Spring-neap tidal and circadian variability in the distribution of two groups of *Pseudo-nitzschia* species in an upwelling-influenced estuary

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Abstract

High-resolution physical and biological measurements were carried out in the Ría de Pontevedra (NW Spain) in late spring during the 'HABIT Pontevedra 2007' survey, which utilized high vertical resolution instruments. Cell maxima of *P. delicatissima* (6 x 10^5 cells L^{-1}) and *P. seriata* (2 x 10^6 cells L^{-1}) groups were observed during the first half of the cruise during downwelling and a significant decrease in cell numbers occurred during subsequent upwelling conditions. The effect of tidal (both semidiurnal and spring-neap) and event driven (upwelling-downwelling cycle) variability were evident. The observed sequence of events suggests that *Pseudo-nitzschia* populations were advected from the shelf. The circadian variability was regulated by tidal forcing and *Pseudo-nitzschia* spp. maxima were observed at low tide. From results presented here we conclude that the magnitude of spring-neap tidal and circadian variability has to be considered when designing and implementing harmful algal bloom monitoring programmes.

Keywords: *Pseudo-nitzschia* spp; upwelling-downwelling cycle, spring-neap tidal variability, circadian variability, Galician Rías.

Introduction

Pseudo-nitzschia spp. of the *seriata* and *pseudo-delicatissima* groups are associated with chronic ASP events in the Galician Rías Baixas (Fraga *et al.* 1998). Toxic outbreaks are short-lasting in mussels but toxins are accumulated for very long periods (months or even permanently) in scallops, a fact that led to exceptional procedures approved by the EU to regulate ASP toxins in pectinid bivalves (Salgado *et al*. 2003).
The Galician Rías, are a site of intensive shellfish production—300 x 10^3 t y^{-1} of blue mussels and 17 x 10^3 t of other shellfish species per year (FAO, 2012) and there are therefore considerable socioeconomic impact of toxin producing microalgae in general and of *Pseudo-nitzschia* spp.
This paper evaluates the effect of spring-neap tidal and circadian variability in the distribution of species of the *Pseudo-nitzschia delicatissima* and *P. seriata* groups, for blooms which developed during a downwelling-upwelling cycle.

Material and Methods

The study was carried out on board R/V *Mytilus* from 28 May to 8 June 2007 in Ria de Pontevedra (Fig. 1).
Measurements of physical properties of the water column were carried out with an IPSAP (IFREMER Particle Size Analyzer Profiler) probe, a Scanfish-PS19 towed fish, and profiles of current velocity with a moored ADCP (Acoustic Doppler Current Profiler).
Water samples were collected for nutrient analyses and for quantitative analyses of phytoplankton to describe the spring-neap and circadian tidal variability of *Pseudo-nitzschia* spp. *Pseudo-nitzschia* species were separated in two groups, *P. delicatissima* and *P. seriata*, depending on their valve width (Hasle 1965).

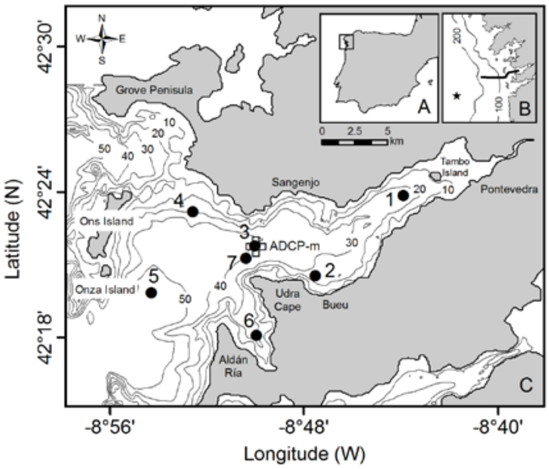

Fig. 1. Ría de Pontevedra (Galician Rías Baixas, NW Spain), showing the location of the 7 sampling stations and the ADCP-mooring site.

