15-Years of sampling in the Bay of Biscay:
What are Oceanographic time series telling us?

J. Cabal[1], A. López-Urrutia[1], C. González-Pola[1], J.M. Rodríguez[1], E. Nogueira[1], X. A. G. Morán[1], L. Valdés[1], M. Varela[2], M. Alvarez-Ossorio[2], A. Bode[2], A. Lavín[3], M. Rodríguez[3], A. Miranda[4], M. Cabanas[4], R. Anadón[5], M. Llope[5]

[1]C.O. de Gijón, Instituto Español de Oceanografía (MEC). Avda. Príncipe de Asturias 70 bis, E-33212 Gijón - Asturias, Spain.
[2]C.O. de Coruña, Instituto Español de Oceanografía (MEC). Paseo Marítimo Alcalde Francisco Vázquez 10, E-15001 A Coruña, Spain.
[3]C.O. de Santander, Instituto Español de Oceanografía (MEC). Promontorio de San Martín s/n. Apdo 240. Santander. Spain.
[4]C.O. de Vigo, Instituto Español de Oceanografía (MEC). Cabo Estay- Cánido. Apdo. 1552. 26280 Vigo. Spain.
[5]Dpto. de Biología de Organismos y Sistemas. Universidad de Oviedo. C/ Catedrático Rodrigo Uria s/n . 33071 Oviedo. Spain .

METHODS

The project "Studies on time series of oceanographic data" or Radiales (Valdés et al., 2002) was established as a pilot project by the Instituto Español de Oceanografía (IEO). The project comprises a network of 19 sampling stations in 5 different transects distributed along the N and NW coast of Spain (Fig. 1). Each station is visited monthly. Samples are taken for hydrography, nutrients and planktonic communities following standard protocols (González-Pola et al. ,2005; Valdés et al, en prensa).

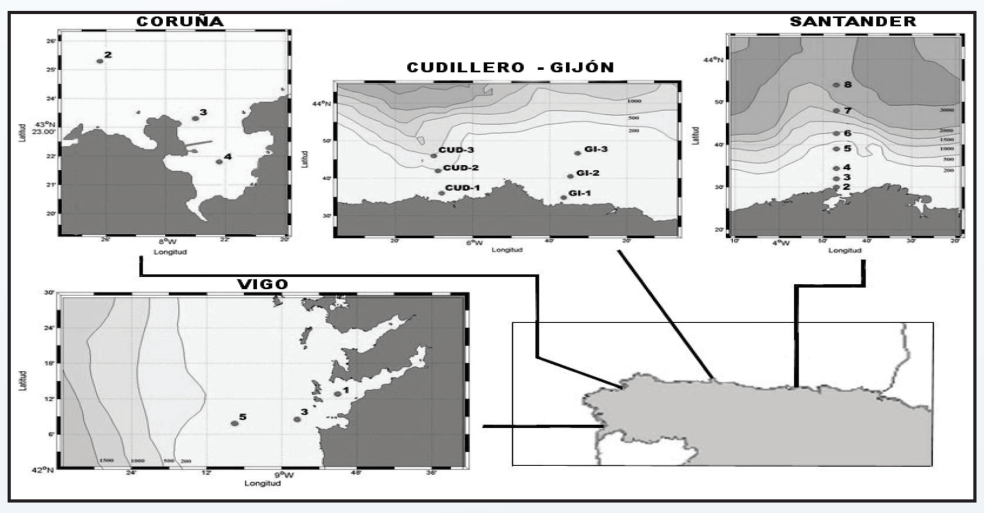

Figure. 1. Location of sampling stations in N and NW Spain: Vigo, Coruña, Cudillero and Santander, which Time Series started at 1997, 1990, 1993, 2001 and 1991

RESULTS

Surface Temperature

The Project RADIALES has provided hydrographical data for the southern Bay of Biscay since 1991. Using these time series, a warming trend of 0.05ºC yr^{-1} in the surface layer over the shelf off Santander has been calculated by Lavín et al. (1998).

Temperature patterns over the shelf are different in Galicia (sections of Coruña and Vigo) and in the Cantabrian Sea (sections of Cudillero and Santander). The warming trend in surface waters varies at regional scale, this in upward in the Cantabrian Sea, but less evident in Galicia. It is also noted that due to coastal upwelling maximum temperatures in Galicia do not reach the values observed in the Cantabrian Sea. A special feature noted in the last 5 years is that the seasonal cycle of surface temperature in the Cantabrian sea has increased its amplitude with warmer summers and colder winters Sea surface Temperature (SST) have been rising by 0.2 -0.5 ºC in the last decade.

