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# Toward predicting *Dinophysis blooms* off NW Iberia: A decade of events

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ABSTRACT

*Dinophysis acuminata* and *Dinophysis acuta* are recurrent species off NW Iberia but their outbreaks occur under different conditions. A decade (2004–2013) of weekly data for each species at two sentinel stations located at the entrance of Rias de Aveiro-AV (NW Portugal, 40°38.6′ N) and Pontevedra-PO (Galicia, Spain, 42°21.5′ N), were used to investigate the regional synchronism and mesoscale differences related to species detection, bloom (>200 cells $L^{-1}$) initiation and development. Results highlight the high interannual variability of bloom events and summarize the associated meteorological/oceanographic conditions. *D. acuta* blooms were observed in 2004–2008 and 2013, and the species highest maxima at AV occurred after the highest maxima of its prey *Mesodinium*, with a time-lag of 2–3 weeks. *D. acuminata* blooms were observed every year at both stations. The cell concentration time series shows that the blooms generally present a sequence starting in March with *D. acuminata* in PO and three weeks later in AV, followed by *D. acuta* that starts at AV and three months later in PO. Exceptionally, *D. acuminata* blooms occurred earlier at AV than PO, namely in high spring upwelling (2007) or river runoff (2010) years. A four-year gap (2009–2012) of *D. acuta* blooms occurred after an anomalous 2008 autumn with intense upwelling which is interpreted as the result of an equatorward displacement of the population core. Numerical model solutions are used to analyze monthly alongshore current anomalies and test transport hypotheses for selected events. The results show a strong interannual variability in the poleward/equatorward currents associated with changes in upwelling forcing winds, the advection of *D. acuta* blooms from AV to PO and the possibility that *D. acuminata* blooms at AV might result from inocula advected southward from PO. However, the sensitivity of the results to vertical position of the lagrangian tracers call for more studies on species distribution at the various bloom stages.



## 1. Introduction

Harmful Algal Bloom (HAB) species are regular components of the phytoplankton in northwestern Iberian upwelling waters, a coast annually affected mainly during summer and autumn by blooms, sometimes in very high concentration of cells, of *Dinophysis* species. These dinoflagellates are diarrhetic shellfish poisoning (DSP) producers and are the main cause for long periods of shellfish harvesting closures with serious socio-economic impacts in the region. *Dinophysis*, though tolerating upwelling turbulence, are favored by thermal and haline stratification and there is little evidence that blooms are induced by elevated nutrient concentrations (Delmas et al., 1992; Reguera et al., 1995; GEOHAB, 2008). They seem to be excelent survivors and can attain high growth rates (Reguera et al., 2012).

*Dinophysis* are obligate mixotrophic species that in cultures depend simultaneously on the availability of prey, *e.g.* the phototrophic ciliate *Mesodinium rubrum*, and on light intensity for photosynthesis (Kim et al., 2008). In nature, populations of the predator and prey still need to aggregate to enhance encounter rates. Despite these specificities, the development of *Dinophysis* blooms follow the general phases of population development (initiation, growth, maintenance and decay) that, together with their transport by currents, need to be studied in order to better

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predict the events and mitigate their effects (Reguera et al., 2012). Furthermore, Reguera et al. (2012) pointed out that the conditions for the initiation, or for the supply of inoculum populations, may hold the key to explain *Dinophysis* bloom interannual variability.

Twenty five years of HAB monitoring on NW Iberia waters show that blooms of the endemic dinoflagellates *Dinophysis acuta* and *Dinophysis acuminata* are recurrent although presenting a high interannual variability whose causes are still poorly understood. Both species coexist but their maxima never coincide in space or in time (Palma et al., 1998), and their peaks can alternate in late summer and early autumn associated with different stratification patterns (Reguera et al., 1993). In the west coast of Portugal (Fig. 1), the region between Figueira da Foz (F.Foz) and Aveiro (AV), *i.e.* between 40°10′ N and 41° N, is the most problematic area, where the species maxima are normally reported (Palma et al., 1998; GEOHAB, 2005; Vale et al., 2008), and have been observed in thin subsurface layers within the pycnocline (Moita et al., 2006). This area is in general considered the epicenter for *D. acuta* blooms in northwestern Iberia where they often occur first and are more intense than in adjacent areas (Moita et al., 2006; Escalera et al., 2010). For similar reasons, Ría de Pontevedra, in Galicia, is thought to be a hot-spot for *D. acuminata* blooms in NW Iberia (Pazos et al., 2005). Exceptionally in some years, intense blooms of *D. acuta* were observed only in Galicia and not further south (*e.g.* 1989, Reguera et al., 1995) or the reverse with *D. acuminata* blooms in Portugal (*e.g.* 2007, this work).

