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Environmental drivers of phytoplankton distribution and composition in Tagus Estuary, Portugal

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Abstract

A 7-year (March 1999−November 2005) monitoring program was developed in the Tagus estuary to study phytoplankton dynamics and several key controlling factors, namely nutrient content, light availability, atmospheric and hydrodynamic conditions (temperature, wind, rainfall, river flow, and salinity). Water was collected at four sampling sites on a monthly basis. Phytoplankton biomass, analyzed as Chl *a*, was moderate to low, when compared to other mesotidal estuaries: interannual average Chl *a* values ranged from 1.4 in winter to 8.0 μg L^{-1} in summer. A consistent seasonal pattern was observed, with a unimodal peak extending from late spring to summer. The phytoplankton community, as determined by biomarker pigment concentration using HPLC and CHEMTAX, was dominated by diatoms (57%), and included cryptophytes (23%), dinoflagellates (6.8%), chlorophytes (5.4%), euglenophytes (4.9%), and prasinophytes (2.6%). The method was capable of detecting phytoplankton taxa generally underestimated or overlooked when using standard microscopic techniques. Diatoms were the main bloom-formers in the summer Chl *a* maximum. A stepwise regression analysis showed that air temperature, river flow and irradiance explained 47% of the observed Chl *a* variance, illustrating the importance of climatic factors as driving forces for seasonal and interannual variability of phytoplankton.

Keywords: phytoplankton; environmental drivers; chlorophyll *a*; chemotaxonomy; monitoring; Tagus estuary

1. Introduction

The relevance of long-term studies in ecosystem management programs is now widely recognized. In order to measure anthropogenic influence on a certain ecosystem, a good knowledge of the system natural variability is a necessary requisite. Estuaries are, by definition, transitional states, suffering more acutely the outcome of climate variability. However, variability and unsteadiness are intrinsic properties of estuarine ecosystems; their biological communities are well adapted to several temporal variability scales and to spatial gradients of key factors, such as salinity or temperature.

Phytoplankton, as the basis of the trophic chain, constitutes the biological community in which scientific attention is focused when a management plan is needed or an assessment of the ecosystem health is required (e.g. Monbet, 1992; Cloern, 1999; Sin et al., 1999). Estuarine phytoplankton is submitted to superimposed temporal scales derived from tidal regime and seasonal freshwater runoff, which greatly affect water column stability, residence time, light and nutrient availability. Vertical mixing of the water column is also largely influenced by less regular events such as wind-driven water mixing. The influence of these processes on phytoplankton biomass and productivity has been a recurrent subject in the recent literature, and is still the subject of debate.

Knowledge of the taxonomical composition of phytoplankton is essential to study the spatial and temporal community dynamics and to characterize it into functional groups. Furthermore, an index of ecosystem eutrophication is the shift

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from a diatom dominating to a phytoflagellate phytoplankton community (Cloern, 1996). The identification and distribution of phytoplankton classes is increasingly done by the detection of photosynthetic pigments in the water column by high-performance liquid chromatography (HPLC) analytical techniques. HPLC pigment analysis does not have the taxonomic precision of microscopy, but is suitable for the analysis of the hundreds of samples required in ecological studies (Wright et al., 1996). Quantitative estimates of various phytoplankton classes from biomarker pigment concentrations has been attempted using several statistical approaches (Gieskes et al., 1988; Everitt et al., 1990; Letelier et al., 1993), but these generally suffer from a number of difficulties that limit their application (Mackey et al., 1996). CHEmical TAXonomy software (CHEMTAX) has been described by Mackey et al. (1996), using pigment/chlorophyll *a* ratios to characterize algal classes. There have been a vast number of recent studies on phytoplankton community structure using pigment analysis and CHEMTAX in ocean waters (e.g. Wright et al., 1996; Rodriguez et al., 2002) but more rarely in estuaries (Pinckney et al., 1998; Ansotegui et al., 2001). The distribution and composition of phytoplankton in the Tagus estuary using HPLC pigment analysis and CHEMTAX from May 2001 till November 2005 is reported in the present study.

The relevance of interannual studies is enhanced with the recent public concern on global climate change. Rainfall is a proxy of interannual climate variability, whereas river flow reflects precipitation integrated both spatially (over the catchment) and temporally. The Tagus river basin is the largest in the Iberian Peninsula, where the rainfall regime is characterized by high temporal variability (Trigo et al., 2004). The variability observed in a 75-year period in the last century was correlated with North Atlantic oscillation (NAO). The effect of climatic factors on the distribution of phytoplankton biomass can only be assessed over pluri-annual monitoring programs.

