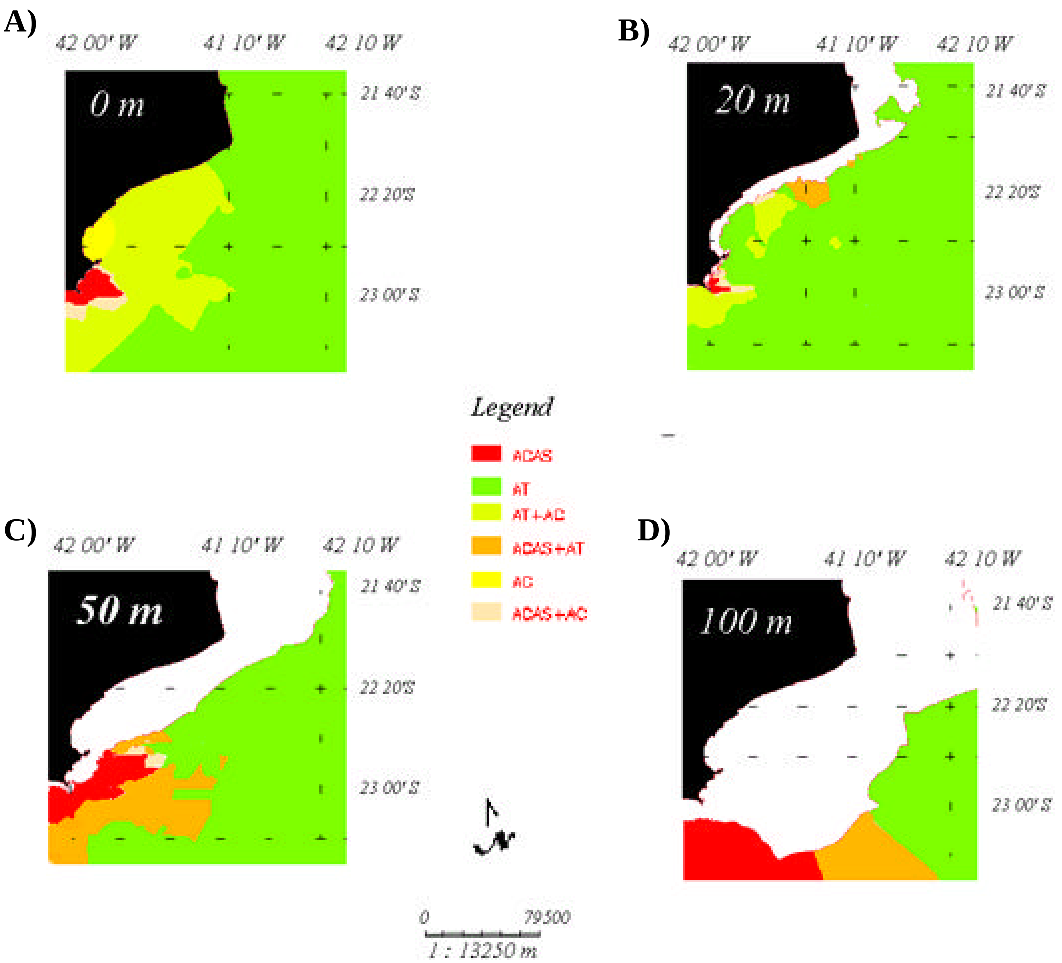

Figure 2- Water masses thematic charts for surface, 20 m, 50 m and 100 m depths.

Nitrate spatial representation pointed low concentrations (<1 µM NO_3) in the whole surface water, except in the upwelled area off Cabo Frio (3- 4 µM NO_3) (**Figure 3 a**). Concentrations were higher (2-6.5 µM NO_3) at Z_m bottom (**Figure 3 b, c**) and at shelf bottom (**Figure 3 d**), matched with the areas where SACW and mixtures of SACW and TW or CW predominate. High concentrations of nitrate, nitrite and phosphate associated with CW were observed during this period (Moser, 1997). These high concentrations of nutrients could be related to the organic matter recently decomposed, common in shallow regions (Gianesella-Galvão *et al.*, 1996).

FIG. 3

The Z_m bottom was always above Z_{eu} bottom, varying from 0 to 100 m while Z_{eu} varied from 10.9 to 142.8 m.

