

Conditions associated with unusual summer blooms of *Dinophysis acuta* in an upwelling area

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Summary

Dinophysis acuta is an important producer of diarrhetic shellfish poisoning (DSP) toxins and pectenotoxins in European Atlantic coastal waters. Blooms ($> 10^3$ cell l⁻¹) of this species in the Galician Rías Baixas (NW Spain) are very seasonal (early autumn). They have been associated with alongshore transport, at the end of the upwelling season, of a population with its “centre of gravity” 100 nm south (off Aveiro, Portugal). Exceptional blooms of *D. acuta* developed *in situ* in August 1989 and 1990 under moderate upwelling and stratification, following a temporal pattern that has not been observed since. A second “normal” bloom occurred at the end of the upwelling season co-occurring with a paralytic shellfish poisoning (PSP) outbreak of *Gymnodinium catenatum*. One objective of the EU ASIMUTH project was “identification of key past events which will be re-analysed and used for training the modelling system”. Here we re-analyze oceanographic data from cross-shelf transects sampled during 3 mini-cruises on September 13, 27 and October 11, 1990, before, during and after the autumn transition, and from weekly monitoring in Ría de Vigo and Ría de Pontevedra. Our objective was to parameterize shelf conditions associated with the onset, development and decline of this exceptional summer bloom of *D. acuta*.

Introduction

Several species of the genus *Dinophysis* are known producer of diarrhetic shellfish poisoning (DSP) toxins and pectenotoxins leading to lengthy shellfish harvesting bans in European Atlantic coastal waters (Van Egmond et al. 1993). These harmful events are especially damaging in the Galician Rías (NW Spain) where they represent the main threat for the mussel aquaculture industry (Blanco et al. 2013). *Dinophysis acuminata* Claperède & Lachmann and *D. acuta* Ehrenberg are the main agents of DSP outbreaks (Reguera et al. 2014) in Western Iberia coastal waters. The former occurs through the whole upwelling season (spring to early autumn), but blooms of the latter are very seasonal (early autumn). Two different mechanisms have been proposed to explain blooms of *D. acuta* in the Galician Rías Baixas: i) *in situ* growth favoured by moderate upwelling conditions and strong thermal stratification during exceptionally hot and dry summers (Reguera et al. 1995) and ii) physical transport observed during downwelling conditions after the autumn transition resulting from a combination of poleward longshore and cross-shelf transports (Sordo et al. 2001; Escalera et al. 2010). Here we re-analyse oceanographic data from shelf transects sampled during 3 mini-cruises in late summer and early autumn 1990 and from weekly monitoring data from Ría de Vigo and Ría de Pontevedra, to identify and parameterize environmental conditions that may have triggered the exceptional bloom of *D. acuta* in 1990.

Material and Methods

The survey was carried out on board R.V. *Francisco de Paula Navarro* during three one-day cruises over shelf transects, which took place on September 13, 27 and October 11, 1990. Water samples for phytoplankton counts were collected with Niskin bottles. Vertical profiles of temperature, salinity, and pressure were obtained with a SeaBird SBE-19 CTD. In addition, Sippican XBTs were launched along a diagonal transect from Ría de Vigo to its adjacent shelf. Weekly samples for phytoplankton

counts within the monitoring programme were collected with a dividable (0-5, 5-10, 10-15m) hose sampler at two stations located in Ría de Vigo and Ría de Pontevedra. Upwelling indexes every 6 h were obtained from the Spanish Institute of Oceanography (www.indicedeafloramiento.ieo.es). Data analysis and representation were performed using the statistical and programming software R 2.1.12.

Results and Discussion

During the first cruise (13 Sept.) there was an offshore Ekman transport generated by northerly winds. From 20 to 30 September there was a wind shift and southerlies became predominant resulting in onshore Ekman transport and a significant increase of temperature with maximum values close to 19°C at surface (Figure 1). Results from the second mini-cruise (27 September) strong thermal gradients were associated with a dense bloom of *D. acuta*. Maximum cell densities (5.4×10^4 cells l^{-1}) were found at 20m on a shelf station off Ría de Vigo. Dense blooms of *D. acuta* have been described to result from a combination of stratification and physical advection by local winds patterns (Reguera et al. 2012). Our results suggest that persistent thermal stratification combined with moderate upwelling during mid-late summer 1990 in the Galician shelf created the conditions for unusual summer blooms of *D. acuta*. Bloom erosion was associated with the shift from southerly to northerly winds (from 1 October), a common mechanism for dissipation of physically-induced autumn blooms in the Iberian upwelling system resulting in an offshore Ekman transport with maximum values $2000 \text{ m}^3 \text{ s}^{-1} \text{ km}^{-1}$ on 7 October.

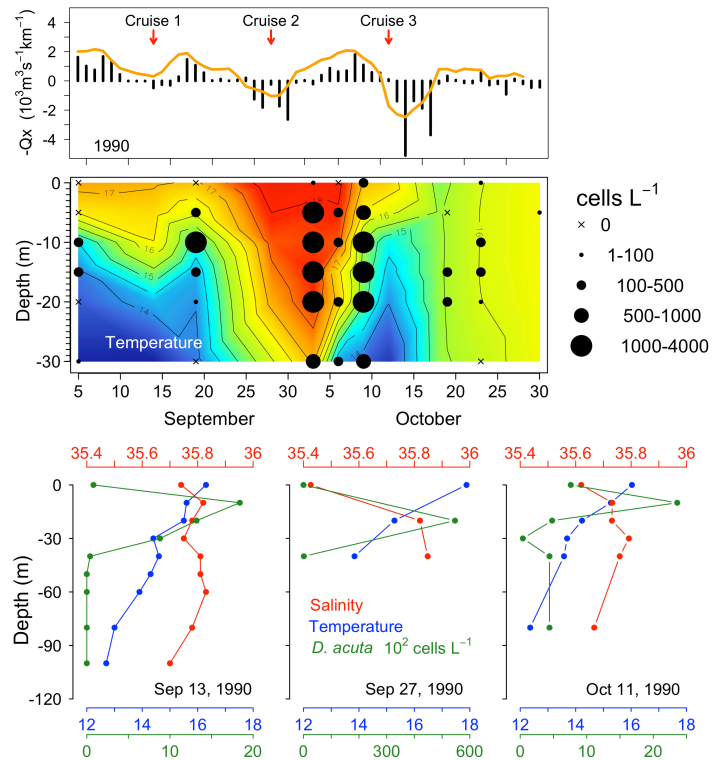


Figure 1. Time series of upwelling index (upper), temperature and *D. acuta* cell densities (middle) recorded from 4 September to 31 October at Ría de Vigo station. Vertical profiles of salinity, temperature and *D. acuta* (lower) during the three one-day cruises at a shelf station.

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