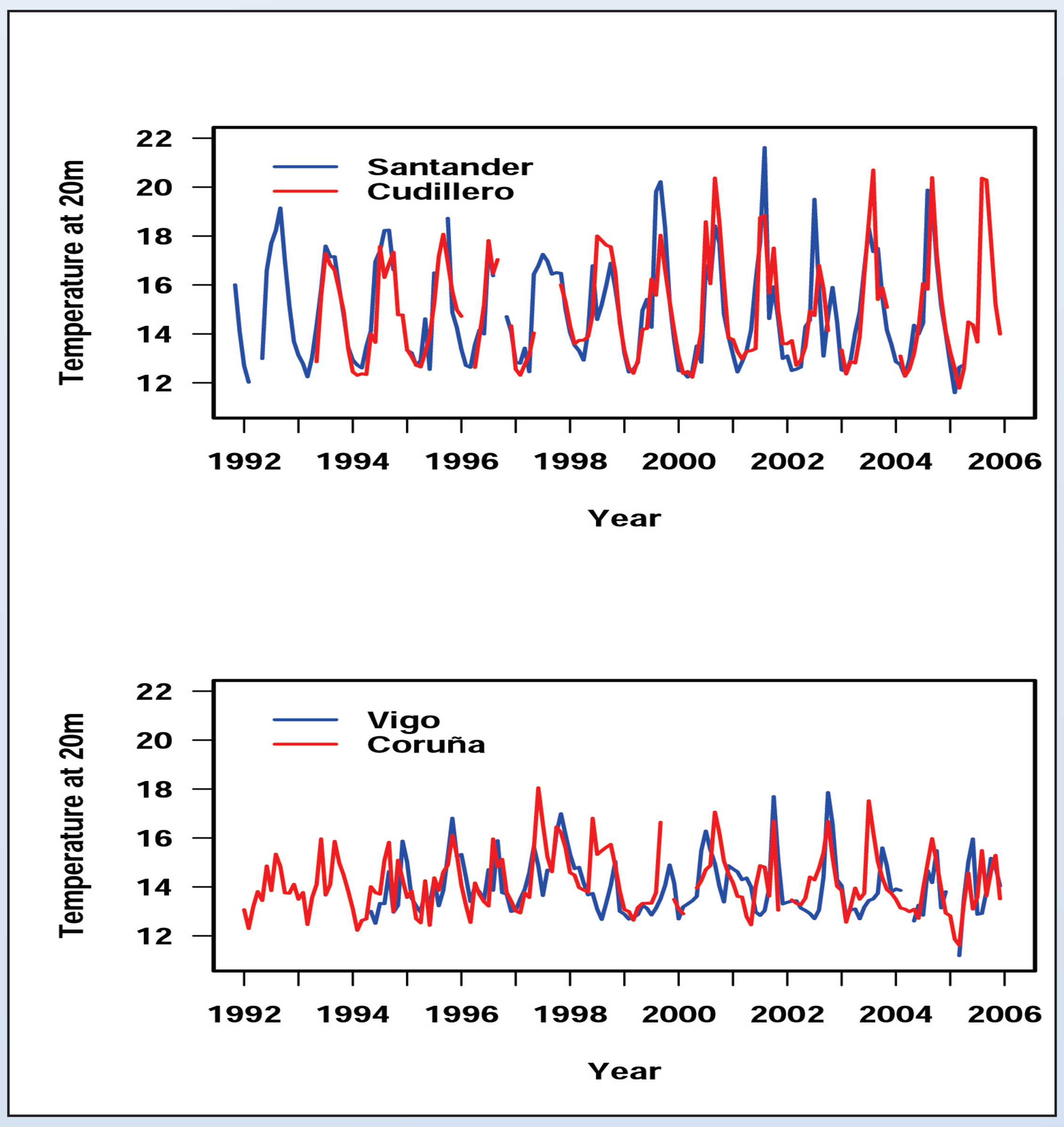

Figure. 2. Temperature at 20m for the shelf-break stations in the Cantabrian Sea (Upper panel) and in the Galician coast (Lower Panel).

