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Catarina Andreia de Oliveira Pereira

ECOLOGIA DE FITOPLANCTON COSTEIRO

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Ciências do Mar e das Zonas Costeiras (2º Ciclo), realizada sob a orientação científica do Professor Doutor Mário Jorge Pereira, Professor Auxiliar do Departamento de Biologia da Universidade de Aveiro.

Dedico este trabalho aos meus pais e ao meu marido pelo incansável apoio e carinho que me proporcionaram durante todas as fases deste projecto.

o júri

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palavras-chave

Fitoplâncton, dinoflagelados, ecologia, dinâmica, zona costeira.

resumo

Este trabalho baseia-se no estudo da dinâmica das comunidades fitoplantónicas, mais especificamente nas populações de diatomáceas e dinoflagelados, transportadas para o interior da Ria de Aveiro. Durante um período de 18 meses, foram realizadas amostragens semanais, 90 minutos antes da preia-mar, à superfície da água, numa estação localizada na entrada da Ria da Aveiro. Foi intuito deste estudo caracterizar alguns dos parâmetros físicos e químicos assim como descrever a dinâmica e distribuição temporal de diatomáceas (Bacillariophyceae), dinoflagelados (Dinophyceae) e clorofila *a* na boca da Ria de Aveiro (Barra), sistema estuarino. Foram identificadas um total de 40 *taxa*, aos quais pertencem nove géneros de diatomáceas e onze géneros de dinoflagelados. Os géneros mais representados foram *Ceratium, Dinophysis* e *Protoperidinium*, seguidos pelos géneros *Pseudo-nitzschia* e *Paralia*. A boca do estuário foi dominada por *Ceratium fusus*, *Ceratium furca, Dinophysis acuminta*, *Dinophysis acuta*, *Protoperidinium* cf. *divergens, Protoperidinium pentagonum, Pseudo-nitzschia* cf. *seriata*, *Pseudo-nitzschia* cf. *pungens* e *Paralia sulcata*. Na primavera e verão de 2006 observou-se uma dominância de dinoflagelados tendo sido associada, a sua ocorrência, a temperatura superficial da água mais elevada. Nos períodos menos quentes, em particular no Inverno houve dominância de diatomáceas. O aumento da temperatura superficial da água, durante 2006, constituiu por si só um ano atípico, permitindo antever, a ocorrência de comunidades fitoplânctónicas diferentes das anteriormente registadas a esta latitude. Investigação futura, contínua, e efectuada por períodos de tempo mais longos permitirá verificar se estas variações estão associadas às alterações climáticas assim como verificar efeitos ao nível da restante cadeia trófica.

keywords

Phytoplankton, dinoflagellates, ecology, dynamics, shelf coastal waters.

abstract

This paper is based on the study of the dynamics of the phytoplanktonic assemblages, more specifically in the populations of diatoms and dinoflagellates transported into the inner zone of the Ria de Aveiro. For a period of 18 months, weekly samplings were made 90 minutes before high tide, in surface water, in a station located at the entry of the Ria de Aveiro. The purpose of this study was to characterize some of the physical and chemical parameters, as well as to describe the temporal dynamics and distribution of diatoms (Bacillariophyceae), dinoflagellates (Dinophyceae) and chlorophyll *a* in the mouth of the estuary of the Ria de Aveiro (Barra), estuarine system. A total of 40 *taxa* were identified, nine were diatoms genera and eleven were dinoflagellates genera. The most represented genera were *Ceratium, Dinophysis* and *Protoperidinium*, followed by the *Pseudo-nitzschia* and *Paralia* genera. The mouth of the estuary was dominated by *Ceratium fusus*, *Ceratium furca, Dinophysis acuminata*, *Dinophysis acuta*, *Protoperidinium* cf. *divergens, Protoperidinium pentagonum, Pseudo-nitzschia* cf. *seriata*, *Pseudo-nitzschia* cf. *pungens* and *Paralia sulcata*. In the spring and summer of 2006, a dominance of dinoflagellates was observed; this occurrence was associated with higher water temperature. In less warmer periods, particularly in winter, there was a dominance of diatoms. The year 2006, due to the increase of water temperature has been, for itself, an atypical year, allowing us to foresee the occurrence of different phytoplanktonic assemblages from the ones previously recorded at this latitude. Further continuous investigation carried out for longer periods of time will allow us to verify if these variations are associated with climate change, as well as to verify effects at the level of the remaining trophic chain.

“Devemos nos perguntar como será este ambiente, dentro de 20 ou 40 anos. Será que então conseguiremos explicar aos nossos filhos e netos como costumava ser o planeta. Será que eles nos perdoarão pela omissão que assumimos quanto à sua gestão e preservação? Ou será que os nossos descendentes nem sequer irão se dar conta do que fizemos com o património natural, pois lá ao longe o ecossistema poderá já não ser sequer um assunto tangível.”

Egberto Melo Moreira Jr.

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Capítulo I

Introdução Geral

Introdução Geral

1. Enquadramento do Tema e Objectivos

A costa oeste portuguesa é afectada por diferentes ventos dependendo da época no ano. Na Primavera e no Verão é atingida por ventos nórdicos que podem ser excessivamente fortes, enquanto que no Inverno os ventos predominantes são de oeste, sendo estes últimos de pequena intensidade. É possível comprovar o aumento e a estabilidade destes ventos nórdicos da costa, que sustêm a ocorrência de afloramento costeiro (*upwelling*), atingindo o seu auge entre Abril e Setembro (Fiúza, 1983; Moita et al., 2003) a sua diminuição é verificada, aproximadamente, entre Agosto e Outubro (Fiúza et al., 1982; Moita et al., 2003; Varela & Prego, 2003). O Noroeste da costa ibérica exibe uma grande variação das comunidades fitoplanctónicas na região de afloramento costeiro (Estrada, 1984; Varela et al., 1991; Sousa & Bricaud, 1992; Tenore et al., 1995; Bao et al., 1997; Casas et al., 1997; Moita et al., 2003; Varela & Prego, 2003), com uma predominância de diatomáceas durante o fluxo (Margalef et al., 1979; Figueiras & Ríos, 1993) e uma dominância de dinoflagelados em águas estratificadas e pobres em nutrientes (Moita et al., 2003). Estes padrões caracterizam as águas costeiras durante os eventos de afloramento (Estrada, 1984; Varela et al., 1991).

Os estuários estão entre os mais produtivos ecossistemas marinhos do mundo, sendo o fitoplâncton, um importante componente destes sistemas. Entre os factores mais importantes que influenciam a produção de fitoplâncton incluem-se a luz e a disponibilidade de nutrientes (Underwood & Kromkamp, 1999).

Foi intuito deste estudo caracterizar alguns dos parâmetros físicos e químicos assim como descrever a dinâmica e distribuição temporal de diatomáceas (Bacillariophyceae), dinoflagelados (Dinophyceae) e clorofila *a* na boca da Ria de Aveiro (Barra), sistema estuarino.

Pretendeu-se, desta forma avaliar e acompanhar a dinâmica das comunidades fitoplanctónicas (diatomáceas e dinoflagelados) por um período de amostragem suficientemente longo de forma a detectar a sua reincidência.

2. Estrutura da Dissertação

Esta dissertação intitulada de *"Ecologia de Fitoplâncton Costeiro"* está dividida em três capítulos que se expõem por:

Capítulo I, constituído por uma introdução geral onde se descreve o enquadramento do tema, os principais objectivos e uma síntese da estrutura da dissertação. É também apresentada uma breve descrição da região de estudo, do local de amostragem e da metodologia utilizada nas campanhas efectuadas.

O Capítulo II, designado por *"Phytoplankton in Shelf coastal waters (NW Portugal, Ria de Aveiro): dynamics and ecology"* descreve o padrão sazonal da dinâmica e distribuição temporal das comunidades fitoplanctónicas que entram para a Ria de Aveiro, na enchente de maré, através da ligação ao Oceano Atlântico, durante um período de amostragem de 18 meses (entre Maio de 2006 e Outubro de 2007). Com este estudo foi possível relacionar os resultados biológicos com os parâmetros ambientais e tentar perceber de que forma pode ser afectada a dinâmica das comunidades fitoplanctónicas, nomeadamente de diatomáceas e de dinoflagelados.

O capítulo III é constituído pela discussão geral do estudo onde se sintetizam as principais conclusões e se assinalam alterações, ao nível das comunidades fitoplanctónicas, passíveis de serem associadas ao clima e que se têm feito sentir na costa Portuguesa.

3. Região de Estudo

As zonas costeiras constituem ecossistemas ímpares possuindo, em termos sociais e económicos, funções comerciais, turísticas e recreativas importantes. Estas regiões suportam cerca de 60% da população mundial (Vitousek et al., 1997) e, no caso particular de Portugal, onde a zona costeira possui uma extensão de cerca de 950 Km, cerca de 75% da população nacional (Santos et al., 2001). As características dos sistemas costeiros e o aumento da população nas regiões costeiras levam a um aumento das pressões antropogénicas sobre os mesmos (e.g. descarga de efluentes residuais), as quais podem conduzir à diminuição da sua qualidade.

A costa oeste portuguesa está localizada ao longo os 9º W do meridiano e entre os 37º e 42º N, paralelos e está no limite norte do sistema de afloramento costeiro (Fiúza, 1983). A costa portuguesa situa-se na orla norte da cinta do anticiclone subtropical e na costa oceânica, facto que determina a maioria das condições climatológicas e oceanográficas existentes (Fiúza 1982).