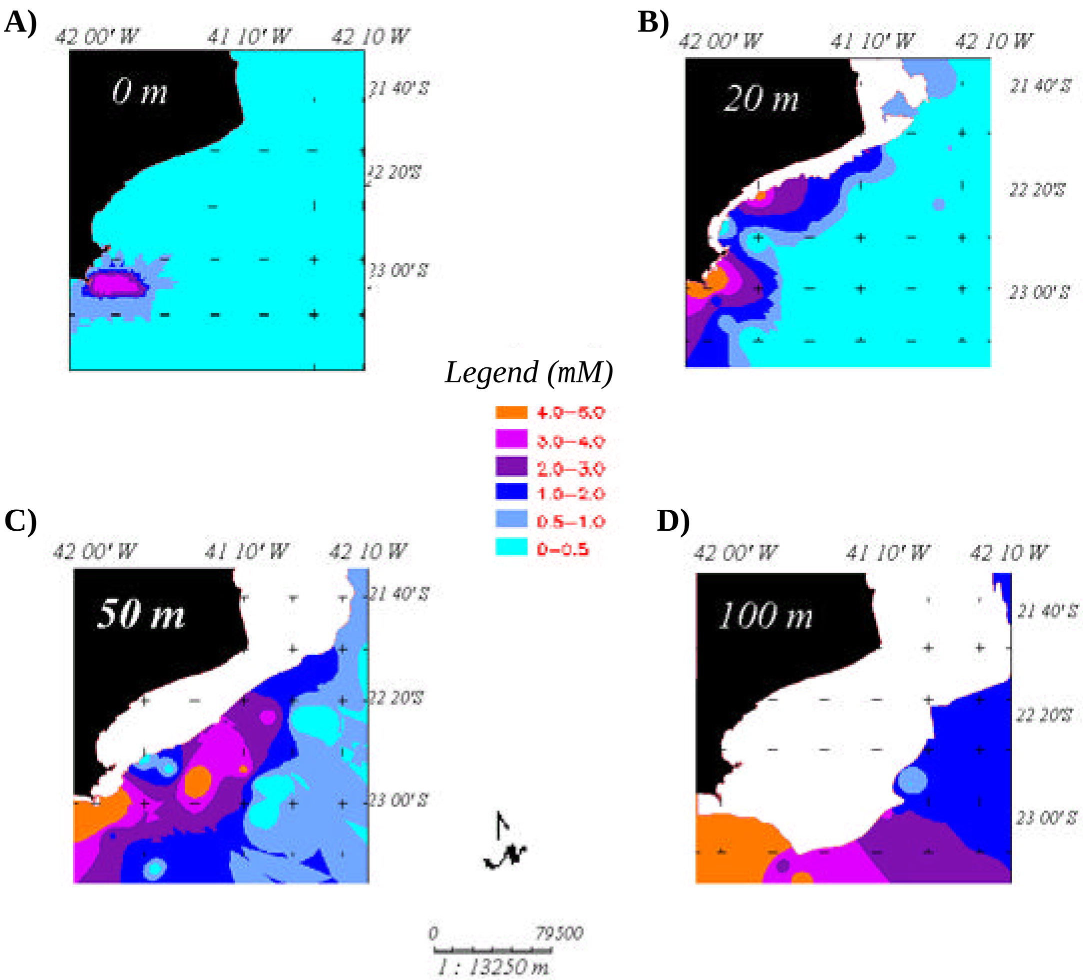

Figure 3: Thematic charts of nitrate concentrations for surface, 20 m, 50 m and 100 m depths.

Chlorophyll-a, during this survey, was low in the whole Bacia de Campos (**Table I**). The maximum value was 2.35 mg m $^{-3}$ and the average value was 0.24 mg m^{-3} chl-a while during summer, as presented in Moser (1997) and Moser and Gianesella-Galvão (1998), phytoplankton biomass reached 25.55 mg m^{-3} chl-a, in front of Cabo Frio coastal area, with an avarege value of 0.60mg m $^{-3}$ chl-a for the whole studied area (**Table I**). In both surveys the phaeophytin concentrations were low, denoting a good healthy status of the phytoplanctonic cells. TAB. 1

Phytoplankton biomass as chlorophyll-a presented slightly higher values close to the coast (> 1 mg m $^{-3}$) (**Figure 4 a, b**). The highest values were observed close to Cabo Frio. Chlorophyll-a concentration at the bottom of Z_m (20 and 50 m) did not surpass 0.8 mg m^{-3} chl-a. The chlorophyll-a concentration was extremely low close to the bottom and in the offshore area (**Figure 4 c, d**). FIG. 4

