

Recent decadal variability in climate, oceanography and plankton in the northern Spanish shelf



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Variability in time series of oceanographic (temperature, salinity), chemical (nutrients) and plankton variables (species abundance, chlorophyll, primary production) since 1990 was analysed along an upwelling gradient in the northern Spanish shelf (Galicia and Mar Cantábrico) and related to climate.

Hydrography

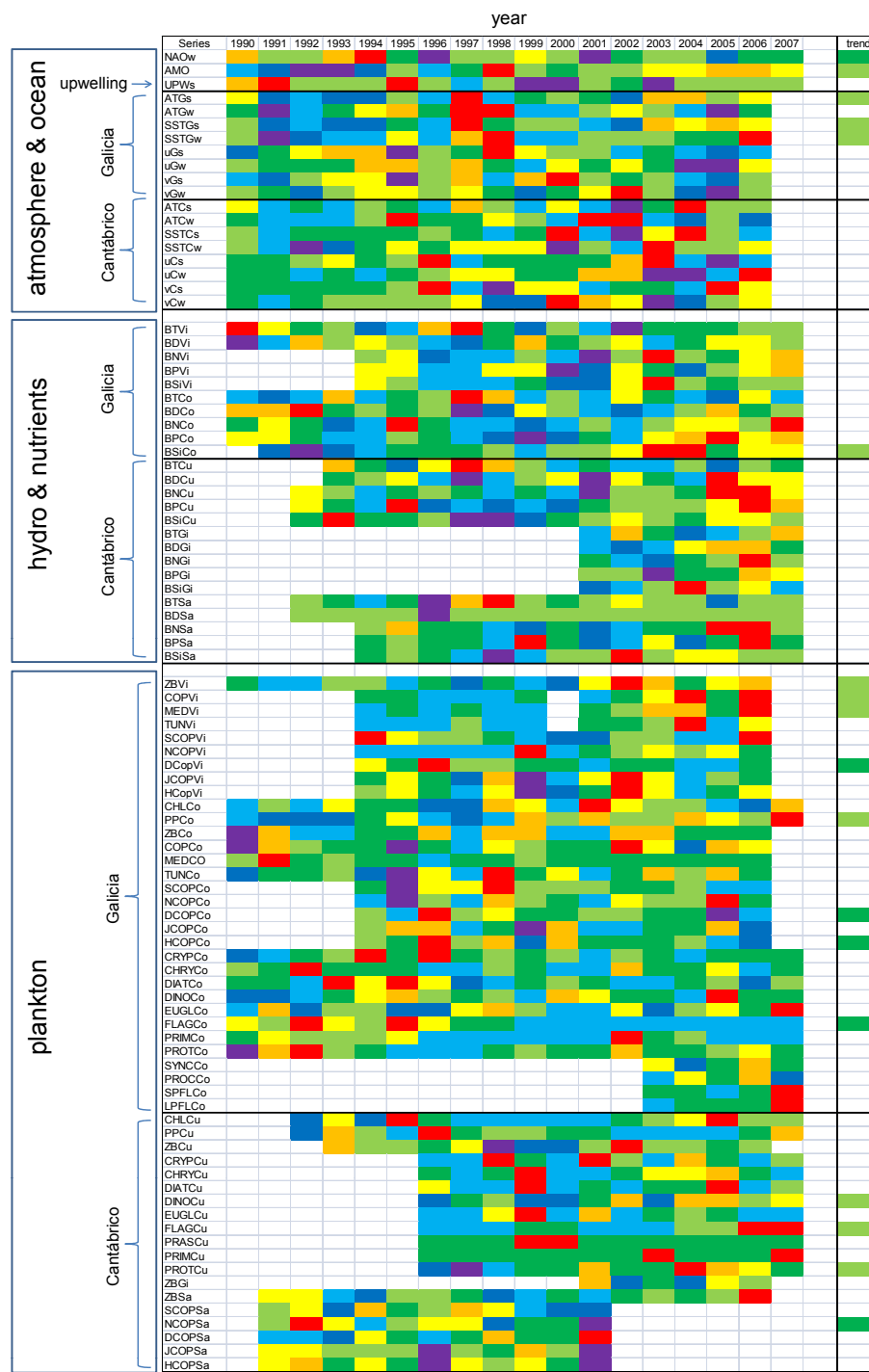
Warming ($>0.02 \text{ }^\circ\text{C yr}^{-1}$) was significant through the water column and year-round, though subjected to strong interannual variability related to regional atmospheric anomalies. Such interannual variability together with the alternating upwelling-downwelling circulation regime prevented to draw any consistent pattern concerning stratification.

Plankton

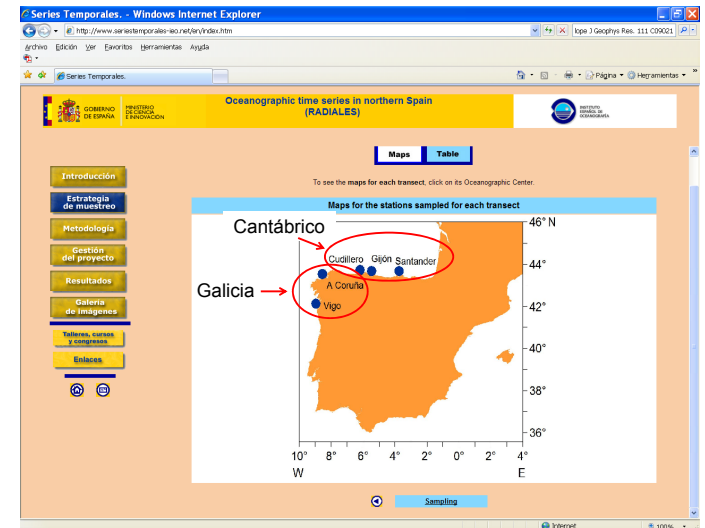
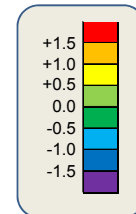
Dinoflagellates increased in all series and diatoms decreased in Galicia, following the decreasing trend in upwelling. No significant trends emerged in chlorophyll, while primary production increased in Galicia and decreased in the Mar Cantábrico.