3.1 Ria de Aveiro

No Litoral Ocidental de Portugal, encontra-se a Ria de Aveiro, um estuário mesotrófico pouco fundo, ligado ao Oceano Atlântico por uma estreita abertura. Estando sujeito a entradas significativas vindas do oceano e ainda a descargas industriais e domésticas (Almeida et al., 2002).

Em conformidade com a classificação de estuários proposta por Pritchard (1989), a Ria de Aveiro pode ser incluído no tipo de estuário designado por “bar-built estuary”. Esta tem um comprimento máximo e largura de cerca de 45 e 10 Km respectivamente. O tempo de residência está estimado de um dia junto ao canal de entrada/saída e de quinze dias nas áreas mais internas (Silva, 1994).

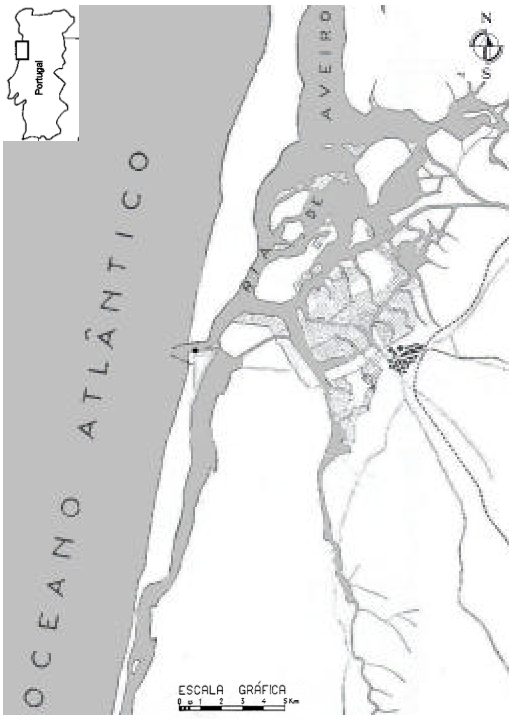

Figura 1. Mapa ilustrativo da Ria de Aveiro com indicação do local de amostragem.

A Ria apresenta uma topografia complexa (Figura 1), com quatro braços principais espalhados a partir da boca em varias direcção, formando um ecossistema multi-estuarino (Almeida et al., 2002).

3.2 Local de amostragem

Com o objectivo de conhecer a comunidade fitoplanctónica, advinda do Oceano Atlântico, que entra na Ria de Aveiro na enchente de maré, realizou-se a amostragem num ponto fixo localizado na entrada do sistema estuarino (Figura 1). Esta localização permitiu a amostragem sistemática, sem interrupção, mesmo quando as condições de clima e perturbação de mar eram desfavoráveis.

A amostragem foi executada na boca da Ria de Aveiro, mais precisamente no Marégrafo (40º 38' 39.04'' N, 8º 44' 55.60'' W) (figura 2), canal caracterizado por um nítido gradiente longitudinal de salinidade influenciado pela excursão de maré. Esta amostragem realizou-se semanalmente, na mudança da lua, durante um período de 18 meses (entre Maio de 2006 e Outubro de 2007), com um total de 72 colheitas, sempre 90 minutos antes de preia-mar (HT), à superfície da água.

Figura 2. Estação de amostragem localizada na entrada de
Ria de Aveiro – Marégrafo (cortesia de Rita Alves).

Em cada amostragem procedeu-se *in situ* à medição dos parâmetros do ambiente (salinidade, temperatura da água, pH e oxigénio dissolvido), recolhendo-se uma amostra de água, à superfície, com um garrafão de polietileno, para posterior tratamento e análise do parâmetros químicos (fosfatos, sílica, amónia e nitratos), quantificação da clorofila *a* e da matéria orgânica. Para a análise do fitoplâncton vivo, colheu-se uma pequena amostra de água através de uma rede de plâncton 25 µm de malha. Também se fixou, com Lugol a 1%, cerca de um litro de água da superfície para posterior identificação e quantificação do fitoplâncton.

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Capítulo II

Phytoplankton in shelf coastal waters (NW Portugal, Ria de Aveiro): dynamics and ecology

Phytoplankton in shelf coastal waters (NW Portugal, Ria de Aveiro): dynamics and ecology

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Phytoplankton in shelf coastal waters (NW Portugal, Ria de Aveiro): dynamics and ecology

Abstract:

This work aimed to study the temporal dynamics of the phytoplankton assemblages at the mouth of Ria de Aveiro (a temperate shallow estuary in NW Portugal). Sampling was performed weekly in the mouth of the estuary, between May 2006 and October 2007, 90 minutes before high tide. Physical and chemical water column parameters were determined; Canonical Correspondence Analysis (CCA), applied to the abiotic data matrix, revealed a clear temporal variation determined by temperature. A total of 40 *taxa*, belonging to 9 different genera of diatoms and 11 genera of dinoflagellates, were identified (and quantified). The genus *Ceratium, Dinophysis* and *Protoperidinium* were the most represented, followed by the genus *Pseudo-nitzschia* and *Paralia*. Dinoflagellates density varied from 1x10^2 cells L^{-1} to 3.5x10^3 cells L^{-1}. The estuary mouth was dominated by *Ceratium fusus*, *Ceratium furca, Dinophysis acuminata*, *Dinophysis acuta*, *Protoperidinium* cf. *divergens* and *Protoperidinium pentagonum, Pseudo-nitzschia* cf. *seriata*, *Pseudo-nitzschia* cf. *pungens* and *Paralia sulcata*. Spring and summer months of 2006 were clear dominated by dinoflagellate species. CCA analysis revealed two main phytoplankton groups, forced by water temperature and salinity optima: dinoflagellate species, associated with high temperature and salinity values, and marine diatoms species situated opposite to the temperature vector. The majority of the species had their temperature optimum in the range 15.0 – 17.0 ºC. *Ceratium longipes* had the lowest optimum (13.4 ºC), with *Ceratium macroceros* having the highest optimum value (18.2 ºC).

Keywords: Phytoplankton, dinoflagellates, diatoms, dynamics, ecology, shelf coastal waters.

1. Introduction

The Portuguese west coast is affected by different winds in different seasons: in spring and summer months northerly winds, which can be very strong, and in winter months weak westerly winds. It is possible to confirm the rise and stability of these northerly along-shore winds which hold the occurrence of coastal upwelling that has it upper limit between April and September (Fiúza, 1983; Moita et al., 2003). A reduction of these upwelling events is verified between August and October (Fiúza et al., 1982; Moita et al., 2003; Varela and Prego, 2003). The north-western Iberian coast exhibits a large scale variation of phytoplankton assemblages in the shelf region due to upwelling (Estrada, 1984; Varela et al., 1991; Sousa and Bricaud, 1992; Tenore et al., 1995; Bao et al., 1997; Casas et al., 1997; Moita et al., 2003; Varela and Prego, 2003), with the diatoms dominating during flow (Margalef et al., 1979; Figueiras and Ríos, 1993) and dinoflagellates dominating in the offshore nutrient-poor stratified waters (Moita et al., 2003). This pattern characterizes the coastal shelf waters during upwelling episodes (Estrada, 1984; Varela et al., 1991) and spring blooms (Fernandez et al., 1991). Superficial waters in the coast are eutrophic ecosystems, where the overflow of fresh water from the land and the waters exchange with the adjacent open sea, influence directly and strongly the physics and biology (Sarmiento et al., 2004; Resende et al., 2007).

Estuaries are between the worlds most productive marine ecosystems and phytoplankton is an important component of the pelagic component. Light and nutrient availability are main factors in the production of phytoplankton (Underwood and Kromkamp, 1999). Several studies about phytoplankton communities in estuaries concluded that Bacillariophyceae are the most important group, either in terms of abundance or in terms of diversity (e.g. Madariaga, 1995; Orive et al., 1998; Muylaert et al., 2000; Trigueros and Orive, 2001; Urrutxurtu et al., 2003; Resende et al., 2005). The Ria de Aveiro phytoplankton ecology was described by Resende et al., (2005) which studied diatoms ecological preferences. The distribution of this assemblage was determined by the salinity spatial gradient and by the temporal temperature gradient. In Ria de Aveiro diatoms assemblage composition was mainly controlled by the effect of river inflow and tidal incursion. Therefore, diatoms constitute an ideal group to study biodiversity and to understand the factors controlling it. Diatoms are valuable indicators of environmental conditions, since they respond directly and sensitively to many physical, chemical and biological changes that occur in these systems (Snoeijs, 1999). The fact that each diatom species has a specific optimum and tolerance for some environmental parameters makes them particularly useful indicators in estuarine systems (Lim et al., 2001; Resende et al., 2005). In contrast to dinoflagellates, diatoms are considerably less sensitive to turbulence and may even be stimulated by motion (Smayda, 1997). Species like chain-forming dinoflagellates have a selective advantage in areas of convergence and downwelling and are able to survive in more turbulent waters around upwelling areas (Margalef et al., 1979 and Fraga et al., 1989).

The aims of this study were to describe the distribution and temporal dynamics of the physical and chemical parameters, diatoms (Bacillariophyceae), dinoflagellates (Dinophyceae) and chlorophyll *a* in the mouth of Ria de Aveiro (Barra) estuarine system. The role of the physico-chemical parameters as forcing functions of the phytoplankton assemblages (dinoflagellates and diatoms) distribution and the dynamics of the dinoflagellates tidal excursion to the estuarine system was also studied. Ecological optima and tolerances were also estimated for the phytoplankton species collected in this study.

