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A HAB warning system for shellfish harvesting in Portugal

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ABSTRACT

The development of sustainable shellfish aquaculture is highly dependent on the provision of reliable monitoring and predictive information on the occurrence of harmful algal blooms (HABs). The Portuguese HAB early warning system and shellfish closures presented here is a prototype, developed in the ASIMUTH project. It relies on weekly monitoring data composed of observations of HAB species and toxin concentrations within shellfish, and ocean circulation forecasts generated by an operational oceanographic model. The shellfish harvesting areas comprise coastal areas, estuaries + rías and coastal lagoons. The weekly bulletin characterizes the current shellfish closure situation and next week's forecasts for potentially impacted areas. The period analyzed ranged from 27 July 2013 to 17 March 2014, and describes the first skill assessment of the warning system. The forecast accuracy was evaluated, considering the number of forecasts that were verified to be correct the following week (85%) as well as the number of events not forecasted (false negatives, 12%) and those expected but did not occur (false positives, 3%). Variations were most visible in the first weeks of bulletin implementation and during autumn–winter months. The complementary use of field data, remote sensing and operational models led to more accurate predictions of blooms and range of the event.

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1. Introduction

Harmful algal blooms (HABs) are a worldwide concern that are becoming more frequent and occurring over larger areas. In many of these areas harmful events were not known and suddenly emerge to become problematic, causing serious restrictions to the sustainable development of coastal areas and sometimes a threat to human health (Trainer et al., 2010). The poisoning syndromes have been given the names paralytic, diarrhetic, neurotoxic, amnesic, ciguatera and azaspiracid shellfish poisoning (PSP, DSP, NSP, ASP, CFP and AZP respectively). Except for ASP, all are caused by biotoxins synthesized by dinoflagellates (Anderson, 2009). The ASP toxin, domoic acid, is produced by diatoms. The main species reported by the Portuguese monitoring program of HABs belong to the genera *Pseudo-nitzschia*, *Dinophysis*, *Gymnodinium* and more recently *Ostreopsis* and *Karenia* These different HAB species have distinct oceanographic preferences reflecting different life-form (morphotype) characteristics and adaptive strategies (Moita et al., 2006; Palma et al., 2010; Silva et al., 2009; Smayda, 2002).

In Portugal, the responsibility for the national monitoring of HABs is held by the Portuguese Institute for the Sea and Atmosphere (IPMA), by its Phytoplankton and Marine Biotoxins laboratories, since 1985, on a weekly basis. Indicative sampling rates comprise for biotoxins: a sample/indicator species or all species/week/sampling point; as for phytoplankton: a representative sample of each production area and a sample from a sentinel station with the frequency identical to that of biotoxins. The most critical period for closures usually ranges between April to October.

Multiple methods exist for monitoring algal concentrations and signalling the presence of algal blooms (Walsh et al., 2001; Anderson et al., 2006; Culverhouse et al., 2006; Miller et al., 2006), ranging from molecular and cell biology approaches to large-scale field surveys, numerical modelling, and remote sensing from space (Anderson, 2009). *In situ* species-specific cell counts have the highest confidence but spatial resolution is low. In turn remote sensing has the advantage of providing large spatial coverage although resolution is often limited by clouds. Near coast processes can also bias data from satellite imagery. Operational models allow near real-time forecasting and can be used to calculate the temporal and spatial coverage of phytoplankton distribution and chlorophyll-a. The forecasted transport and extent of particles is dependent on the resolution and uncertainty of the input spatial field (Stumpf et al., 2010).

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Around the world, HAB alert bulletins and warning systems vary in complexity and can be delivered in a range of platforms from traditional environmental data to purely computational methods (Anderson et al., 2015). Reports show and rely on field observations, ocean colour satellite imagery, models, historical trends, public health reports, buoy data and forecasts of potential bloom progression (e.g. bulletins from NOAA, EUA; Marine Institute, Ireland; INTECMAR, Galicia)

The Portuguese early warning system for HABs and shellfish closures is an operational prototype. This study reports the first skill assessment of the system. The output is a weekly bulletin that provides information on the status of shellfish harvesting areas and associated oceanographic conditions. The current situation and next week forecast are presented, in a simple and concise way. It is aimed to support informed decisions and coordination of responses to a bloom in order to minimize impacts. The bulletin is tailored to Portuguese aquaculture needs, and its end users comprise coastal authorities and fish farmers in several locations along the Portuguese coast. The bulletin results from the collaborative effort between IPMA and Instituto Superior Técnico.

This bulletin was developed within an EU-funded research project, ASIMUTH, a project awarded with a prize for the 'Best Challenge Service' in the Copernicus Masters 2013, a competition for the most innovative business and society solutions based on Earth observation data.

2. Materials and methods

2.1. Origin of data

2.1.1. Field data

The *in situ* data are from the National Monitoring Program of Shellfish, held by IPMA, and comprise weekly monitoring of water samples for harmful algae and of shellfish specimens for the presence of biotoxins. The Portuguese coast is divided into 9 coastal areas (L1–L9) contiguous to several estuaries and coastal lagoons (Fig. 1). The sampling stations are located in known plankton retention/accumulation areas or in shellfish production areas. The limits of production areas are based upon historical data from local catches by captaincy/maritime jurisdiction and the homogeneity of geographic and coastal features.