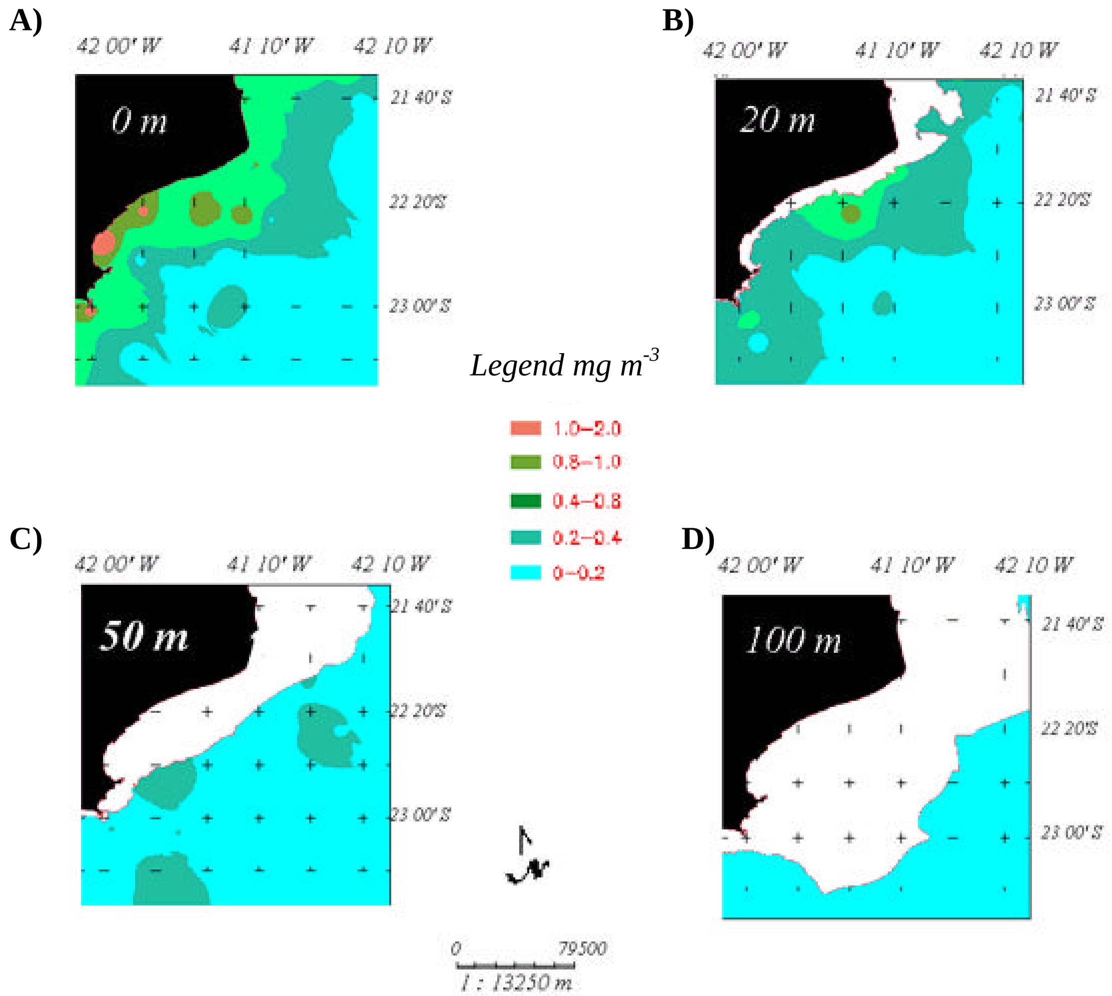

Figure 4: Thematic charts of chlorophyll-a concentrations for surface, 20 m, 50 m and 100 m depths

Table I: Average, standard deviation, maximum and minimum values for phaeophytin and chlorophyll-a concentrations, during winter survey (this study) and summer survey (in Moser,1997) at the studied area.