2. Material and Methods

2.1 Study site and sampling strategy

Ria de Aveiro (NW Portugal) is a mesotrophic shallow estuarine system on the Western Northern Coast of Portugal, connected to the Atlantic by a narrow opening. It is subjected to considerable inputs of industrial and domestic discharges occurring mainly at its periphery (Almeida et al., 2002). In agreement with the estuaries classification proposed by Pritchard (1989), Ria de Aveiro can be included in the type of "bar-built estuary" (river valleys submerged where the recent sedimentation was so important to compete with the sea level rise). This system has a maximum length and width of 45 and 10 km, respectively. The residence time is less than 1 day for the central area close to the inlet/outlet channel; in the inner areas values higher than 15 days were found (Silva, 1994). The Ria has a complex topography, with four main arms spreading from the mouth towards different directions, forming a multi-estuarine ecosystem (Almeida et al., 2002).

Sampling was performed at the mouth of the estuarine system, Ria de Aveiro (40º 38' 39, 04'' N, 8º 44' 55, 60'' W); this channel is characterized by a clear longitudinal salinity gradient influenced by tidal excursion. Sampling was performed weekly, during a period of 18 months (May 2006 to November 2007: two summer seasons were covered), always ninety minutes before high tide (HT), at the water subsurface (20 cm).

2.2 Environmental parameters

Salinity, water temperature, pH and dissolved oxygen (WTW MultiLine P4 portable meter) were measured *in situ*. Water samples for chemical analyses and chlorophyll *a* quantification were collected at the water subsurface, using a polyethylene bottle and immediately stored in the dark and at low temperature (4 ºC), until further processing. In the laboratory, these water samples were filtered through GF/C filters (1.2 µm pore diameter) and polycarbonate (0.2 µm pore diameter), which were later used on the estimation of phytoplankton biomass. Filtrates were used for nutrient determination. The analysis of ammonia was performed by the indophenol blue technique, according to Hall and Lucas (1981). For the phosphate, in the form of orthophosphate, the stannous chloride method was used (APHA, 1992). Silica was determined by the colorimetric method in Rodier (1984) and the nitrates concentration by the sodium salicilate method, according to Rodier (1984). Suspended organic matter (total and volatile) was conducted accordingly to methodology described in APHA (1992). Phytoplankton biomass was estimated with resource to chlorophyll *a* (Chl *a*) concentration, which was determined by spectrophotometric analysis in acetone extracts at 665 nm and 750 nm, before and after acidification (Strickland and Parsons, 1972), and calculated according to Lorenzen's (1967) monochromatic equation.

2.3 Phytoplankton

Qualitative *in vivo* phytoplankton samples were taken from the water subsurface with short tows of 25 µm mesh-size plankton net. These samples allowed a preliminary taxonomic survey, using a bright-field microscope. Samples for taxonomic and quantitative study were cropped with a glass bottle (1 litre capacity) at the water subsurface (in "well-mixed" estuaries, as it is the case of Ria de Aveiro, the vertical distribution of the salinity is uniform) and immediately preserved with Lugol 1% (iodine/iodide potassium). In the laboratory, samples were concentrated by settling during 8 days. The armoured dinoflagellates were enumerated according to the methodology described by Utermöhl (1958), using an inverted microscope Olympus CKX 41 and floras of Sournia (1973), Rampi and Berhard (1980), Balech (1995), Tomas (1996), Bérard-Therriault et al. (1999), Tenenbaum (2006), for the dinoflagellates species identification. For diatoms a small sedimentation chamber was prepared by adhering (with silicone) an acrylic ring to a coverslip. A fixed volume (1 mL of the concentrated sample was counted, after preparing the appropriate concentration which varied between 5x and 200x, according to the cell density in the initial sample) of each detritus-free sample was then pipetted into the chamber and the liquid was evaporated at room temperature (20-25 ºC), away from dust particles. When these samples were dry and shown to have a homogeneous distribution, the ring was removed and the coverslips were mounted on a glass microscope slide with Naphrax®. The whole 1 mL aliquot was always counted (at least 400 diatom valves were enumerated on each slide) (Resende et al., 2005, 2007). Identification was undertaken to the species level, using the floras Germain (1981), Halim (1960), Lange-Bertalot (2001) Peragallo and Peragallo (1897-1908), Hustedt (1930, 1977, 1985), Round et al. (1990), Simonsen (1987), Sims (1996), Sournia (1986), Tomas (1996) and Witkowski et al., (2000). The taxonomic study was performed on a bright-field microscope Olympus CX 31 and, when necessary, on a Scanning Electron Microscope (SEM) JEOL JSM-6301 F; in the latter case, samples were washed by centrifugation and an aliquot of each sample was transferred, with a micropipette, to an aluminium stub and air-dried (Pereira et al., 2003).

2.4 Data analysis

Canonical Correspondence Analysis (CCA) was applied to the environmental data matrix, using the computer programme CANOCO version 4.5 (ter Braak and Smilauer, 1998), to identify the major sources of variability in the environmental descriptors (ter Braak, 1995).

Standardization was $(x - (\bar{x}_n) / s x_n)$ applied to the environmental parameters and normalization to phytoplankton densities by log $(x+1)$ (Zar, 1996). Down weighting of rare species was performed. The relationship between dinoflagellates and diatom densities and environmental factors was investigated by means of Canonical Correspondence Analysis (CCA) using computer programme CANOCO version 4.5 packages (ter Braak and Smilauer, 1998). A forward selection procedure was performed on the set of environmental variables. A Monte Carlo test using 199 permutations (P=0.05) was performed to test the significance of the correlations between the environmental factors and the species distributions. Only the significant variables were included in the model (ter Braak and Verdonschot, 1995).

Weighted averaging was used to estimate optima ($\hat{u}_k$) and tolerances (t_k) for temperature, for the *taxa* presented in the CCA diagram. Because *taxa* had unequal occurrences, the recommendations of Birks et al. (1990) were followed.

Formulae were as follows:

$$\hat{u}_k = \sum_{i=1}^{n} y_{ik} x_i \Big/ \sum_{i=1}^{n} y_{ik}$$

$$t_k = \left[\sum_{i=1}^{n} y_{ik} \left(x_i - \hat{u}_k \right)^2 \Big/ \sum_{i=1}^{n} y_{ik} \right]^{1/2}$$

where $\hat{u}_k$ is the optimum value of the taxon k, t_k is the tolerance of the taxon k for the parameter in cause, y_{ik} is the abundance of the taxon k in sample i and x_i is the value of the parameter in sample i.

ANOSIM and SIMPER analyses were performed using computer programme Plymouth Routines in Multivariate Ecological Research – PRIMER version 6.0. Data matrix was padronized and ANOSIM tests were preceded by the transformation of the padronized data matrix into a similarities data matrix by the Jaccard coefficient (Clarke and Gorley, 2006 $^{a,\ b}$).

3. Results

3.1 Environmental parameters

Water temperature, between May and November 2006, registered higher values than in equal period of the following year 2007. Following this 2006 spring end, summer and autumn warm months temperature decreased during the winter and spring of 2007 and, in the end of the summer 2007 water temperature followed a typical temperate pattern of variation at this latitude (Figure 1A). The registered maximums of water temperature were 22.4 ºC in 2006 and 18.9 ºC in 2007, and the average estimated values were of 17.5 ºC in 2006 and 15.3 ºC in 2007 (Table 1). During the study period salinity varied between 31.0 PSU and 36.1 PSU (Table 1) (Figure 1). pH values were higher in 2007 with an unclear distributional pattern (Figure 1A) varying between 7.83 and 8.96 (Table1). During 2006 dissolved oxygen in the water column was lower than in 2007 (Figure 1A) with a minimum of 71.6 % and a maximum of 140.9 % (Table 1). Suspended solids and volatile solids showed a very similar distributional pattern of variation during the sampling period (Figure 1 A) with average values of respectively 8.45 mg L^{-1} and 2.05 mg L^{-1} for 2006 and 7.50 mg L^{-1} and 1.79 mg L^{-1} for 2007 (Table 1).

Nitrate varied between 0.003 µg L^{-1} and 0.093 µg L^{-1} for 2006 and for 2007 varied between 0.006 µg L^{-1} and 0.089 µg L^{-1} (Figure 1B). Ammonia concentration presented a variation with a minimum value of 0.001 µg L^{-1} and a maximum value of 0.088 µg L^{-1}, with an average value of 0.043 µg L^{-1} in 2006 and 0.038 in 2007 µg L^{-1} (Table 1). Phosphates showed average values of 0.003 µg L^{-1} for 2006 and 0.006 µg L^{-1} for 2007 (Table1). Silica average estimated values were similar in the two years of sampling, 0.004 µg L^{-1} in 2006 and 0.003 µg L^{-1} in 2007, although in 2007 was estimated a maximum value of 0.018 µg L^{-1}.