Temperature in the Mid-depth Waters

Waters below the mixed layer, down to at least 1000 m depth, showed an intense warming trend from the begining of the series (Fig. 3, González-Pola et al., 2005). However the severe winters of 2005 and 2006 at the Bay of Biscay dropped quickly the temperature of the upper central water (<300m) to early 90`s values.

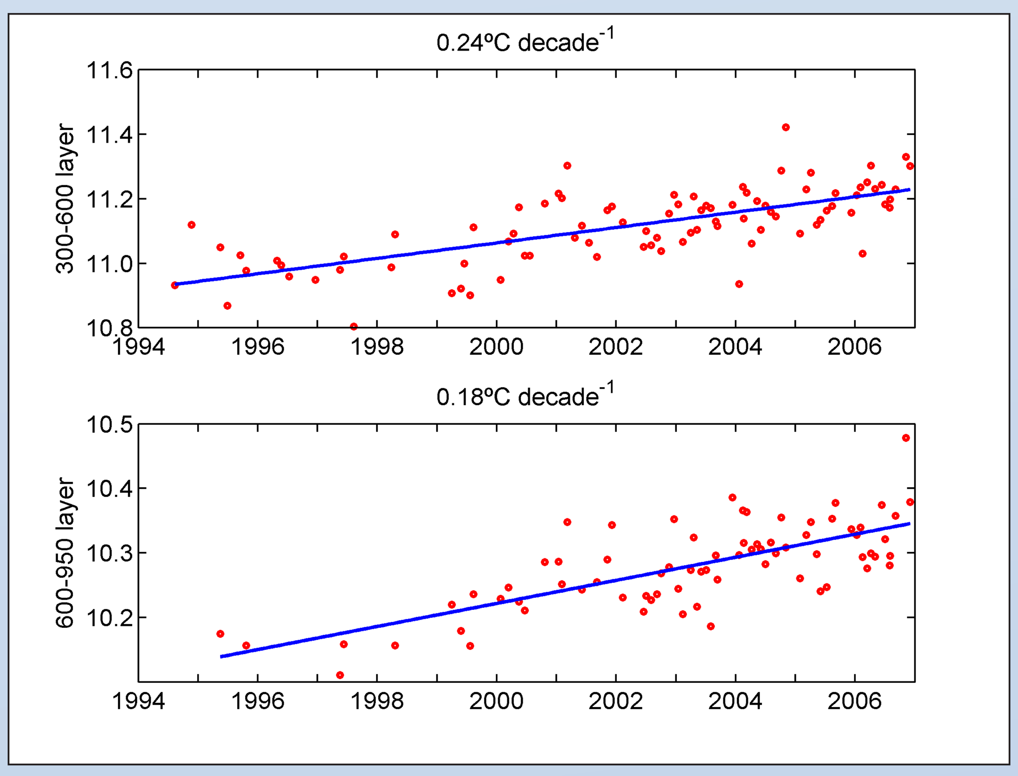

Figure 3.Potential temperature at mid-depth waters at the Bay of Biscay

