Towards forecasting *Dinophysis blooms* off NW Iberia: a decade of events

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Summary

In NW Iberia, *Dinophysis acuminata* occurs under different conditions than *D.acuta* but both species are recurrent every year. A decade (2004-2013) of each species weekly data at two stations located at the entrance of Rías de Aveiro -AV (Portugal) and Pontevedra -PO (Spain), are used to investigate the regional synchronism and mesoscale differences of conditions related to each *Dinophysis* species detection, bloom (>200 cells.L^{-1}) initiation and development, characterized by a high interannual variability. *D.acuta* blooms were detected on 2004-2008 and 2013, while *D.acuminata* blooms occurred every year. The time series analysis shows that the blooms follow a sequence starting in March with *D.acuminata* in PO, three weeks later in AV, in May *D.acuta* in AV and, three months later in PO. Exceptionally, *D.acuminata* blooms occurred earlier at AV than PO in high spring upwelling (2007) or river runoff (2010) years. The 4 years gap (2009-2012) of *D.acuta* blooms occurred after an anomalous 2008 autumn with intense upwelling which seems to have flushed the species offshelf and displaced the population core equatorwards. Numerical model solutions are used to test transport hypothesis for selected events confirming the advection of *D.acuminata* blooms from PO to AV and *D.acuta* from AV to PO.

Introduction

Dinophysis are DSP producers and mixotrophic species that in cultures dependent simultaneously on the availability of preys, *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 increase their densities and enhance encounter rates (Reguera et al., 2012). 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 predict the events and mitigate their effects (Reguera et al., 2012). Conditions for the initiation or for the supply of inoculum populations may hold the key to explain *Dinophysis* bloom interannual variability. This work aims at investigating the conditions related to *D. acuta* and *D. acuminata* blooms initation and development in NW Iberia, a coast influenced by seasonal upwelling, from late spring to early Autumn, and by river discharges. Data used include: (i) a decade of *Dinophysis* weekly data samples from two sites separated by 200Km, where the species often present regional maxima; (ii) meteorological reanalysis; (iii) satellite images to provide a synoptic view of the sea surface conditions prior to bloom development; (iv) hydrodynamic model solutions to investigate the crosshore transport and the advection of *Dinophysis* populations between the two regions.

Material and Methods

Species data are from station **PO,** located at the southern side of ria de Pontevedra, Galicia (42°21'30.00"N; 8°46'20.00"W) and station **AV,** at the entrance of ria de Aveiro (40°38'38.95"N; 8°44'55.18"W). Data were provided by the Galician (INTECMAR) and Portuguese (IPMA) HABs Monitoring Programs. Samples were preserved with Lugol solution and subsamples were identified and counted by the Utermöhl method, after settling. Sea surface temperature (SST) maps were obtained from EUMETSTAT´s Ocean and Sea Ice Satell Applic. Facility and the Operat. Sea Surf. Temp. and Sea Ice Anal.- OSTIA. Meteorological conditions were obtained from the ECMWF ERA Interim re-analyses. Bakun upwelling indices - UI ($m^3s^{-1}m^{-2}$) were calculated, based on the N-S wind component. Particle-tracking experiments used a 3D hydrodynamic model configured to reproduce

NW Iberia shelf circulation. Time series of environmental data for the various selection criteria were constructed using Ferret (Hankin et al., 2006). The subsets were analysed using a R software package.

5) Results and Discussion

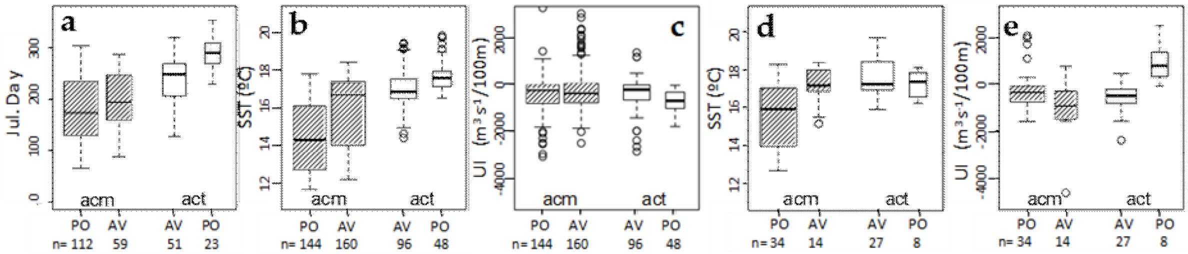

Figure 1. *D.acuminata* (acm) and *D.acuta* (act) bloom conditions box-and-whisker plots at AV and PO stations showing 25 and 75%ile, min, max and median of: (a) bloom (>200cells L^{-1}) occurrence date (Julian day); (b) SST (ºC) and (c) UI (m^3s^{-1}/100m) on the 15 days preceding the 1st bloom event in the year and on the sampling dates of very high concentrations (>1000 cells.L^{-1}).

Fig.1a shows the sequence of blooms along the year, starting with *D.acuminata* at PO on 6March (Jday min=65) and later in AV on 28March (Jday min=87), followed by *D.acuta* blooms that begin first at AV on 8May (Jday min=128) and then in PO on 17Aug (Jday min=229). Since the first cells of *D.acuminata* are observed at the same time in the two stations (~Jday 50, not shown), the differences on the median observed on the time of bloom initiation suggest not only that PO provide better conditions for the species growth but also their advection from PO to AV, a fact confirmed on some events (e.g. 2006) by the hydrodynamic model. Concerning *D.acuta*, the lag of bloom initiation between AV and PO is higher, suggesting the AV populations are generally retained in the region until the development of conditions for their transport into PO, as confirmed for 2005 and 2013 events by the model. The SST observed two weeks before bloom initiation reflects the conditions for the species outbreaks, and show the range of temperature for *D.acuminata* blooms is much larger than for *D.acuta* (Fig.1b). With the exception of *D.acuminata* in PO (median=14.5ºC), most events of both species in AV and of *D.acuta* in PO occur between 17 and 18ºC (see median). Most high concentration blooms of *D.acuminata* occur around 16ºC in PO, while 17ºC is the optimal temperature for this species in AV and for *D.acuta* development in both stations (Fig. 2d). Most blooms of both species occur under weak upwelling conditions (negative values in Fig. 2c). However, high concentration events of *D.acuta* in PO were observed under downwelling conditions (Fig.2e), in agreement with a northward advection of the populations from AV, a mechanism discussed by Escalera et al. (2010). The high concentrated blooms of *D. acuminata* in AV were observed with more intense upwelling, suggesting its alongshore equatorward transport from PO or the transfer of conditions normally observed in PO that moved to AV (case of spring 2007). A detailed analysis of the series shows that *D.acuminata* blooms exceptionally occurred earlier in AV than in PO when there was a high spring upwelling (2007) or river runoff (2010). A 4 years gap (2009-2012) of *D.acuta* blooms occurred after a 2008 exceptional intense autumn upwelling that seems to have flushed the species offshelf, promoting an equatorward population core displacement, a condition only reversed in summer 2013 characterized by the weakest upwelling and consequently high SSTs.

6) References

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