3.2 Biological assemblages

During the study period a total of 40 *taxa*, belonging to 9 different genera of diatoms and 11 genera of dinoflagellates were identified and quantified (Table 2). Dinoflagellates have higher percentage of occurrence in the warmer months (spring, summer and autumn months of 2006: May to November of 2006) and again in the summer months of 2007. Diatoms showed the higher percentages of occurrence in the colder months (Figure 2). Diatom density ranged from 2.6×10^{2} cells L^{-1} to $2,28 \times 10^{3}$ cells L^{-1} and dinoflagellates density ranged from 1×10^{2} cells L^{-1} to 3.5×10^{3} cells L^{-1}.

The genus *Ceratium, Dinophysis* and *Protoperidinium* were the most represented with 21 species, followed by the genus *Pseudo-nitzschia* and *Paralia*, with 3 *taxa*. Along the 18 months of sampling, the estuary mouth was dominated by *Paralia sulcata*, *Pseudo-nitzschia* cf. *seriata* and *Pseudo-nitzschia* cf. *pungens* from diatoms and *Ceratium fusus*, *Ceratium furca, Dinophysis acuminata*, *Dinophysis acuta, Prorocentrum micans, Protoperidinium* cf. *divergens* and *Protoperidinium pentagonum* from dinoflagellates (Table 2). The sampling period in this study, covered two consecutive summers, in which were found *Actinoptychus senarius*, *Cylindrotheca closterium*, *P. sulcata, Proboscia alata*, *Striatella delicatula*, *C. furca*, *C. fusus*, *Ceratium kofoidii*, *D. acuta*, *D. acuminata*, *Dinophysis caudata*, *Phalacroma rotundatum*, *P. micans*, *P.* cf. *divergens*, *P. pentagonum*, *Protoperidinium diabolum* and a winter in which were found *A. senarius*, *Biddulphia* *alternans*, *P. sulcata*, *C. furca*, *C. fusus*, *D. acuta*, *P. rotundatum, P. micans*, *P.* cf. *divergens*, *P. pentagonum* and *Scrippsiella lacrymosa* (Table 2).

3.3 Canonical correspondence analysis

Ordination resulting from the CCA produced the biplots presented in Figure 3 (the species represented in the CCA diagram and respective codes are listed in Table 5). Forward selection of environmental parameters retained nine variables that significantly explained the species distribution (Table 3).

In the CCA analysis performed with the physico-chemical parameters axis 1 is mainly influenced by temperature, nitrate, pH and dissolved oxygen, while axis 2 is primarily driven by salinity, phosphates, chlorophyll *a*, silica and volatile solids. Most of the samples collected in autumn and winter months are situated on the right side of the biplot, opposite to the temperature vector, associated with high levels of pH and nitrate (Figure 3A). On the other hand, most of the spring and summer samples occupy the left side, in association with the temperature vector, being also characterized by higher levels of the salinity.

In figure 3B, diatoms and environmental variables, the first quadrant is defined by the parameters pH, dissolved oxygen, nitrates, volatile solids and suspended solids and the diatoms *Cylindrotheca closterium* (CYCL), *Thalassionema nitzschioides* (THNZ) *Bacillaria paxillifera* (BAPX), *Biddulphia alternans* (BIAL). The second quadrant is defined by the environmental parameters salinity, ammonium, phosphates and the diatoms *Rhizosolenia* (RH), *Eucampia zodiacus* (EUZO). The third quadrant is defined by the environmental parameters temperature of the water column and by the diatoms *Striatella delicatula* (STRD), *Pseudo-nitzschia* (PS), *Chaetoceros* (CH), *Probostia alata* (PRAL). Finally, the forth quadrant is defined by the environmental parameters chlorophyll *a* and silica and the diatom *Actinoptychus senarius* (ACSN) and *Paralia sulcata* (PASU).

In figure 3C, dinoflagellates and environmental variables, the first quadrant is defined by the environmental parameters ammonium and nitrates and by the dinoflagellates *Gonyaulax* cf. *polygrama* (GONP), *Protoperidinium* cf. *crassipes* (PRCR), *Phalacroma rotundatum* (PHRO), *Prorocentrum* sp. (PC), *Ceratium trichoceros* (CETC), *Protoperidinium pentagonum* (PRPT). The second quadrant is defined by the environmental parameters chlorophyll *a*, silica, volatile solids and suspended solids and the dinoflagellates *Ceratium tripos* (CETP), *Protoperidinium conicum* (PRCN), *Dinophysis odiosa* (DIOD), *Corythodinium tesselatum* (COTE), *Ceratium horridum* (CEHO), *Protoperidinium oceanicum* (PROC), *Ceratium longipes* (CELG), *Ceratium candelabrum* (CECD), *Dinophysis caudata* (DICA), *Prorocentrum micans* (PCMI), *Ceratium fusus* (CEFS), *Ceratium furca* (CEFU), *Ceratium macroceros* (CEMC), *Protoperidinium* cf. *divergens* (PRDI). The quadrant number three is defined by the environmental parameters temperature of the water column and salinity and by dinoflagellates *Protoperidinium diabolum* (PRDB), *Dinophysis acuta* (DIAT), *Protoperidinium claudicans* (PRCL), *Dinophysis acuminata* (DIAC); the dinoflagellates

Polykrikos cf. *kofoidii* (POKO) are positioned in the intersection of the third to the for fourth quadrant. Finally, the forth quadrant is defined by the environmental parameters pH, dissolved oxygen, and phosphates and by the dinoflagellates *Scrippsiella lacrymosa* (SCLA), *Gonyaulax spinifera* (GONS), *Pyrocystis lunula* (PYLU), *Alexandrium catenella* (ALCA), *Protoperidinium meunieri* (PRME), *Gyrodinium spirale* (GYSP), *Ceratium kofoidii* (CEKO).

3.4 PRIMER analysis

SIMPER analysis showed a higher average dissimilarity in summer 2006 vs winter 2006 and 2007, and showed significant similarities between spring 2006 vs summer 2006 and summer 06 vs autumn 2007 (Table 4). ANOSIM analysis pointed out the similarities between spring, summer and autumn 2006 and autumn 2007, a pattern followed by the physico-chemical parameters, namely temperature (Figure 1A) and the succession of the phytoplankton assemblages (Figure 2).

3.5 Weighted average

The temperature ($\hat{u}_k$) and tolerances ($\hat{t}_k$) estimated for the *taxa* selected by the CCA are listed in Table 5. *Taxa* optima can be related with the environmental parameters in the CCA, according to their proximity to the extremity of the arrow on the CCA biplot (Figure 3). The majority of the species had their temperature optimum in the range 15.0 – 17.0 ºC. In general, tolerances were low, varying between 0.4 ºC and 3.3 ºC. The species situated on the right side of the plot (Figure 3) revealed a mean temperature optimum of 16.0 ºC. *Taxa* situated on the left side of the plot, associated with the temperature vector, had a mean optimum value of 15.9 ºC. *Ceratium longipes* had the lowest optimum (13.4 ºC), with *Ceratium macroceros* having the highest optimum value (18.2 ºC) (CEMC in the CCA biplot).

4. Discussion

Diatoms and dinoflagellates densities were in general low (the maximum density values in this study were 2.4x10^3 cells L^{-1} and 3.5x10^3 cells L^{-1}, respectively), when compared with the values registered by Trigueros et al. (2001): 1.6x10^6 cells L^{-1} in Urdaibai estuary (north Spain), Varela and Prego (2003): 1.5 x10^4 cells mL^{-1} in the harbor of the Ria of A Coruña and Moita et al. (2003): 5.0 x 10^3 cells mL^{-1} in Lisbon Bay for diatoms.

During the sampling period a clear seasonal succession pattern of distribution was registered: diatoms dominated in the cold months. Ansotegui et al. (2003), in the Urdaibai estuary, and Gameiro et al. (2004), in the Tagus estuary, registered, in late winter early spring, a dominance of the diatoms. This distributional pattern of diatoms dominance in cold months is also given by Casas et al., (1997), Trigueros et al. (2001), Moita et al. (2003) and Varela and Prego (2003).

This study showed, among diatoms, the dominance of *Paralia sulcata*, *Pseudo-nitzschia* cf. *pungens* and *Pseudo-nitzschia* cf. *seriata* and *Thalassionema nitzshioides*; this latest one is considered an indicator of less frequent upwelling conditions in the Portuguese coast (Abrantes, 1988). In the western Galician shelf, maximum values for this species were attained far from the coastline, in an area where upwelling influence decreases (Bao et al., 1997). In this study a bloom of *T. nitzschioides* was registered in later March, at the beginning of the upwelling period. The species *Cerataulina pelagica*, *Pseudo-nitzschia* cf. *seriata*, *Skeletonema costatum*, *Thalassiosira gravida*, *Ceratium fusus*, and *Scrippsiella trochoidea* are regarded by Hallegraeff et al. (2003) as potentially harmful algae.

The proliferation of the dinoflagellates, mostly *Ceratium furca*, *Ceratium fusus*, *Dinophysis acuminata*, *Dinophysis acuta*, *Protoperidinium* cf. *divergens*, *Protoperidinium pentagonum* and *Prorocentrum micans* was observed, along with weak upwelling conditions, in late summer. This distributional pattern is the same described by Resende et al. (2007), in northern Portugal, in the coastal surf zone.

