Internal wave activity and its role on mixing, nutrient supply and phytoplankton community structure during spring and neap tides in the Ría de Vigo (NW Iberian Peninsula)

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ABSTRACT

Despite the evidences of internal wave activity in the NW Iberia upwelling region, their action and role on nutrient supply dynamics and phytoplankton community structure remain unexplored. By using a multidisciplinary approach combining the analysis of Synthetic Aperture Radar (SAR) images and field observations collected in the outer part of the Ría de Vigo (NW Iberian Peninsula), we characterized the internal wave activity during spring and neap tides, their influence on mixing and nutrient supply dynamics, and their role on phytoplankton size-structure and composition. SAR images acquired during the summer months of the 2008-2011 period, revealed that internal waves were more energetic during spring than neap tides, and that the most energetic packets occurred close to the 100 and 150 m isobaths. The intensive sampling carried out in summer 2013, including continuous measurements of microstructure turbulence and sampling for inorganic nutrient concentration and phytoplankton size-structure and composition, showed that turbulence and mixing levels were higher during spring than neap tides. As a result of increased mixing levels, nitrate diffusive input into the euphotic layer was approximately 4-fold higher (35±89 mmol m^{-2} d^{-1}) during spring tides. This nitrate input could represent an important fertilizing mechanism during spring tides and summer stratification periods to explain the continuous dominance of large-sized phytoplankton during the upwelling favorable season.

INTRODUCTION

During spring-summer months (April to September) the NW Iberia is characterized by intense and intermittent upwelling pulses [1]. In addition, during the upwelling season the surface layer is characterized by high thermal stratification, which is favorable for internal wave activity and propagation. Enhanced mixing associated with internal waves dissipation increase vertical nutrient transport, which supports horizontal and vertical gradients in phytoplankton community structure with important implications for fisheries and the export of particulate organic carbon [2,3].
A multidisciplinary approach comprising the analysis of SAR images and the intensive sampling of physical, chemical and biological variables was carried out in the outer part of the Ría de Vigo in summer 2013 with the following goals: 1) to characterize the internal wave activity, 2) to quantify mixing levels and nutrient supply into the photic zone, and 3) to describe the size-structure and composition of the phytoplankton community during spring and neap tides.

MATERIAL AND METHODS

A selection of 20 SAR images (8 ERS1&2-SAR images and 12 Envisat-ASAR in Precision Image mode) acquired during the summer months from 2008 to 2011 on the shelf off the Ría de Vigo, was used to calculate a proxy for the energy of the internal wave packets (E*) for spring and neap tides [4,5]. Two cruises were conducted on board the R/V Mytilus in the outer part of the Ría de Vigo (42.174ºN, 8.890ºW) during spring (20-21 August 2013, CHAOS1) and neap (27-28 August 2013, CHAOS2) tides (Figure 1).

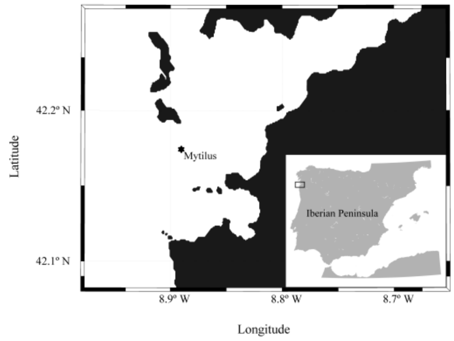

Fig. 1. Map showing the position of the intensive observations carried out on board the R/V Mytilus (42.174ºN - 8.890ºW) in the outer part of the Ría de Vigo in summer 2013.

An intensive sampling (yo-yo) of measurements of microstructure turbulence by using a microstructure profiler (MSS), was carried out covering two complete semi-diurnal tidal cycles (ca. 25 hours). Water samples were collected for the determination of inorganic nutrient concentration and phytoplankton size-structure and composition.

RESULTS AND DISCUSSION

The proxy for internal wave energy revealed that, during the summer months of the 2008-2011 period, internal waves packets were more energetic during spring (E*=22.74) than neap tides (E*=10.16). The most energetic packets were located, both during spring and neap tides, close to the 100 and 150 m isobaths over the shelf.

The cruises conducted in August 2013 sampled different upwelling conditions, covering a transitional period from relaxation-stratification (CHAOS1, spring tides) to upwelling conditions (CHAOS2, neap tides). Larger vertical displacements of the isotherms, as well as increased mixing levels at intermediate depths, suggest that internal wave activity was higher during spring tides (Figure 2).

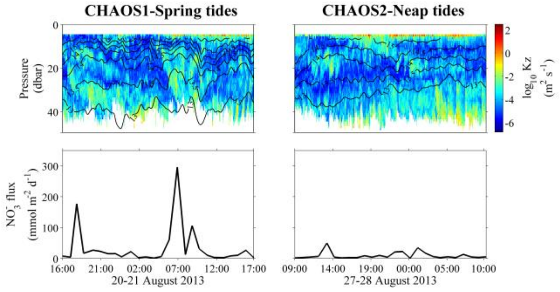

Fig. 2. Temporal variability of vertical diffusivity (Kz) and nitrate diffusive flux computed during spring tides (CHAOS1) and neap tides (CHAOS2). Isotherms are superimposed on the Kz distribution.

As a consequence, the averaged nitrate diffusive flux computed during spring tides (35±89 mmol m^{-2} d^{-1}) was almost four times higher than during neap tides (9±12 mmol m^{-2} d^{-1}). Although microphytoplankton (>20 µm) cells dominated the phytoplankton community in both cruises, the species composition was significantly different. In CHAOS1, when the water column was stratified, small-sized diatoms such as *Chaetoceros socialis* and small-sized *Chaetoceros* spp. were more abundant. These species were replaced by larger ones (medium and large *Chaetoceros* spp.) one week later when an intense upwelling pulse occurred during CHAOS2.

Our results indicate that, especially during spring tides and stratification conditions, enhanced mixing driven by internal waves could represent an important fertilizing mechanism which could contribute to explain the continuous dominance of large-sized phytoplankton during the upwelling favorable season.

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