Water samples for phytoplankton observations, 45–50 per week, were collected during high tide, preserved with Lugol's iodine and observed by the Utermöhl technique, within 48 h of collection (IOC, 2010). The samples were checked for the presence of harmful species using the IOC list (Ref: Accessed at http://www.marinespecies.org/hab/).

Biotoxins analyses in shellfish were performed using the methods established in European Regulation (Anon., 2005, 2006, 2011). For amnesic shellfish toxins, the analysis were determined by liquid chromatography with ultraviolet detection based on Quilliam et al. (1995), and paralytic shellfish toxins were determined by liquid chromatography with fluorescent detection according to the Lawrence method (Lawrence et al., 2005). Quantitative determination of the okadaic acid toxins group was carried out by colorimetric phosphatase inhibition assay (Smienk et al., 2013) and by liquid chromatography with mass detection following the EU-Harmonised standard operating procedure for determination of lipophilic toxins by LC–MS/MS (version 04, http://aesan.msssi.gob.es/en/CRLMB/web/home.shtml).

2.1.2. Remote sensing data

Sea Surface temperature and ocean colour remote sensing data were available through the MyOcean portal (http://www.myocean.eu.org). Daily images were generated for the Portuguese coast.

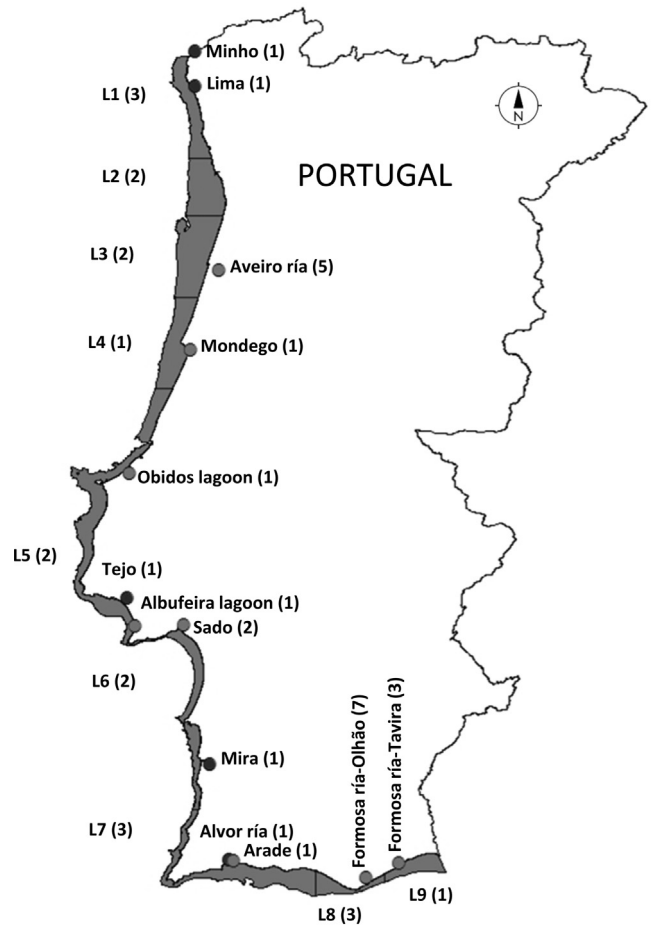

Fig. 1. Portugal shellfish harvesting areas (38.736946, −9.142685). The Portuguese coast is divided into 9 coastal areas (L1–L9) that comprise estuaries and coastal lagoons (number of sampling points).

2.1.3. Modeling strategies

The output of the Portuguese Coast Operational Modeling system (MOHID-PCOMS) is the central tool of the warning system. The model runs operationally with a 3-day forecast capacity, simulating the thermo-haline structure and velocity fields for the West Iberian coast (34.4–45.0° N and 12.6–5.5 °W). The model has been used extensively in a variety of contexts, and a detailed description of the governing equations of the model, its structure and products is presented by Mateus et al. (2012). The PCOMS model predicts the current patterns based on the tide, water temperature and salinity, wind direction and intensity, bathymetry of the sea bed and coastline geometry. The model is systematically validated with tidal gauge data and sea surface temperature (SST) from remote sensing. Results are disseminated to the internet, where data is made freely available at: http://opendap.mohid.com:8080/thredds/catalog.html.

The modelling strategy relies on the definition of several polygons corresponding to coastal bivalve production areas (Fig. 1). For the simulations each polygon is filled with Lagrangian elements (LE). Since this LE particles have passive transport, they are moved through the modelling domain in two dimensions (x, y), according to local current fields computed by the PCOMS model. The particles movements are tracked for the simulation period, to identify their transport to adjacent boxes. The impact of any particular box or area is evaluated based on the possibility of its particles reaching other areas.

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