Winter	***chlorophyll- a (mg/m^3)***	***Phaeophytin (mg/m^3)***
average	0.24	0.30
standard deviation	±0.27	±0.12
maximum	2.35	0.65
minimum	0.00	0.00
Summer		
average	0,60	0,15
standard deviation	±1,93	±0,43
maximum	25,55	5,20
minimum	0,00	0,00

All the analyzed features suggest that the upwelling phenomenon was in its “initial phase”, *sensu* Gonzalez-Rodriguez *et al.* (1992), when cold, rich nutrient water arises at the surface but the phytoplankton had not sufficient time to incorporate the nutrients in its biomass: the SACW upwelling was restricted to the area around Cabo Frio and nitrate concentrations inside the euphotic zone were similar to those from deep SACW waters. The low chlorophyll-a concentrations observed suggests that phytoplankton was in the lag growth phase. Saldanha (1993), in experiments simulating SACW advections, observed that under low temperatures (< 18° C), similar to those from surface waters in Cabo Frio, phytoplankton takes over four days to reach its exponential growth phase.

The groups parcelled out by the cluster analysis were: group A, formed by sampling points near the coast, with nutrients concentrations and low chlorophyll-a (mean value 0.39 mg m $^{-3}$); group B, about 20 Km offshore at the south portion of the area and close to the coast at the north portion of the area. This group presented low concentrations of chlorophyll-a (mean value: 0.19 mg m $^{-3}$); group C, far from the coast, under TW influence and with low chlorophyll-a concentrations (mean value 0.11 mg m^{-3}) and group D, close to the shelf bottom, under SACW influence and with the lowest chlorophyll-a concentrations (mean value 0.03 mg m $^{-3}$).

Thematic maps, builded up on the basis of the cluster results, shows groups related to distance from the coast (groups A, B and C) and to depth (group D) (**Figure 5 a, b, c, d**). These groups are strongly associated with phytoplankton biomass distribution. The thematic representation of surface waters shows group A predominating at coastal area up to 30 Km offshore, from south of Cabo Frio to central portion of the study area. The nuclei observed in surface waters match with chlorophyll-a concentration higher than 1 mg m^{-3}. Group B presents a great spatial distribution through the whole study area, reaching 120 Km offshore in the central area. Group C is observed far from the coast and corresponds to the lowest chlorophyll-a concentrations. The thematic charts of 20 and 50 m showed a sequence of groups A, B and C to offshore stations. Group D is observed just in the spatial representation of the shelf bottom (100 m). FIG. 5