Results and discussion

Southerly winds during the first half of the cruise, generated onshore Ekman transport (620 $m^3 s^{-1} km^{-1}$), whereas the onset of northerly winds during the second half led to a reversed circulation, with a maximum estimate of 1535 $m^3 s^{-1} km^{-1}$ (offshore Ekman transport) (Fig. 2).

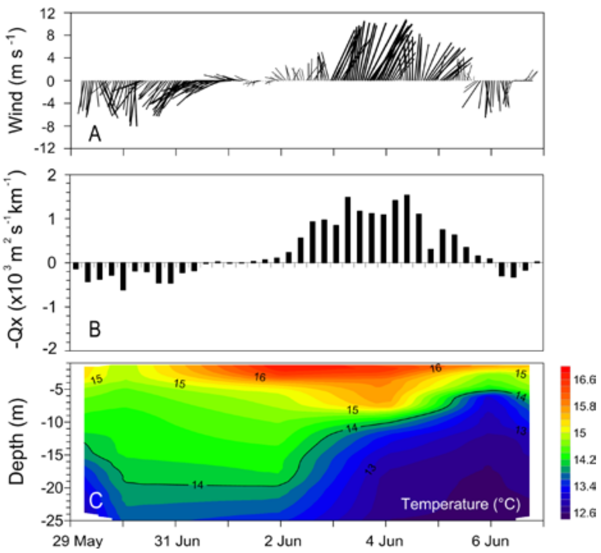

Fig. 2. Changes of A) wind direction and velocity B) Ekman transport and C) temperature from 29 May to 7 June 2007 at station 2.

The survey coincided with the annual onset of *Pseudo-nitzschia* blooms in the Galician Rías Baixas. The *P. seriata* group was more abundant than that of *P. delicatissima* throughout the cruise. The spatial and temporal distribution of the *P. seriata* group showed higher cell densities in the first half of the survey with a maximum of 2 x 10^6 cells L^{-1} (Fig. 3).

P. delicatissima group showed a similar pattern to that of the *P. seriata* group but with lower cell densities and a maximum of 6.6 x 10^5 cells L^{-1} (Fig. 4).

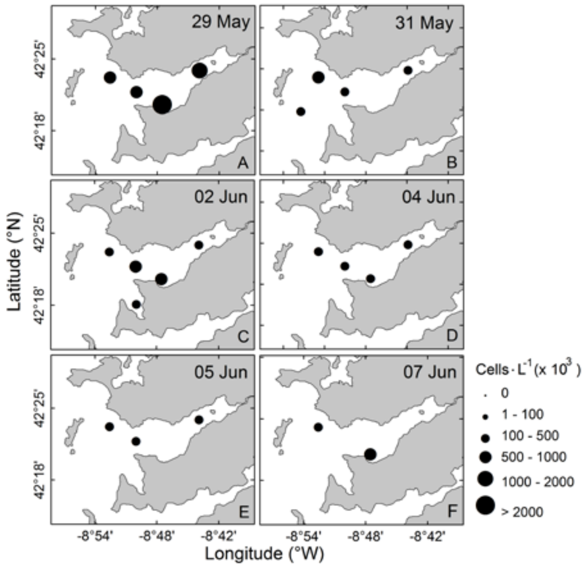

Fig. 3. Spatial and temporal evolution of *P. seriata* (x 10^3 cells L^{-1}) during the survey.