The temporal variations of the environmental parameters obtained by the present study showed a similar pattern of distribution of those obtained on the central Portuguese coast by Moita et al. (2003) and in Ria de Aveiro by Resende et al. (2005). The CCA multivariate analysis showed a distributional pattern of the biologic assemblages mainly determined by temperature. Summer months were characterized by higher values of temperature, chlorophyll *a* and salinity. Therefore, on the left side of the plot, associated with these variables, were situated the species with high temperature *optima*. Dinoflagellates were all ordered in close association with salinity and temperature, which means that they were particularly abundant in warm periods. The temperature *optima* estimated are in well agreement with the species distribution in the CCA diagram. The difficulty in the interpretation and reliability of the estimated *optima* and tolerances is a common problem in ecology. In some cases, a species is characterized by an individual behavior in one system, while in another aquatic system it behaves differently, thus leading to different *optima* and tolerances (Resende et al., 2005, 2007). According to Nygaard (1996) these differences are probably a consequence of the existence, within several species, of two or more strains with different tolerances and environmental response. This has important consequences on the reliability of the indicator value of species in different environments. The species *Actinoptychus senarius*, *Ceratium horridum*, *Ceratium fusus*, *Gyrodinium spirale*, *Thalassionema nitzschioides*, *Ceratium kofoidii*, *Dinophysis caudata*, *Ceratium furca*, *Dinophysis acuta*, *Paralia sulcata*, *Dinophysis acuminata*, *Phalacroma rotundatum*, *Prorocentrum micans*, *Protoperidinium* cf. *divergens*, *Protoperidinium* cf. *pentagonum*, *Protoperidinium diabolum*, *Eucampia zodiacus*, *Proboscia alata*, *Striatella delicatula* and *Biddulphia alternans* showed estimated *optima* intervals of distribution comparable with the published by Resende et al. (2005, 2007) in the Ria de Aveiro and northern Portugal coastal zone.

Protoperidinium meunieri appeared in our collections. This species, cited in the golf the Saint-Laurent (Bérard-Therriault et al. 1999), has is first appearance in the Portuguese coastal zone. *Alexandrium catenella* (Whedon and Kofoid) Balech cold water (Tomas, 1996), but not restricted (Varela and Prego, 2003), toxic species, appeared also in our collections pointing out water temperature and climatic changes.

5. Conclusions

The year 2006, due to the increase of water temperature has been, for itself, an atypical year, allowing us to foresee the occurrence of different phytoplanktonic assemblages from the ones previously recorded at this latitude. Further continuous investigation carried out for longer periods of time will allow us to verify if these variations are associated with climate change, as well as to verify effects at the level of the remaining trophic chain.

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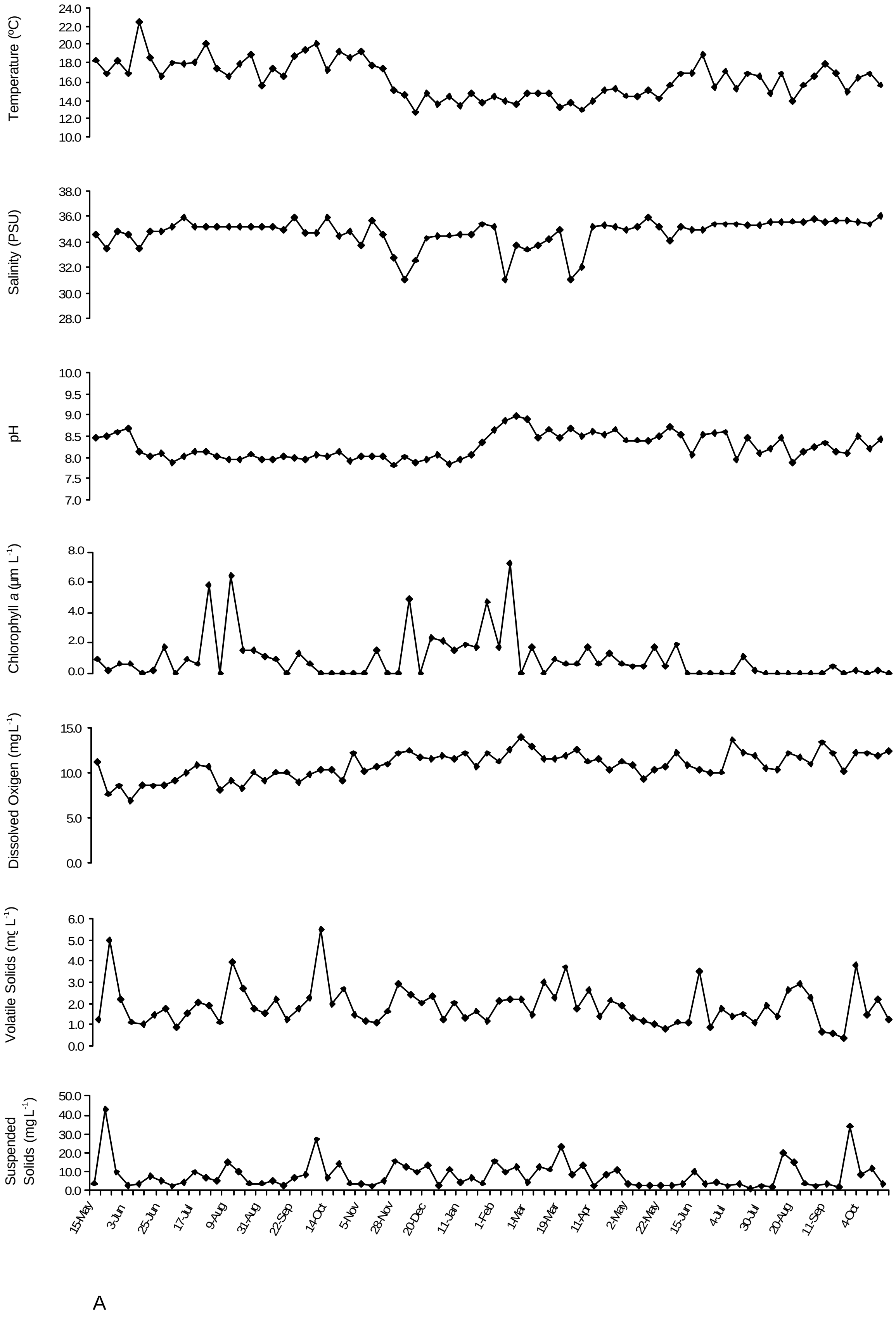
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34.0
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30.0
28.0
pH
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9.0
8.5
8.0
7.5
7.0
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4.0
2.0
0.0
Dissolved Oxigen (mg L-1)
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10.0
5.0
0.0
Volatile Solids (mg L-1)
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5.0
4.0
3.0
2.0
1.0
0.0
Suspended Solids (mg L-1)
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40.0
30.0
20.0
10.0
0.0
15-May
3-Jun
25-Jun
17-Jul
9-Aug
31-Aug
22-Sep
14-Oct
5-Nov
28-Nov
20-Dec
11-Jan
1-Feb
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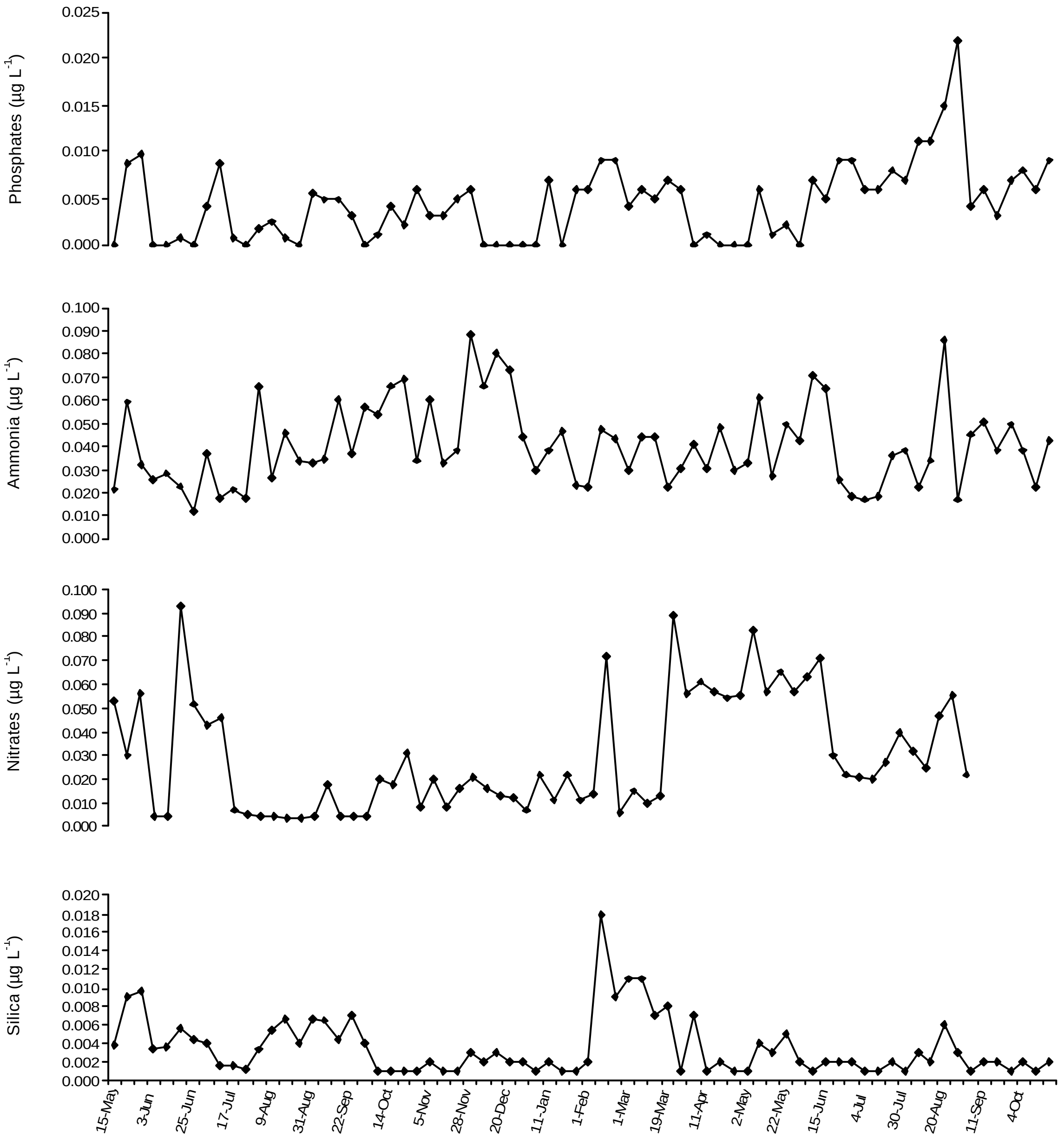
4-Oct
A