The very sudden increase in *Dinophysis* cell numbers detected in some coastal monitoring sites cannot be fully explained by the species growth rates alone. There is evidence that populations of both species can be transported alongshore but relaxation/downwelling events may also cause their accumulation inshore (Reguera et al., 1995; Sordo et al., 2001; Crespo et al., 2006; Escalera et al., 2010). Upwelling, through pycnocline shallowing, can serve as a mechanism of concentrating populations that can be advected by the inshore poleward currents when the winds weaken, a physical mechanism observed by Sordo et al. (2001) and Oliveira et al. (2009). Contrasting climatic conditions were also evoked to explain the selection in the Galician rias of *Dinophysis acuminata* and *Dinophysis acuta* blooms in 2002 and in 2003 respectively (Escalera et al., 2010): *D. acuminata* was associated with thermohaline stratification and persistent northerly winds while *D. acuta* was related to an exceptionally hot summer with the lowest upwelling index of the previous 50 years. Díaz et al. (2013) showed that the early initiation of *D. acuminata* blooms in the Galician Rías Baixas, observed in 2002 and 2012, were related to positive anomalies in SST and atypical predominance of upwelling winds during the immediately previous winters.

This work aims at investigating in detail the conditions related to *Dinophysis acuta* and *Dinophysis acuminata* bloom initiation and intensification in two sites off NW Iberia (Galician rias and NW coast of Portugal) separated by 200 km. Data include: (i) a decade (2004–2013) of *Dinophysis* weekly data samples from two monitoring stations where the species often present regional maxima; (ii) meteorological reanalysis data and (iii) daily sea surface maps to provide a synoptic view of the sea surface conditions prior to bloom development; (iv) hydrodynamic model solutions to investigate the advection of *Dinophysis* populations between the two regions.

## 2. Study area, data and methods

### 2.1. The study area

The area of study is located at the NW coast of Iberia (Fig. 1), in the northern limit of the upwelling system associated with the north Atlantic anticyclonic gyre. In this region, the upwelling occurs seasonally, from late spring to early Autumn with a

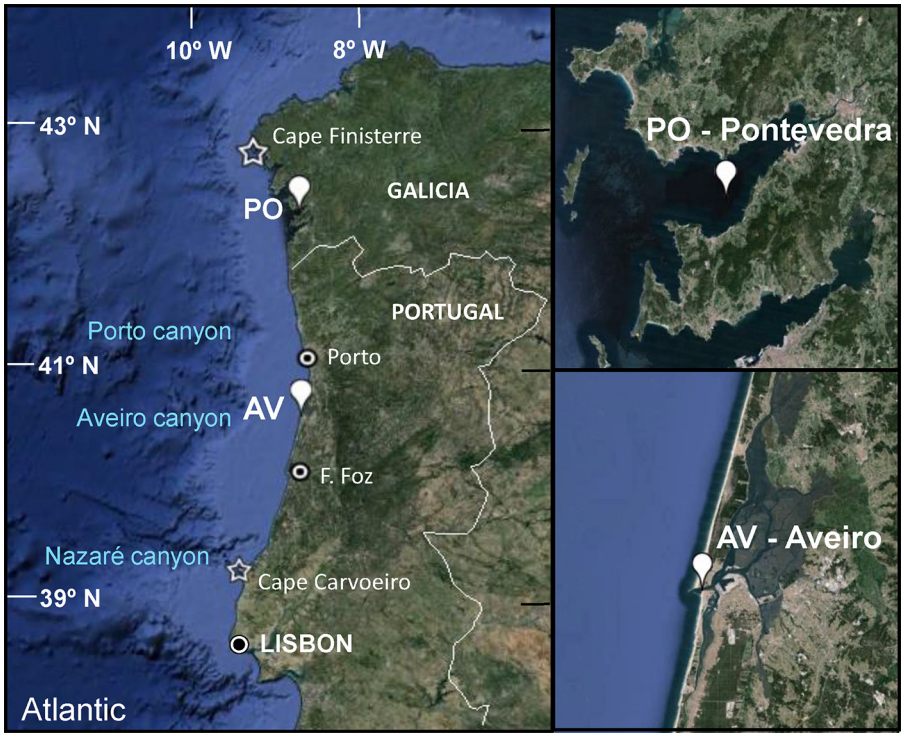


**Fig. 1.** Map of NW Iberia showing the position of the two HAB long term monitoring stations, PO located in front of Buéu in Ría de Pontevedra (Galicia, NW Spain) and AV at the entrance of Ria de Aveiro (Portugal).