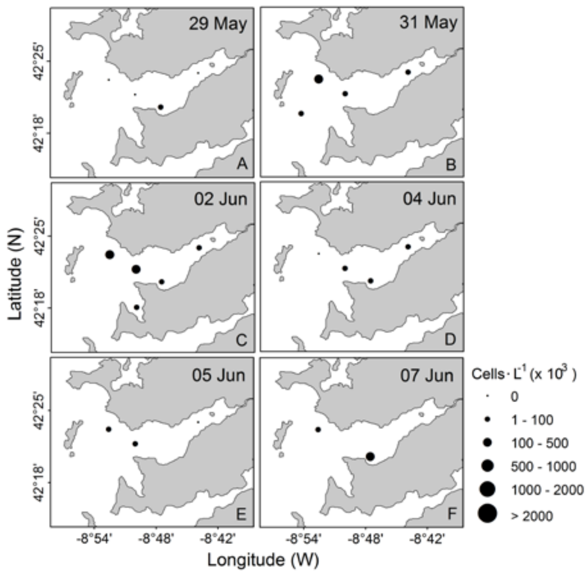

Fig. 4. Spatial and temporal evolution of *P. delicatissima* (x 10^3 cells L^{-1}) during the survey.

Circadian variability of the *P. delicatissima* and *P. seriata* groups during the two 24-h cycles at station 2 seemed to be dominated by tidal forcing. During both 24-h cycles, the *P. seriata* group was dominant. Intratidal distribution showed cell maxima of *P. delicatissima* and *P. seriata* groups appeared at low tide during maximum stratification (Figs. 5 and 6).

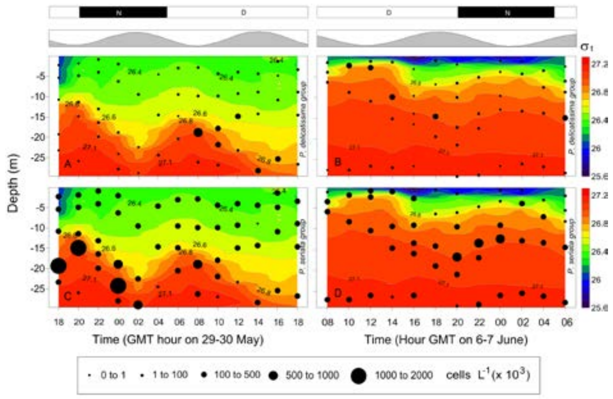

Fig. 5. Intratidal distribution of *Pseudo-nitzschia delicatissima* and *P. seriata* groups (x10^3 cells L^{-1}) sampled during two 24h-experiments at station 2.

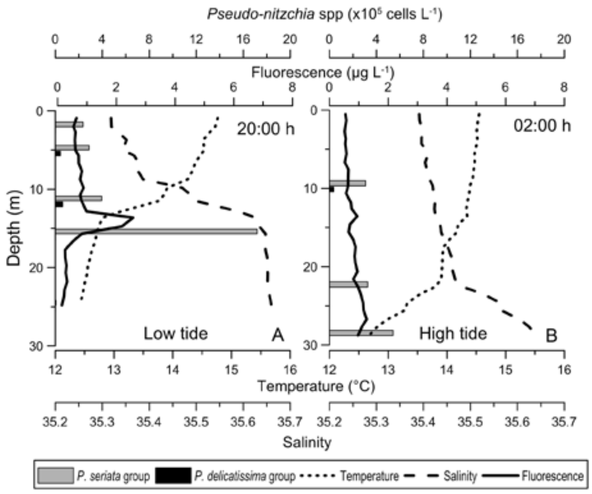

Fig. 6. Vertical distribution of *P. delicatissima* and *P. seriata* groups and CTD-profile during low (A) and high tide (B).

Results here show a different mechanism of bloom formation than that described by Velo-Suárez *et al.* (2008) in the same location. These authors showed maximum densities of *Pseudo-nitzschia* spp (>1.5x10^6 cells L^{-1}) forming thin layers located within a very steep pycnocline (~2 kg m^{-3} /10 m) under upwelling-favourable winds; sinking and erosion of the thin layer—that included a senescent population of *Pseudo-nitzshia* spp.—was then associated with downwelling-favourable winds.

