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A decade of weekly dissolved organic carbon values in the coastal upwelling of the NW Spain (Atlantic Galician Rías)

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ABSTRACT

Dissolved organic carbon (DOC) was measured weekly in five coastal upwelling Galician rías (Ría de Vigo, Ría de Pontevedra, Ría de Arousa, Ría de Muros and Ría de Ares–Betanzos) and the first decadal DOC series was examined in these rías. The temporal variability of DOC was assessed by considering biweekly values at 10 oceanographic stations for the decade 2002–2011. Seasonal variability in surface DOC concentrations was observed, with higher values (101 ± 8 μmol L^{-1}; average ± STD) during the accumulation period (DOC^b; May–October) in all inner and outer stations. During the rest of the year (DOC^c; November–April) surface DOC concentrations decreased to 88 ± 6 μmol L^{-1}. The temporal distribution of DOC and temperature were comparable, with a marked seasonal variability, suggesting that the temperature was the main proxy for DOC. The average decadal seasonal increase in surface DOC ($\Delta DOCs = DOC^b - DOC^c$) was between 7 and 18 μmol L^{-1} for all stations. The interannual variability of surface DOC ranged between 0 and 18 μmol L^{-1}; 0 and 11% of the average DOC of each station. Decadal DOC trends were slightly positive in middle-inner areas of the Rías Baixas (Ría de Vigo, Ría de Pontevedra, Ría de Arousa and Ría de Muros) in agreement with positive temperature trends. The outer area of the Rías Baixas showed positive DOC trends in the stations of Ría de Vigo and Ría de Arousa and negative DOC trends in the stations of Ría de Pontevedra and Ría de Muros, although temperature presented positive trends in these four stations. The Ría de Ares–Betanzos exhibited negative trends in DOC and temperature.

1. Introduction

Dissolved organic carbon (DOC) is the major form of organic carbon in aquatic environments, playing a key role in global biogeochemical cycles (Carlson, 2002). DOC produced within the system (autochthonous DOC) originated from phytoplankton exudation, cell lyses and grazing (Nagata, 2000). Allochthonous DOC primarily originates from plant and soil materials (Cauwet, 2002). DOC fractions have been characterized according to their reactivity (Hansell, 2013). Labile DOC, with a turnover-time of hours to days is preferentially used by bacterioplankton, although it can be used by primary producers, and does not accumulate. Recalcitrant DOC can be subclassified in: i) semi-labile and semi-refractory DOC fractions, which can accumulate in the surface ocean and cycle in the order of months to decades; they account for most of DOC that is exported from the euphotic zone (Lorenzoni et al., 2013) and; ii) refractory and ultra-refractory DOC fractions, the largest and least reactive pool of DOC in the ocean, with assumed cycling over millennial time scales (Hansell, 2013).

Coastal marine ecosystems are one of the most productive and biogeochemical active zones of the biosphere (Gatuso et al., 1998). Coastal processes are intensified in eastern boundary upwelling systems when along-shore equatorward wind drives the surface layer offshore, inducing the rise of deep, cool and inorganic nutrient-rich waters into the coastal photic layer (Walsh, 1991; Wollast, 1998). The Galician coast, 42–44°N, is at the northern limit of the NW Africa upwelling system, which extends from 10°N to 44°N. In this area, coastal winds are favorable to the upwelling of deep, cool inorganic nutrient-rich and also organic-poor waters into the coastal photic layer from March–April to September–October. The downwelling of warm, inorganic-poor and organic-rich shelf surface coastal waters takes place during the rest of the year (Wooster et al., 1976; Fraga, 1981). Several inlets of varying sizes make up the Galician coast. These inlets, called rías, are freely connected to the adjacent shelf. The largest and deepest rías, four large coastal indentations of more than 2.5 km^3 (Rías Baixas: Ría de Vigo, Ría de Pontevedra, Ría de Arousa and Ría de Muros) and a medium sized ría of 0.75 km^3 (Ría de Ares–Betanzos), occupy the NW area of the Galician coast (Atlantic Galician Rías; Fig. 1). The hydrodynamics of these rías, essentially dictated by coastal winds, are characterized by a reinforced positive circulation during upwelling periods and a depressed positive or even negative circulation during downwelling pulses. These rías circulate 'like' partially mixed estuaries but they are forced by shelf wind-stress (as coastal upwelling systems) not by continental runoff (as estuaries). Middle and outer parts of the rías behave as an extension of the adjacent shelf. Only the most inner parts of these rías (<15 m) can be considered 'like' a partially

