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Interannual variability in hydrobiological variables in the coast of A Coruña (NW Spain) from 1991 to 1999

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Results of monthly sampling at a 70-m-deep shelf station off A Coruña (NW Spain) from 1991 to 1999 illustrate the relationships between changes in biological productivity, seasonal upwelling, and interannual changes in the composition of Eastern North Atlantic Central Waters (ENACW). During most of the 1990s the North Atlantic Oscillation (NAO) index was positive, resulting in warm and wet weather off NW Spain. It also produced a subsurface poleward current, which transported ENACW of high salinity and low nutrient content. In contrast, negative NAO index values in 1995 and 1996 coincided with the return of low-salinity, nutrient-rich ENACW.

Key words: North Atlantic Central Water, North Atlantic Oscillation, nutrients, productivity, upwelling.

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Introduction

Biological productivity in the Galician Shelf (NW Spain) strongly depends on the seasonal upwelling of nutrient-rich Eastern North Atlantic Central Waters (ENACW) driven by northeasterly winds from spring to autumn (Blanton *et al.*, 1987). The intensity and duration of the upwelling period is known to vary between years but there is limited information on other sources of variability, such as the nutrient load of the upwelled waters. Here we report results from monthly sampling from 1991 to 1999 at a 70-m-deep shelf station off A Coruña. Water properties were measured with a CTD and dissolved nutrients and chlorophyll concentrations were analysed from water samples collected with bottle casts (Casas *et al.*, 1997). An upwelling index was calculated following Blanton *et al.* (1987). Variability in large-scale atmospheric processes in the study area was taken to be reflected in the North Atlantic Oscillation index (NAO), as calculated by Hurrell (1995). Our objective is to illustrate interannual differences in the physical and chemical properties of the upwelling waters and of concurrent changes in biological production.

Interannual variability in upwelling waters

Episodic upwelling events, indicated by relatively cold, high-chlorophyll surface water and nutrientrich subsurface water, were clearly identified in all years of the study. Temperature at 70-m depth and the upwelling index follow similar patterns (Figure 1). However, the characteristics of the upwelled water were fairly variable (Figure 2). For instance, in 1992 and 1993 upwelling during the spring was characterized by water of high salinity (>35.8 psu) and low nutrients (5 μM NO_3). This type of ENACW was associated with persistent southwesterly winds, which also leads to a subsurface poleward current along the western Iberian Peninsula (Fiuza *et al.*, 1998). Low-salinity, nutrient-rich (12 μM NO_3) ENACW returned in 1995 and 1996 when the spring chlorophyll concentrations remained high and even increased during the summer (i.e. August 1995). Such conditions usually accompany northerly winds (Dickson *et al.*, 1988). Also, the unusual persistence of harmful algal blooms in 1995 suggests that these nutrient-rich ENACW might favour blooms of toxic phytoplankton species.

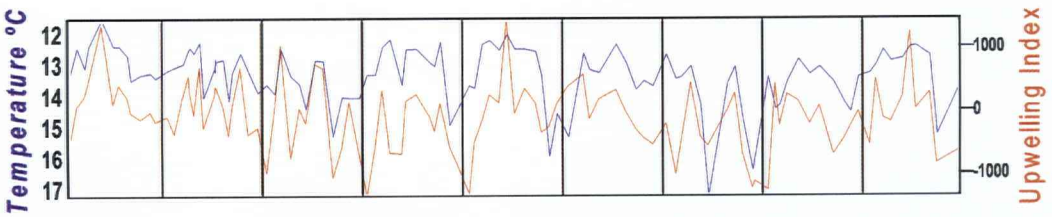

Figure 1. Upwelling Index ($m^2 s^{-1} \times 1000$) and the 70-m depth temperature (°C) during the sampling period.

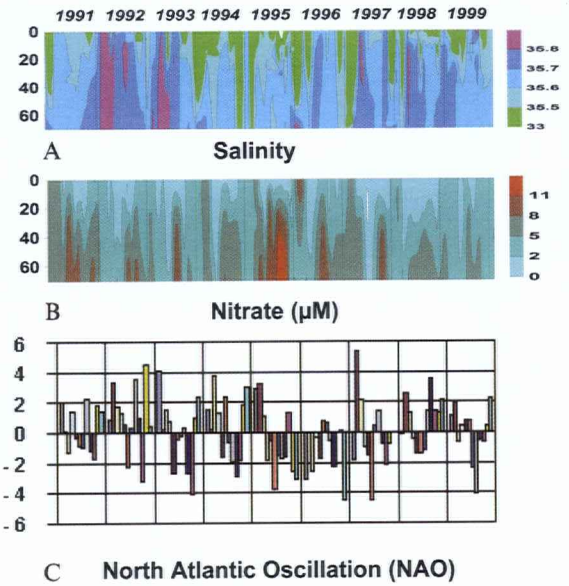

Figure 2. Decadal distribution of: (a) Nitrates (µg-at. N l^{-1}), (b) salinity, and (c) North Atlantic Oscillation Index.

Interannual climatic variability

Positive NAO values are associated with more frequently southwesterly winds that bring warm and wet weather off northwestern Spain and produce a warm, high salinity poleward current. Negative NAO values lead to more northerly winds that result in cold, dry air and an equatorward current carrying cooler, lower salinity water. Values of NAO from 1990 to 1999 exhibited considerable variability with a tendency to be positive over most of this period. As a consequence, episodic upwelling events were often associated with the high salinity ENACW and only between 1995 and 1996 when there was persistent upwelling associated with negative NAO values was low-salinity ENACW observed, consistent with Dickson *et al.* (1988). We postulate that the origin of the ENACW, which upwells near the coast, influences biological production in the study area through differences in nutrient inputs, along with variable water stability gradients induced by differences in salinity between water layers in the upper water-column.

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