The spring-neap tidal variability of *Pseudo-nitzschia* groups was observed also from MERIS and MODIS satellite images (ground-truthed with plankton counts), which recorded a top water layer displacement of high concentrations of chlorophyll towards the coast on 28 May (Fig. 7).

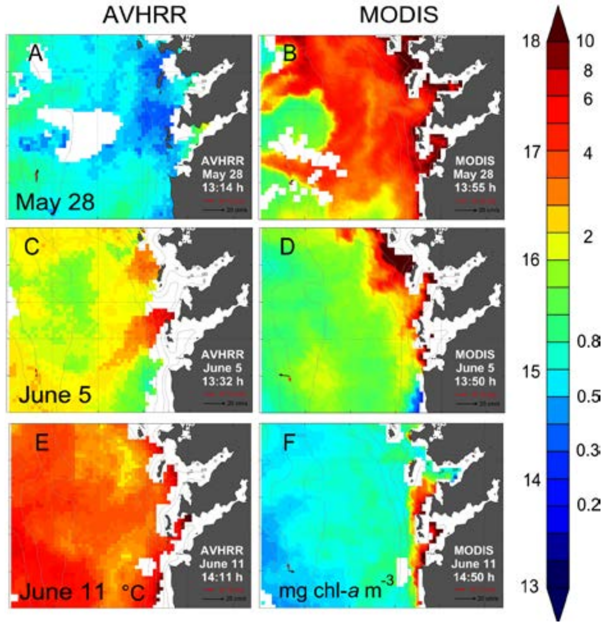

Fig. 7. Sea Surface Temperature and Chl-*a* fluorescence estimates from AVHRR and MERIS satellite data during the cruise period. White patches represent clouds.

This kind of filaments have been reported to constitute an important mechanism of cross-shelf transport of phytoplankton populations during upwelling events in the Iberian upwelling system (Barton *et al.* 2001, Smyth *et al.* 2001) and may be responsible for the significant decrease in *Pseudo-nitzschia* densities observed during the second half of the cruise.

Conclusions

Hydrodynamic control is crucial in the formation, transport and dissipation of *Pseudo-nitzschia* spp. blooms in the Galician Rías Baixas (NW Spain).

Upwelling-downwelling cycles, modulated by semidiurnal and spring-neap tides are the main forcing elements controlling the formation, transport and dissipation of *Pseudo-nitzschia* populations.

The sudden increase of *Pseudo-nitzschia* densities were caused by physical advection, in contrast with previously described scenarios of *in situ* growth and thin layer formation in the Galician Rías.

Pseudo-nitzschia blooms were tracked with MERIS and MODIS satellite images, which recorded a surface displacement (approx. 0-10 m) of high concentrations of chlorophyll towards the coast.

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References

Barton, E.D., Inall, M.E., Sherwin, T.J. et al. (2001). Progress in Oceanography 51: 249- 267.

FAO (2012) Food and Agriculture Organization of the United Nations, Rome, 230 pp.

Fraga, S., Alvarez, M.J., Míguez, Á. et al. (1998). In: Reguera, B., Blanco, J., Fernández, M.L. & Wyatt, T., (eds) Harmful Algae, Xunta de Galicia & IOC of UNESCO, pp. 270-273.

Hasle, G.R., 1965. Skr. Nor. Vidensk. Akad. Oslo I . Mat. Naturu. Kl. Ny Ser. 18:1- 45.

Salgado, C., Maneiro, J., Correa, J. et al. (2003). In Molluscan Shellfish Safety, Villalba, A., Reguera, B. Romalde, J.L, & Beiras, R. (eds.). Xunta de Galicia & IOC of UNESCO, pp. 169-177.

Smyth, T.J., Miller, P.I., Groom, S.B. et al. (2001). Progress in Oceanography. 51 (2-4): 269-281.

Velo-Suárez, L., González-Gil, S., Gentien, P. et al. (2008). Limnology and Oceanography. 53(5): 1816-1834.