Small phytoplankton and bacteria, measured only since 2002, still do not show clear trends but the results suggest a greater contribution of the smallest cells with warming.

Copepod species richness and biomass increased but with large local variability: warm tolerant species increased and opportunistic species decreased, particularly in the Mar Cantábrico. Gelatinous zooplankton (medusae and tunicates) did not show any common trend at local scales.



Anomalies (matrix) and trends (right column, $P>0.05$) in annual averages of the series (standardized and normalized). Values were colour-coded



In situ series were obtained by the project RADIALES (<http://www.seriestemporales-ieo.net>).

The series were decomposed in linear trends, periodic and autocorrelation components and their residuals were crosscorrelated with those of climate. All series displayed a strong seasonality.

Nutrients

Nitrate, phosphate and silicate increased through the region but the low spatial correlation between series stressed the importance of local factors for fertilization.



The RADIALES project

The objective of the project RADIALES, formulated in 1990, aims at "understanding and modelling the response of the marine ecosystem to the sources of temporal variability in oceanographic and planktonic components, particularly focusing in those factors and processes affecting biological production and potentially altering the ecosystem services". This project represents the oldest multidisciplinary ocean observation initiative still active in Spain.

References

Bode, A., Alvarez-Ossorio, M.T., Cabanas, J.M., Miranda, A. and Varela, M., 2009. Recent trends in plankton and upwelling intensity off Galicia (NW Spain). *Progress in Oceanography*, 83: 342-350.

Bode, A., Anadón, R., Morán, X.A.G., Nogueira, E., Teira, E. and Varela, M., 2011. Decadal variability in chlorophyll and primary production off NW Spain. *Climate Research*, in press.

Bode, A., Alvarez-Ossorio, M.T., Miranda, A., López-Urrutia, A. and Valdés, L., 2011. Comparing copepod time-series in the north of Spain: spatial autocorrelation of community composition. *Progress in Oceanography*, in press.

González-Pola, C., Lavín, A. and Vargas Yañez, M., 2005. Intense warming and salinity modification of intermediate water masses in the southeastern corner of the Bay of Biscay for the period 1992-2003. *Journal of Geophysical Research*, 110(C05020): doi:10.1029/2004JC002367.

Llope, M., Anadón, R., Sostres, J.A. and Viesca, L., 2007. Nutrients dynamics in the southern Bay of Biscay (1993-2003): Winter supply, stoichiometry, long-term trends, and their effects on the phytoplankton community. *Journal of Geophysical Research*, 112: doi:10.1029/2006JC003573.

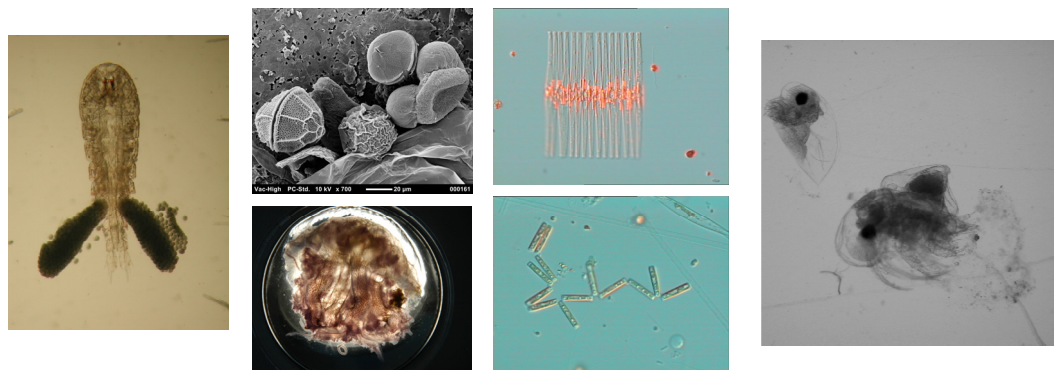
Morán, X.A.G., López-Urrutia, A., Calvo-Díaz, A. and Li, W.K.W., 2010. Increasing importance of small phytoplankton in a warmer ocean. *Global Change Biology*, 16: 1137-1144.

Somavilla, R., González-Pola, C., Rodríguez, C., Josey, S., Sanchez, R.F. and Lavín, A., 2009. Large changes in the hydrographic structure of the Bay of Biscay after the extreme mixing of winter 2005. *J. Geophys. Res.*, 114(C01001): doi:10.1029/2008JC004974.

Valdés, L., López-Urrutia, A., Cabal, J., Alvarez-Ossorio, M., Bode, A., Miranda, A., Cabanas, M., Huskin, I., Anadón, R., Alvarez-Marqués, F., Llope, M. and Rodríguez, N., 2007. A decade of sampling in the Bay of Biscay: What are the zooplankton time series telling us? *Progress in Oceanography*, 74: 98-114.

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Climatic indices and upwelling showed variable and lagged correlations with nutrient and planktonic variables, suggesting the existence of non-linear interactions.