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Influence of upwelling and river runoff interaction on phytoplankton assemblages in a Middle Galician Ria and Comparison with northern and southern rias (NW Iberian Peninsula)

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Abstract

The first oceanographic research (hydrography, nutrient salts, chlorophyll, primary production and phytoplankton assemblages) in a Middle Galician Ria was carried out in Corme-Laxe during 2001, just a year before the Prestige oil spill, being the only reference to evaluate eventual changes in the phytoplankton community. Due to the small size of this ria (6.5 km^2), oceanographic processes were driven by the continental water supplied by Anllons River during the wet season (20–30 m^3 s^{-1} in winter), and the strong oceanic influence from the nearby shelf during the dry season. The annual cycle showed a spring bloom with high levels of chlorophyll (up to 14 μg Chl-*a* L^{-1}) and primary production (3 g C m^{-2} d^{-1}) and a summer upwelling bloom (up to 8 μg Chl-*a* L^{-1} and 10 g C m^{-2} d^{-1}) where the proximity of the Galician upwelling core (<13.5 °C at sea surface) favors the input of upwelled seawater (up to 9 μM of nitrate and silicate) to the bottom ria layer, even during summer stratification events (primary production around 2 g C m^{-2} d^{-1}). Thus, phytoplankton assemblages form a "continuum" from spring to autumn with a predominance of diatoms and overlapping species between consecutive periods; only in autumn dinoflagellates and flagellates characterized the phytoplankton community. In the Middle Rias as Corme-Laxe, the nutrient values, Chl-*a*, primary production and phytoplankton abundance for productive periods were higher than those reported for the Northern (Ria of A Coruña) and Southern Rias (Ria of Arousa) for year 2001; this suggests the importance of the hydrographic events occurring in the zone of maximum upwelling intensity of the Western Iberian Shelf, where a lack of annual cycles studies exists.

Keywords: upwelling; river; phytoplankton; Corme-Laxe; Galician Ria; NW Iberian Peninsula

1. Introduction

The Galician Rias have traditionally been classified as Rias Altas and Rias Bajas, according to their location to the north or south of Cape Finisterre, respectively. However, a third group, located in the middle of the two, i.e. between Cape Finisterre and Cape San Adrian, may be considered. The area surrounding these rias exhibits a peculiar geological development (Torre-Enciso, 1958). They are open bays where oceanic influence may play an important role given their particular orientation and morphology. The main difference between the Middle Rias and the two other groups of Galician Rias is related to hydrography (Prego and Bao,

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1997). They are located very near the area of maximum upwelling intensity of the Galician Coast- between Cape Finisterre and Cape Villano (Fraga, 1981). For this reason, the oceanography of the Middle Rias is of interest from a scientific point of view, since they may be able to reflect the hydrographic and associated biological processes that occur on the surrounding continental shelf in the vicinity of an upwelling core resulting from inputs of different nutrient salts (Prego et al., 1999).

Another reason to study a Galician Middle Ria, such as Corme-Laxe, is to increase our knowledge on a subject lacking in information. Most of the oceanographic studies have been carried out in the north, in the areas of the Rias Altas (Mariño et al., 1985; Bode and Varela, 1998; Varela et al., 2001; Varela and Prego, 2003), and even more so in the south, in the Rias Bajas (Margalef et al., 1955; Vives and López-Benito, 1958; Campos and González, 1976; Tenore et al., 1982; Campos and Mariño, 1982, 1984; Hanson et al., 1986; Figueiras and Niell, 1987; Figueiras and Pazos, 1991; Prego and Fraga, 1992; Gómez-Gesteira et al., 1999; Prego et al., 1999, 2001; Prego, 2002). To date, only partial and preliminary studies have been undertaken in the Middle Rias: macroalgae distribution and ecology (Fischer-Piette and Seoane-Camba, 1963) in the Ria of Camariñas-Muxia and thermohaline and the measurement of currents in the Ria of Corme-Laxe (Castillejo et al., 1976, 1977a,b). This ria is one of the least well-known zones of the Galician coast. Its relative geographic isolation and small size has not made it an attractive subject for research. Its location does, however, have some advantages. First of all, it is situated north of Cape Finisterre, very close to the zone of maximum influence of Galician seasonal upwelling. Therefore, the biogeochemical and physical processes associated with this coastal upwelling core might be able to offer useful information according to the recommendations put forth by Brink et al. (1995). On the other hand, it is also heavily influenced by the Anllons River and its fluvial basin, which pours water into the ria without any kind of reservoir or contention structure. Thus, it would also be of interest to study the coupling of the upwelling phenomenon with continental contributions in a small-sized, open ria such as Corme-Laxe, as it is an unusual case in coastal upwelling areas (Richards, 1981) where the fresh water inputs are null or very low (Hill et al., 1998). Moreover, as the area is sparsely populated and has very little industry, the result is a negligible anthropogenic impact and a quasi-pristine ria in terms of heavy metal contamination (Labandeira et al., 2003).

The objective of this paper was to study the annual hydrographic cycle and the phytoplankton community changes that take place in an open ria in the vicinity of the upwelling core. The severe weather conditions of the Finisterre shelf area are a hindrance to routine sampling. However, owing to its proximity to the area, the events that occur in the ria would be representative of the oceanographic processes that take place in the photic zone of the shelf area off the Cape. This information would also provide a reference to be able to acquire or complete our knowledge on the variation in the spatial distribution of upwelling on the Galician coast and how it results in differences—if any—in phytoplankton biomass, primary production and phytoplankton species composition. In this sense, an attempt was made to compare this Middle Ria of Corme-Laxe and two other rias (A Coruña, a Ria Alta and Arosa, a Ria Baja) in terms of chlorophyll, primary production and phytoplankton species composition.

Another important aspect of this study is that sampling was carried out during 2001, a year before the accident of the Prestige oil tanker, whose heavy fuel was unleashed, affecting the entire NW Galician coastal zone. This information, in addition to similar studies conducted in the Rias Bajas and the Rias Altas (as well as the adjacent continental shelf), in the framework of ongoing projects, will be very useful as a benchmark to evaluate the environmental impact of the fuel.

This is the first complete study of an annual cycle focusing on the hydrography, nutrients and phytoplankton species composition carried out in a Middle Ria of Galicia and in the Cape Finisterre and Villano upwelling core area.

2. Method

2.1. Study area

The Ria of Corme-Laxe (Fig. 1) is located in the NW Iberian Peninsula, on the coast between A Coruña and Cape Finisterre. The ria, with a surface area of 6.5 km^2, a mean depth of 14 m and a water volume of 0.38 km^3 is, along with the Rias of Camariñas-Muxia and Lires, one of the three Middle Galician Rias. The ria is oriented in a NW–SE direction and converges with the Anllons River in its innermost part. The river, 60 km length with an average flow of 11.4 m^{-3} s^{-1}, provides the main freshwater input. On the basis of its topography, the ria may be considered as an open bay with a strong oceanic influence, especially in summer (Castillejo et al., 1976). The rest of the year it shows estuarine conditions in the innermost part with a fluvial supply that quickly mixes with seawater and generates an outward circulation near the north coast of the ria. The hydrodynamics of the ria, as in the case of most Galician Rias (de Castro et al., 2000; Prego et al., 2000, Gómez-Gesteira et al., 2001), is essentially driven by inputs from the river and continental runoff, on the water masses of the nearby shelf, and the wind regime (Labandeira et al., 2001).