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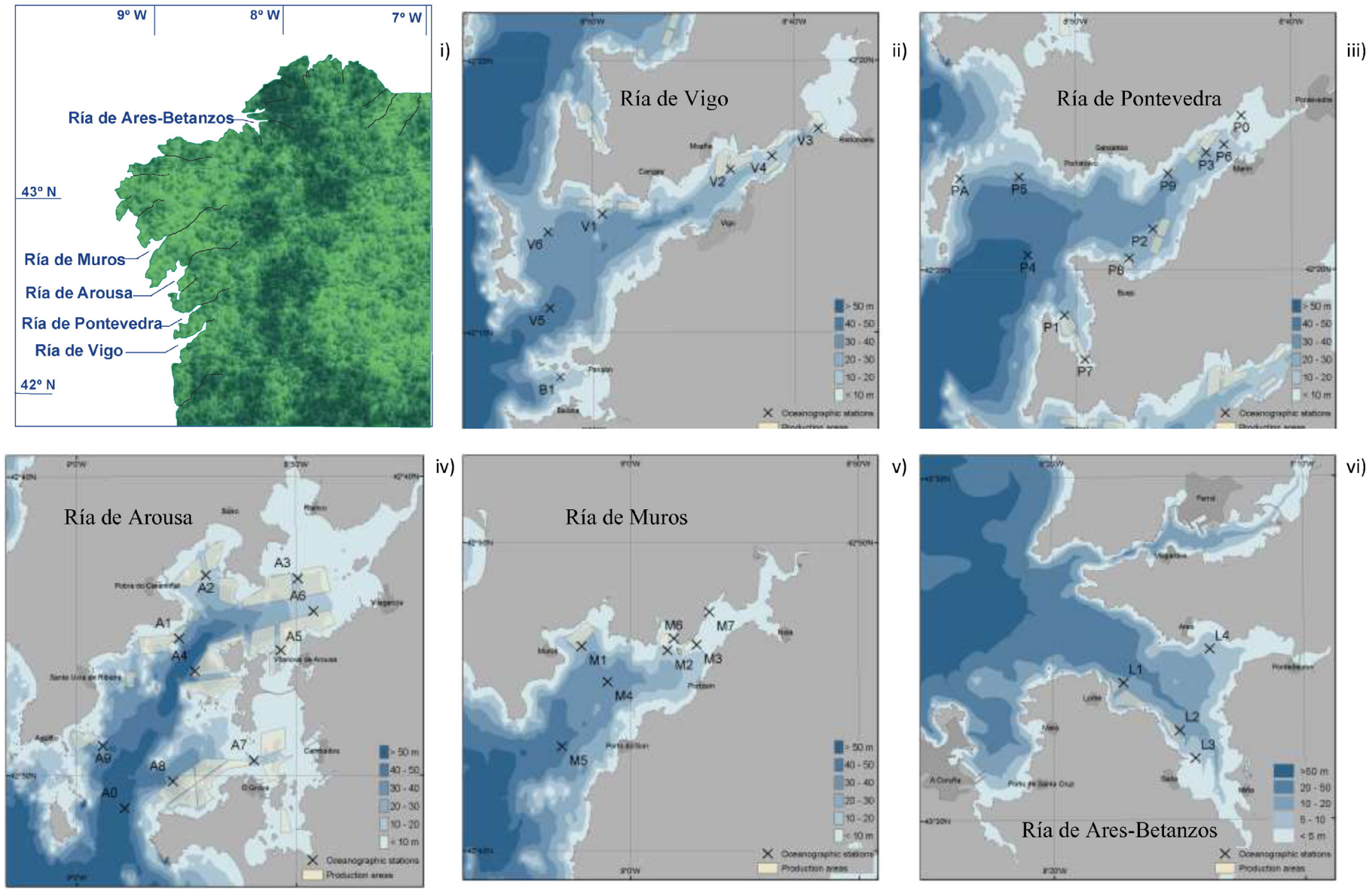

Fig. 1. Weekly oceanographic stations of INTECMAR on the i) Galician coast (NW Spain); ii) Ría de Vigo; iii) Ría de Pontevedra; iv) Ría de Arousa; v) Ría de Muros; and vi) Ría de Ares–Betanzos.