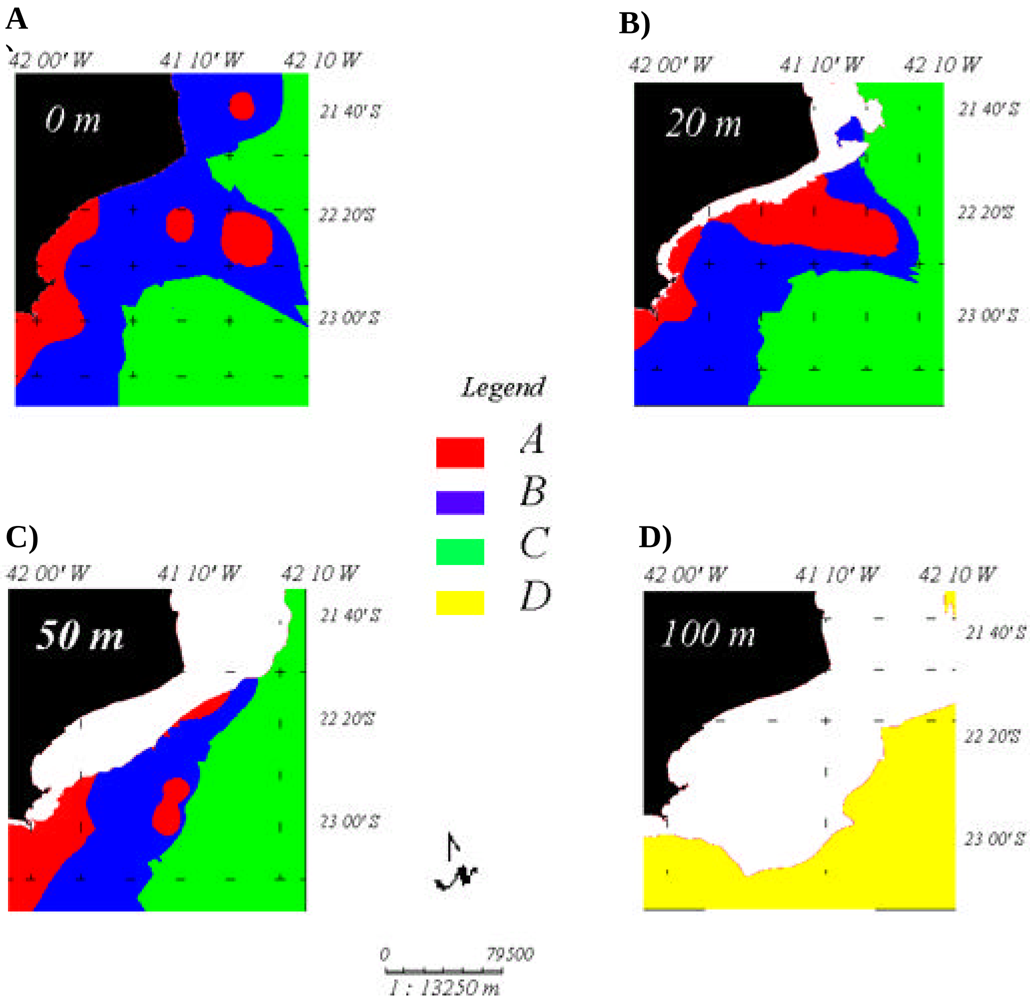

Figure 5: Thematic charts of cluster groups for surface, 20 m, 50 m and 100 m depths.

The use of GIS to the analysis of phytoplankton biomass distribution and related parameters at Bacia de Campos, allowed an easy interpretation of the upwelling phenomenon that dominate the region. Moser & Gianesella-Galvão (1998), through thematic representation of cluster analysis applied to summer data, observed a close relation between the results of this analysis and phytoplankton biomass. Some areas where high values of phytoplankton biomass occurred due to a previous nutrient enrichment related to SACW presence were detected: the region immediately north of Cabo Frio, where meso scale eddies were observed at 20 m; at the north of Bacia de Campos, where SACW was observed at 20 m and at Cabo Frio where an upwelling "productive phase" (sensu Gonzalez-Rodriguez, 1992) was observed. These authors found low chlorophyll-a concentrations close to the shelf bottom.

In the present work the relationship among phytoplankton biomass, hydrography and nutrients distribution was clearly showed through the analysis of the cluster thematic representation. The different groups individualized by this analysis can be matched with four different chlorophyll-a concentrations areas:

Area 1- Cabo Frio coastal region, corresponding to group A, where chlorophyll-a concentrations are between 1- 2 mg m^{-3} chl-a and under SACW influence. Chlorophyll-a concentrations at this area do not differ significantly from those observed at the coastal region (Area 2), although the surface waters in front Cabo Frio presented high nitrate concentrations. This strengthen the idea that the phytoplankton community of this region did not have sufficient time to assimilate the nutrients and use them in growth and celular division processes. This phenomenon was also observed by Gonzalez-Rodriguez *et al.* (1992) and Saldanha (1993).

Area 2- Between Cabo Frio and Cabo de São Tomé down to 20 m depth, corresponding to group B, where chlorophyll-a concentrations are around 1 mg m^{-3} chl-a and the prevailing water masses are mixtures of CW and TW. According to Aidar et al. (1993) CW shows high nutrient concentration when an external source of nutrients is present.

Area 3- The region beyond the 20 m isobath, corresponding to group C, showing low chlorophyll-a concentrations (< 1 mg m^{-3} chl-a) and under TW influence. Aidar *et al.* (1993) also observed low chlorophyll-a associated with TW due to low nutrient concentrations related to this water mass.

Area 4- The region close to the shelf bottom, corresponding to group D, with lowest chlorophyll-a concentration (< 0.2 mg m^{-3} chl-a). The low luminosity was not sufficient to promote phytoplankton biomass increase at this depth.

Conclusions

The spatial distribution of the clusters was strongly associated to those of chlorophyll-a concentrations, more evidently than those of the water masses or nutrients. In spite of small differences among the absolute values of chlorophyll-a observed in the area (0.0 a 2.0 mg m^{-3}), they were sufficient to allow a “biomass based” spatial clustering in four distinct areas, related to coast distance and depth. The classification obtained by cluster analysis may provide the prediction of values of specific variables inside each group, but care should be taken, considering that biological variables are time dependent in respect to many physical forcing.

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