B

Figure 1 – Temporal variation of the environmental variables: (A) water temperature, pH, salinity, dissolved oxygen, chlorophyll *a*, suspended organic matter (total and volatile) and (B) ammonia, phosphate, nitrates and silica (☐Spring ☐Summer ☐Autumn ☐Winter).

Table 1 - Ranges of environmental parameters during the study period, in the sampling place.

	2006			**2007**		
	Min.	Max.	Average	Min.	Max.	Average
Temperature (Cº)	12.7	22.4	17.5	13.0	18.9	15.3
Salinity (PSU)	31.0	35.9	34.6	31.0	36.1	34.8
pH	7.83	8.68	8.08	7.86	8.96	8.40
O_2 (mg L^{-1})	6.90	12.50	9.94	9.28	13.99	11.55
O_2 (%)	71.60	125.80	103.25	89.90	140.90	114.76
Chl *a* (µg L^{-1})	ND*	6.4	1.1	ND*	7.3	0.8
SS (mg L^{-1})	2.18	42.95	8.45	0.78	34.03	7.50
VS (mg L^{-1})	0.90	5.50	2.05	0.40	3.80	1.79
PO_4^{3-} (µg L^{-1})	ND*	0.010	0.003	ND*	3.80	0.006
NH_4^+ (µg L^{-1})	0.012	0.088	0.043	0.017	0.086	0.038
$NO3^-$ (µg L^{-1})	0.003	0.093	0.020	0.006	0.089	0.040
SiO_2 (µg L^{-1})	0.001	0.010	0.004	0.001	0.018	0.003

*ND – Not detected.

Table 2 - List of occurrence of *taxa* during the stations of the year (Spring, Summer, Autumn and Winter) inherent to the period of sample.

	2006				**2007**		
Taxon	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
HETEROKONTOPHYTA							
BACILLARIOPHYCEAE							
Actinoptychus senarius (Ehrenberg) Ehrenberg	x	x	x	x	x	x	
Bacillaria paxillifera (O.F. Müller) Handey					x		
Biddulphia alternans (J. W. Bailey) Van Heurck	x		x	x	x	x	
Cylindrotheca closterium (Ehrenberg) Lewin & Reimann		x	x		x	x	x
Eucampia zodiacus Ehrenberg						x	x
Paralia sulcata (Ehrenberg) Cleve	x	x	x	x	x	x	x
Proboscia alata (Brightwell) Sundström		x	x		x	x	x
Striatella delicatula Kützing		x	x		x	x	x
Thalassionema nitzschioides (Grunow) Grunow ex Hustedt			x		x	x	
DINOPHYTA							
DINOPHYCEAE							
Alexandrium catenella (Whedon & Kofoid) Balech							x
Ceratium candelabrum (Ehrenberg) Stien		x	x				x
Ceratium furca (Ehrenberg) Claparède & Lachmann var. ***eugrammum***	x	x	x	x	x	x	x
Ceratium fusus (Ehrenberg) Dujardin var. ***fusus***	x	x	x	x	x	x	x
Ceratium horridum (Cleve) Gran	x	x	x				
Ceratium kofoidii Jørgensen		x	x		x	x	x
Ceratium longipes (Bailey) Gran	x	x					
Ceratium macroceros (Ehrenberg) Vanhoffen	x						
Ceratium trichoceros (Ehrenberg) Kofoid	x						
Ceratium tripos (O. F. Müller) Nitzsch		x	x				
Corythodinium tesselatum (Stein) Loeblich Jr.&Loeblich		x	x				
Dinophysis acuminata Claparède & Lachmann	x	x	x		x	x	x
Dinophysis acuta Ehrenberg	x	x	x		x	x	x
Dinophysis caudata Seville-Kent var. ***caudata***	x	x	x	x		x	x
Dinophysis odiosa (Pavillard) Tai & Skogsberg		x	x				
Gonyaulax cf. ***polygrama*** Stein			x		x	x	
Gonyaulax spinifera (Claparède & Lachmann) Diesing			x		x	x	x
Gyrodinium spirale (Berg) Kofoid & Swezy					x	x	x
Phalacroma rotundatum (Claparède & Lachmann) Kofoid & Michener		x	x	x	x	x	x
Polykrikos cf. ***kofoidii*** Chatton					x	x	x
Prorocentrum micans Ehrenberg	x	x	x	x	x	x	x
Protoperidinium cf. ***crassipes*** (Kofoid) Balech	x						
Protoperidinium cf. ***divergens*** (Ehrenberg) Balech	x	x	x	x	x	x	x
Protoperidinium pentagonum (Gran) Balech	x	x	x	x	x	x	x
Protoperidinium claudicans (Paulsen) Balech		x	x				
Protoperidinium conicum (Gran) Balech		x	x				
Protoperidinium diabolum (Cleve) Balech	x	x	x		x	x	x
Protoperidinium meunieri (Pavillard) Eebrächter							x
Protoperidinium oceanicum (Van Höffen) Balech		x					
Pyrocystis lunula (Schütt) Schütt			x		x	x	
Scrippsiella lacrymosa Lewis			x	x	x	x	x

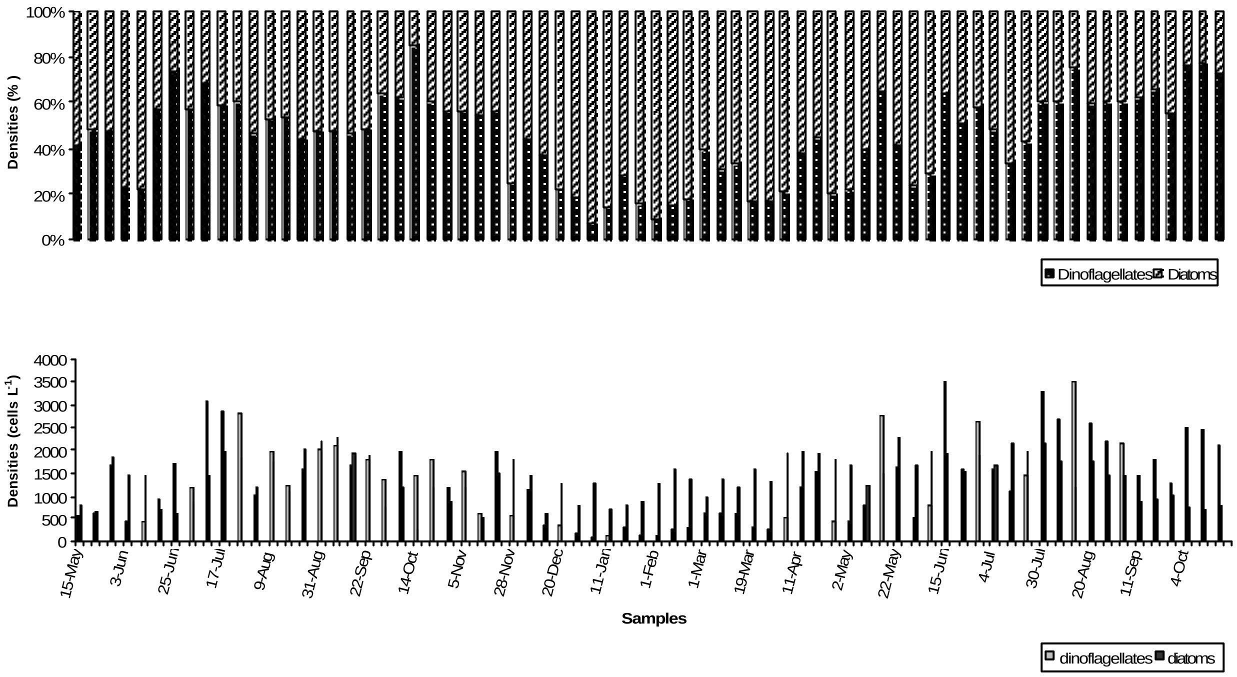
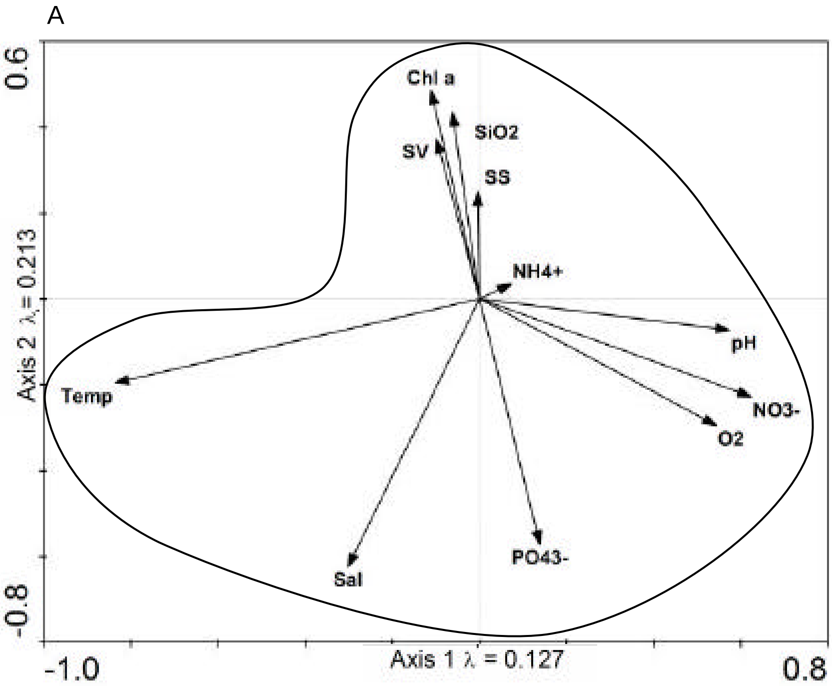