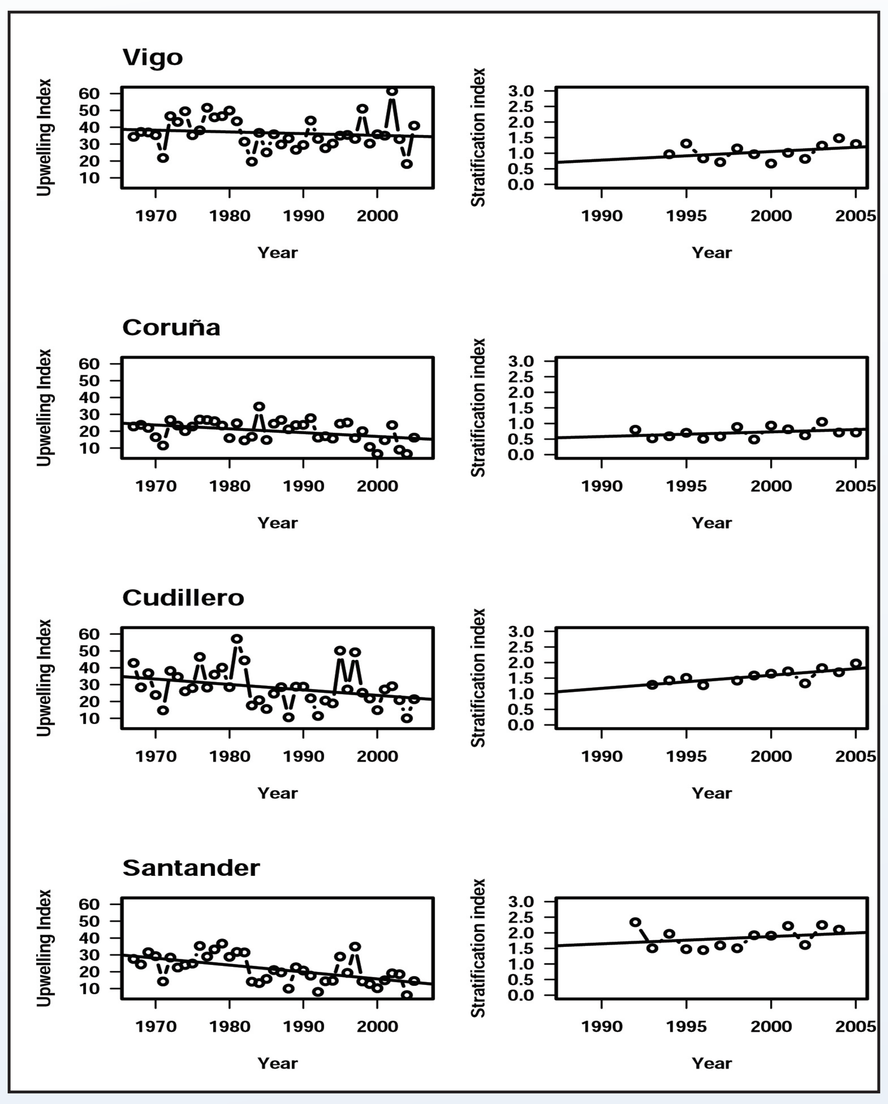

Figure 4. Time series of mean April-September yearly Upwelling index (Left panel) and Stratification index calculated as the standard deviation of water column temperature (Right panel).

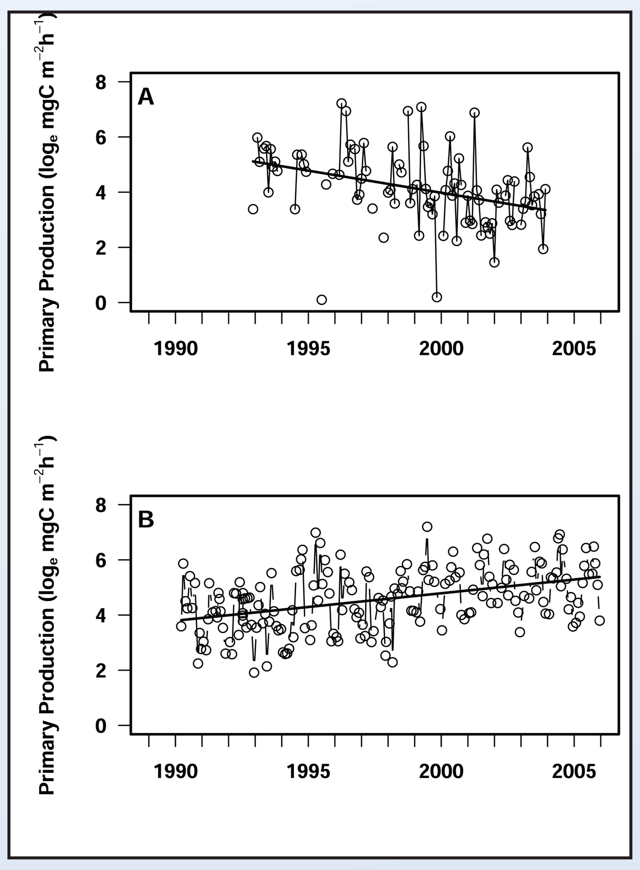

Figure 5. Variation in primary production along the period 1993-2003 at the shelf-break station of the transect Cudillero (A) and at the shelf station of transect Coruña (B).