A 7-year (March 1999–November 2005) monitoring program was developed with the intention of establishing a database on hydrography, nutrient concentrations, suspended particulate matter, vertical light attenuation, chlorophyll *a* (Chl *a*) and photosynthetic pigments, so that future management plans could take into consideration seasonal fluctuation patterns and interannual variability. The objectives of the present study were to examine seasonal, interannual and spatial variations on phytoplankton biomass and class composition in the Tagus estuary, and to determine the influence of environmental parameters on phytoplankton communities, with a particular emphasis on climatic factors.

2. Methodology

2.1. Study area

The present study was carried out in the upper part of the Tagus estuary (Fig. 1). This estuary is one of the largest estuaries on the west coast of Europe, with a broad shallow bay covering an area of about 320 km^2. It is located in the most populated area of Portugal. The Tagus river is the main source of freshwater to the estuary. The area affected by tides reaches 80 km landward of Lisbon. It is a mesotidal estuary with semi-diurnal tides. Table 1 summarizes some other relevant characteristics of the Tagus estuary. The sampling was carried out in the upper estuary, near the downstream limit. Four sampling sites were considered, hereafter designated sites 1, 2, 3 and 4. Sampling sites 1, 3 and 4 are located along a latitude gradient, whereas site 2 is situated in the Northern Channel where several industrial plants are established. The exact location of the study sites is shown in Fig. 1. Sites differed in relation to average water depth during high tide: site 1, 3 m; site 2, 2.5 m; site 3, 3.5 m; site 4, 5.5 m.

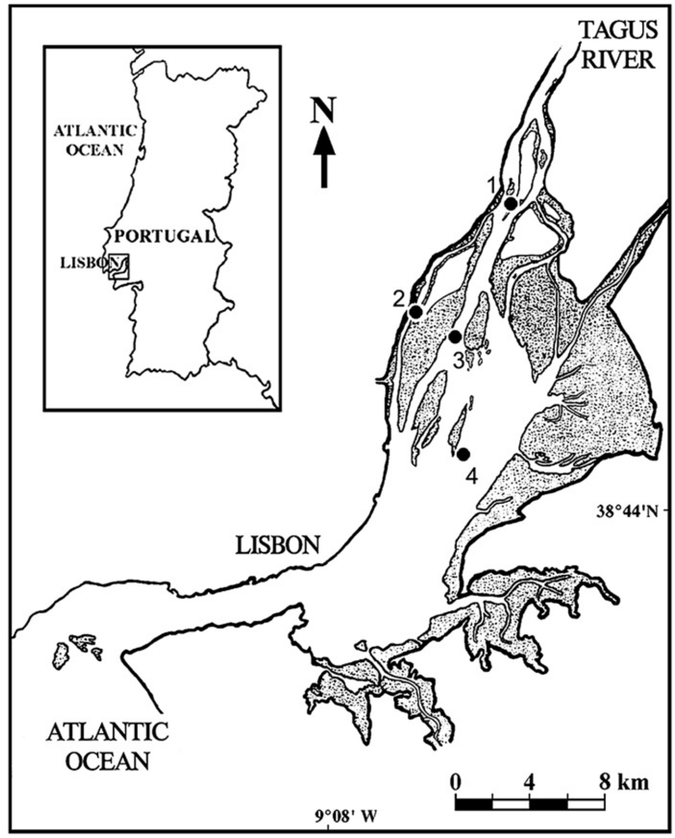

Fig. 1. Map of Portugal with enlarged portion of the Tagus estuary. Shaded areas represent intertidal zones and circles indicate the location of the sampling sites.

2.2. Sampling and field procedures

Water was collected at the surface of the four sites on a monthly basis from March 1999 to November 2005, making a total of 75 dates. Sampling was always conducted during high tide of neap tides to attenuate the influence of the spring–neap tidal cycle. Water temperature, salinity and pH were measured *in situ* with a thermometer, an ATAGO S/Mill-E refractometer and a HI9813 pH meter (Hanna Instruments), respectively. Incident irradiation (I_o) and light intensity at depth z (I_z) were determined with a LIcor-192SA