Figure 2 – Variation of dinoflagellates and diatoms during the sampling period of: (A) express densities in percentage (%) and (B) densities in abundance (cells L^{-1}).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-0.8
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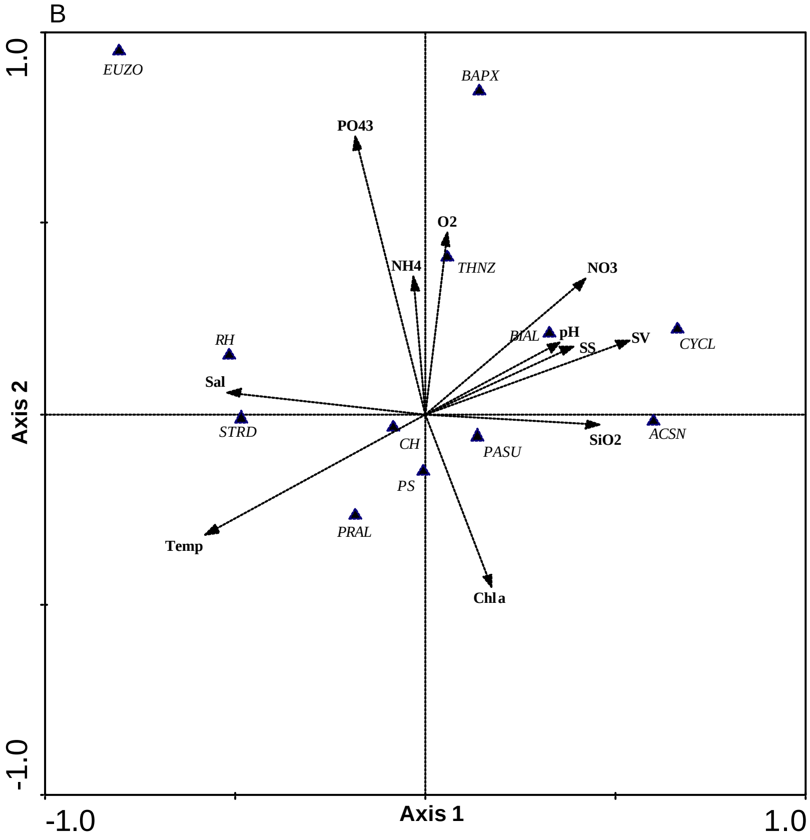
-1.0
Axis 1 λ = 0.127
0.8
Chl a
SiO2
SV
SS
NH4+
pH
NO3-
O2
Temp
Sal
PO43-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-1.0
Axis 2
Axis 1
-1.0
1.0
EUZO
BAPX
PO43
O2
NH4
THNZ
NO3
RH
BIAL
pH
SS
SV
CYCL
Sal
STRD
CH
PASU
SiO2
ACSN
PS
PRAL
Temp
Chl a

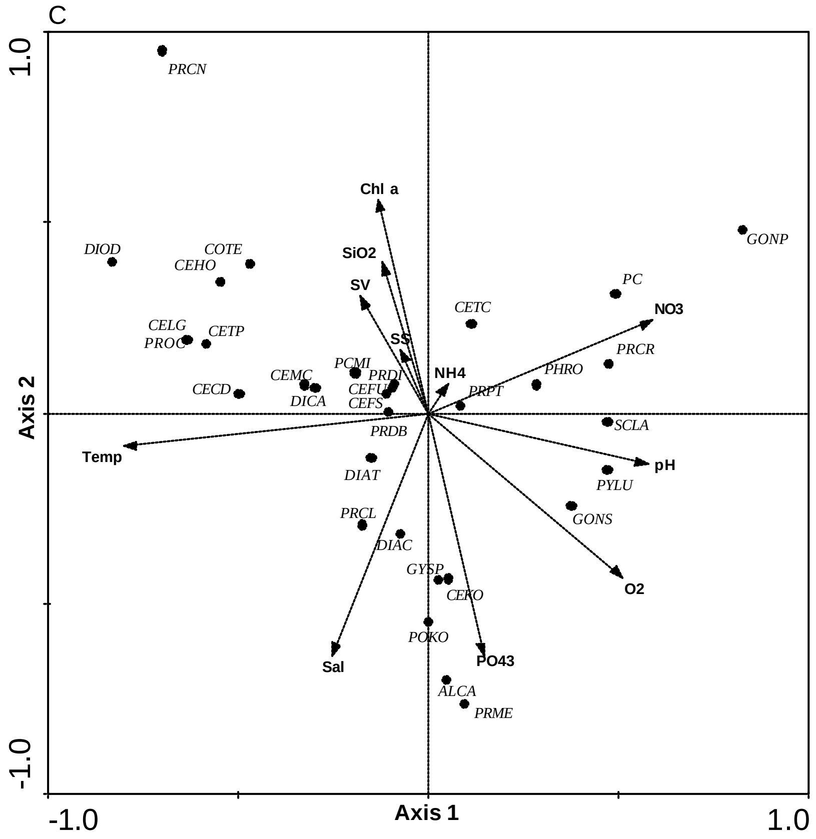

Figure 3 – Spatial ordination resulting from the CCA of: (A) sampling units according to seasons of the year and selected environmental variables: Temp, water temperature; Sal, salinity; pH, pH; O2, quantity of dissolved oxygen; chl *a*, chlorophyll *a*; SS, suspended solid; SV, volatile solids; NO3, nitrate; NH4, ammonia; PO4, phosphate; SIO2, silica. (B) Diatoms and environmental variables for the studied period. (C) Dinoflagellates and environmental variables for the studied period.

Table 3 -Summary of CCA of phytoplankton densities and explanatory variables for the studied period. The statistics are only presented for the first two axes.

	Axis 1		Axis 2
Eigenvalues	0.213		0.127
Species-environment correlations	0.877		0.770
Cumulative percentage variance			
of species data	9.3		14.9
of species-environment relation	34.3		54.9
Sum of all unconstrained eigenvalues		2.285	
Sum of all canonical eigenvalues		0.619	

Table 4 - Results the statistics tests of simper and anosim (Jaccard coefficient).

Groups Statistic	**Average dissimilarity**	**R**
spring 2006 / summer 2006	44.97	0.397
spring 2006 / autumn 2006	51.31	0.008
spring 2006 / winter 2006/07	60.91	0.722
spring 2006 / spring 2007	70.03	0.852
spring 2006 / summer 2007	57.23	0.855
spring 2006 / autumn 2007	51.72	0.772
summer 2006 / autumn 2006	52.64	0.242
summer 2006 / winter 2006/07	71.66	0.887
summer 2006 / spring 2007	68.42	0.830
summer 2006 / summer 2007	52.04	0.721
summer 2006 / autumn 2007	48.60	0.585
autumn 2006 / winter 2006/07	61.91	0.416
autumn 2006 / spring 2007	69.67	0.687
autumn 2006 / summer 2007	61.39	0.587
autumn 2006 / autumn 2007	58.35	0.214
winter 2006/07 / spring 2007	64.05	0.664
winter 2006/07 / summer 2007	69.53	0.882
winter 2006/07 / autumn 2007	70.13	0.827
spring 2007 / summer 2007	54.19	0.480
spring 2007 / autumn 2007	69.23	0.736
summer 2007 / autumn 2007	50.27	0.593

Group	**Average similarity**
spring 2006	63.79
summer 2006	63.04
autumn 2006	46.96
winter 2006/07	59.29
spring 2007	53.90
summer 2007	62.16
autumn 2007	59.27

Table 5 - List of *taxa* (With codes) represented in the CGA diagram and respective optima and tolerances for temperature. *Taxa* are ordered by increasing order of temperature optima.