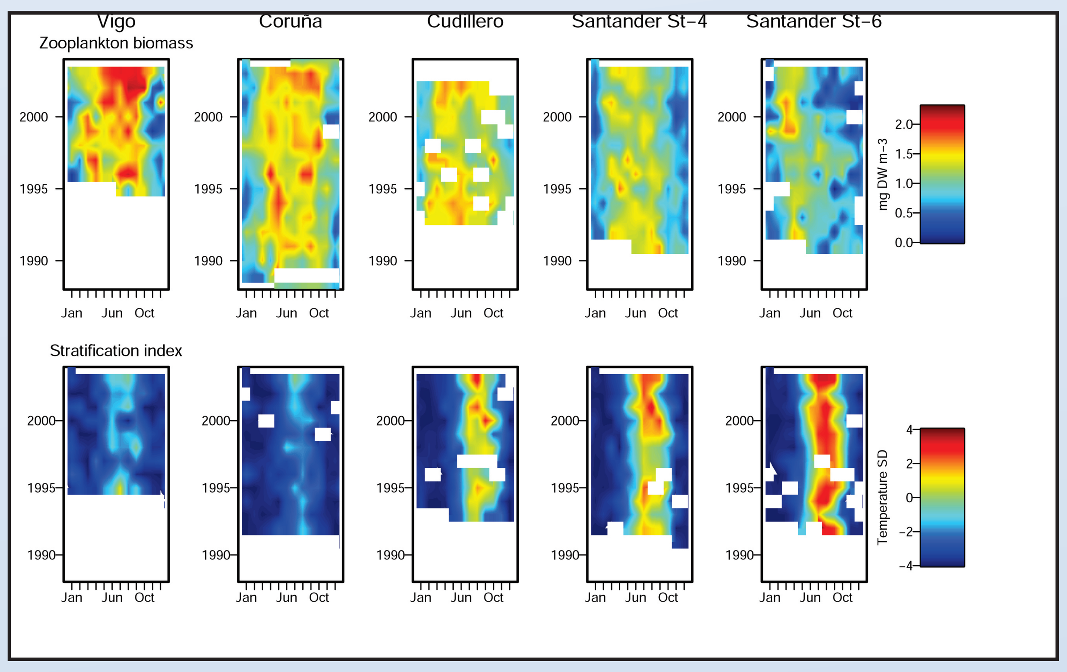

Figure 7. Zooplankton biomass (Upper panels) and stratification index (Lower panels) for each of the shelf-break stations in each transect and for the most oceanic station off Santander