		Temperature	
Code	Taxon	$\hat{u}_k$	t_k
CELG	***Ceratium longipes*** (Bailey) Gran	13.4	-
PROC	***Protoperidinium oceanicum*** (Van Höffen) Balech	13.4	-
DIOD	***Dinophysis odiosa*** (Pavillard) Tai & Skogsberg	13.9	1.2
PYLU	***Pyrocystis lunula*** (Schütt) Schütt	14.8	1.7
POKO	***Polykrikos*** cf. ***kofoidii*** Chatton	15.1	1.2
ACSN	***Actinoptychus senarius*** (Ehrenberg) Ehrenberg	15.2	1.8
CEHO	***Ceratium horridum*** (Cleve) Gran	15.3	2.4
SCLA	***Scrippsiella lacrymosa*** Lewis	15.3	2.0
CEFS	***Ceratium fusus***(Ehrenberg) Dujardin var. ***fusus***	15.4	1.7
GYSP	***Gyrodinium spirale***(Berg) Kofoid & Swezy	15.4	1.4
CYCL	***Cylindrotheca closterium*** (Ehrenberg) Lewin & Reimann	15.5	2.1
THNZ	***Thalassionema nitzschioides*** (Grunow) Grunow ex Hustedt	15.5	1.2
CECD	***Ceratium candelabrum*** (Ehrenberg) Stien	15.5	2.0
CEKO	***Ceratium kofoidii*** Jørgensen	15.5	1.3
DICA	***Dinophysis caudata*** Seville-Kent var. ***caudata***	15.5	1.7
GONS	***Gonyaulax spinifera***(Claparède & Lachmann) Diesing	15.6	1.6
CEFU	***Ceratium furca*** (Ehrenberg) Claparède & Lachmann var. ***eugrammum***	15.7	1.6
DIAT	***Dinophysis acuta*** Ehrenberg	15.7	1.7
PASU	***Paralia sulcata*** (Ehrenberg) Cleve	15.8	2.1
DIAC	***Dinophysis acuminata*** Claparède & Lachmann	15.8	1.7
COTE	***Corythodinium tesselatum*** (Stein) Loeblich Jr.&Loeblich	15.9	1.8
PHRO	***Phalacroma rotundatum*** (Claparède & Lachmann) Kofoid & Michener	15.9	2.1
PCMI	***Prorocentrum micans*** Ehrenberg	15.9	2.0
PRCR	***Protoperidinium*** cf. ***crassipes*** (Kofoid) Balech	15.9	1.7
PRDI	***Protoperidinium*** cf. ***divergens***(Ehrenberg) Balech	15.9	2.0
CH	***Chaetoceros*** sp.	16.1	1.8
PRPT	***Protoperidinium*** cf. ***pentagonum*** (Gran) Balech	16.1	2.1
PRDB	***Protoperidinium diabolum*** (Cleve) Balech	16.1	2.2
PS	***Pseudo-nitzschia*** sp.	16.2	1.8
EUZO	***Eucampia zodiacus*** Ehrenberg	16.3	0.4
ALCA	***Alexandrium catenella*** (Whedon & Kofoid) Balech	16.3	0.6
CETP	***Ceratium tripos***(O. F. Müller) Nitzsch	16.3	2.3
GONP	***Gonyaulax*** cf. ***polygrama*** Stein	16.3	2.2
BAPX	***Bacillaria paxillifera*** (O.F. Müller) Handey	16.6	0.5
PRCL	***Protoperidinium claudicans*** (Paulsen) Balech	16.6	-
CETC	***Ceratium trichoceros*** Ehrenberg) Kofoid	16.8	-
PRAL	***Proboscia alata*** (Brightwell) Sundström	16.9	1.7
STRD	***Striatella delicatula*** Kützing	17.0	1.6
PC	***Prorocentrum*** sp.	17.0	1.3
PRME	***Protoperidinium meunieri*** (Pavillard) Eebrächter	17.0	-
BIAL	***Biddulphia alternans*** (J. W. Bailey) Van Heurck	17.1	3.3
RH	***Rhizosolenia*** sp.	17.4	1.9
PRCN	***Protoperidinium conicum*** (Gran) Balech	17.8	-
CEMC	***Ceratium macroceros*** (Ehrenberg) Vanhoffen	18.2	-

Capítulo III

Discussão Geral

Discussão Geral

O Noroeste da costa ibérica exibe uma grande variação das comunidades fitoplanctónicas na região de afloramento costeiro (Estrada, 1984; Varela et al., 1991; Sousa & Bricaud, 1992; Tenore et al., 1995; Bao et al., 1997; Casas et al., 1997; Moita et al., 2003; Varela & Prego, 2003), com uma predominância de diatomáceas durante o fluxo (Margalef et al., 1979; Figueiras & Ríos, 1993) e uma dominância de dinoflagelados em águas estratificadas e pobres em nutrientes (Moita et al., 2003). Estes padrões caracterizam as águas costeiras durante os eventos de afloramento (Estrada, 1984; Varela et al., 1991).

Durante o período de amostragem observou-se um padrão de sucessão cíclico de distribuição das espécies, em que as diatomáceas dominaram nos meses frios. Tal como verificado por Ansotegui et al. (2003), no estuaries do Urdaibai, e Gameiro et al. (2004), no estuário do Tejo, no final do Inverno e início da Primavera. Este padrão de distribuição com domínio de diatomáceas nos meses frios também é referido por Casas et al., (1997), Trigueros & Orive (2001), Moita et al. (2003) e Varela & Prego (2003).

Este estudo, demonstrou uma dominância das espécies de diatomáceas *Paralia sulcata*, *Pseudo-nitzschia* cf. *pungens* and *Pseudo-nitzschia* cf. *seriata* e *Thalassionema nitzshioides*. Sendo esta última considerada um indicador de menor frequência de afloramento no litoral português (Abrantes, 1988) assim como uma maior abundância (Bao et al., 1997). Neste estudo, foi registado uma florescência de *Thalassionema nitzschioides* apenas no final de Março, aquando o início do período de afloramento. As espécies *Cerataulina pelagica*, *Pseudo-nitzschia* cf. *seriata*, *Skeletonema costatum*, *Thalassiosira gravida*, *Ceratium fusus* e *Scrippsiella trochoidea* foram registadas por Hallegraeff et al. (2003) como algas potencialmente prejudiciais.

A dominância de dinoflagelados reflectiu-se pelas elevadas abundâncias observadas das espécies *Ceratium furca*, *Ceratium fusus*, *Dinophysis acuminata*, *Dinophysis acuta*, *Protoperidinium* cf. *divergens*, *Protoperidinium pentagonum* e *Prorocentrum micans*, associadas ás fracas condições de afloramento, no final do Verão. O mesmo padrão de distribuição foi descrito por Resende et al. (2007), na zona de “surf”, a norte de Portugal.

As variações temporais dos parâmetros ambientais, e agora apresentados, demonstraram um padrão de distribuição semelhante a outros estudos referentes à costa litoral portuguesa, aferidos por Moita et al. (2003) e na Ria de Aveiro por Resende et al. (2007). A análise multivariavel de CCA demonstrou um padrão de distribuição das comunidades fitoplanctónicas determinado pela temperatura e por consequências espécies com óptimos de temperatura elevada, nomeadamente dinoflagelados, associados ou não à ocorrência de nutrientes.

A espécie *Protoperidinium meunieri* estudada no golfo de Saint-Laurent (Bérard-Therriault et al. 1999) tem a primeira ocorrência no litoral português. Assim como a espécie *Alexandrium* *catenella* (Balech, 1995) que indicam uma alteração da temperatura de água, sugerindo mudanças climáticas pertinentes ao nível do ecossistema.

Os impactos associados ás alterações climáticas são cada vez mais relevantes, existindo uma forte preocupação em estudar as consequências advindas destas alterações (Hays et al., 2005). Adivinham-se importantes alterações nas correntes oceânicas e na produtividade do fitoplâncton (Ribbe, 2004) existindo uma enorme preocupação em conhecer as suas consequências ao nível das populações fitoplanctónicas e adaptação ao ecossistema (Hays et al., 2005). Inúmeros factores ambientais afectam a sua estrutura e função, alterando por exemplo, a composição da fauna e/ou do ciclo de nutriente (Kennedy et al., 2002). A ocorrência de temperaturas mais elevadas ao nível das águas superficiais, durante períodos mais longos, as alterações do hidrodinamismo de águas costeiras, o afloramento de nutrientes e de água mais fria proveniente de zonas profundas e de norte (afloramento) facultou a ocorrência de espécies fitoplanctónicas que possuem preferências ecológicas (temperatura da água, salinidade, nutrientes) diferentes às que habitualmente se verificam na costa portuguesa, em particular a norte do canhão da Nazaré. Estudos mais recentes mostraram que o regime de afloramento da costa oeste tem vindo diminuir desde de 1940 (Lemos & Pires 2004). Estes dezoito meses de amostragem permitiram, em conjunto com o descrito por outros autores em trabalhos anteriores e considerando projecções associadas às alterações climáticas, antever, sempre que se verifiquem estas condições e caso os padrões de algumas variáveis oceanográficas se venham a alterar, a ocorrência de comunidades fitoplanctónicas dominadas por espécies de dinoflagelados e de algumas diatomáceas próprias de períodos mais quentes. Algumas destas espécies, conhecidas por também ocorrerem em zonas sub-tropicais e tropicais, poderão não só produzir metabolitos secundários (e.g. toxinas) passíveis de condicionar a qualidade e quantidade de alimento disponível para herbívoros e organismos filtradores. Estas alterações também se poderão traduzir numa alteração ao nível da diversidade por introdução de espécies provenientes de locais mais quentes.

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