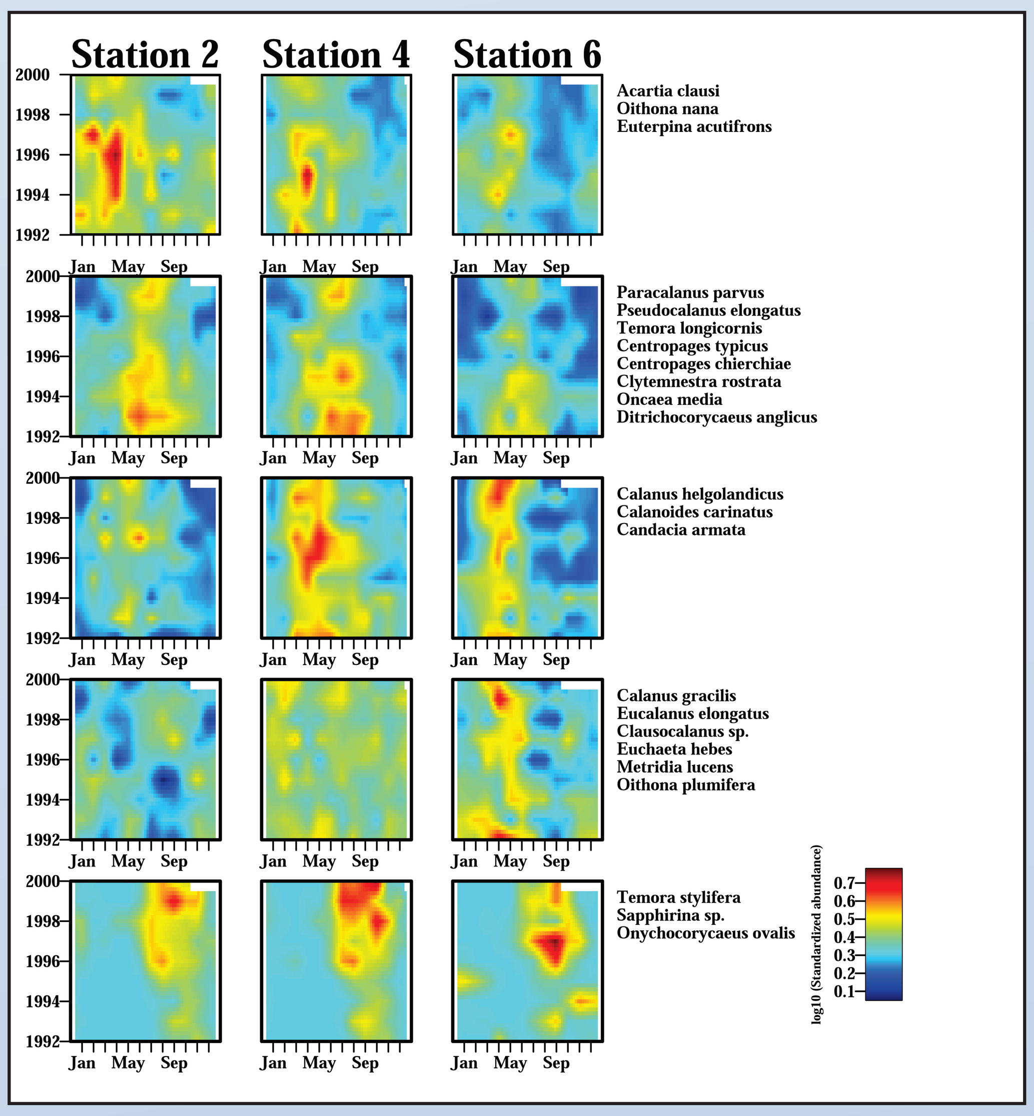

Figure. 8. Species associations in the Santander Transect as depicted from the k-means cluster. For each cluster we calculated the average to inspected graphically the characteristics of the group.

Mesoscale Processes

Upwelling (calculated for each of the transects from the Pacific Fisheries Environmental Laboratory Global Upwelling Index) is more intense west of Cape Peñas and Ortegal up to Finisterre, and acts as a mechanism generating spatial variability between the western and eastern zone of the Cantabrian Sea, and between the coastal mixed waters and the neighbouring oceanic stratified areas. Upwelling events are highly variable in intensity and frequency and they show a significant year to year variability (Fig. 4). Cabanas et al. (2003) showed that a notable shift in the winds has occurred during the last two decades, resulting in a reduction in the spring-summer upwelling off the northwest of the Iberian Peninsula, as shown here in Figure 4. Lavín et al. (1998) noted that the water column off Santander experienced a higher degree of stratification, which also remains stratified for a longer period of time. The same pattern is now observed for the other transects (Fig. 4).

Primary Production

The increase of stratification and decrease in upweling intensity act together lessening the growth of phytoplankton and we can hypothesize that the whole region will be less productive in the future. A response in such direction is evidenced in the transect off Cudillero where primary production decreased significantly in the period 1993-2000).On the contrary, primary production increase in the La Coruña (Fig.5), where stratification index were weeker.

Bacterial abundance

In addition to a clear seasonal signal with maxima in summer and minima in winter, we observed a significant increase of bacterial abundancer during the summer months over the sampling period ($r=0.71$, $p=0.003$, $n=14$)in the Gijón transect (Fig.6).

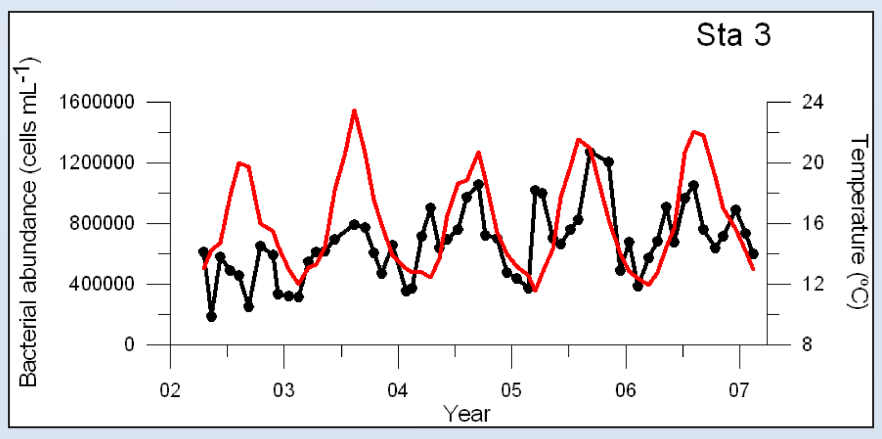

Figure 6. Surface temperature and mean abundance of heterotrophic bacteria for 0-75 m. layer at Station 3 off Gijón.

Zooplankton biomass

Indeed, the annual cycle of zooplankton biomass seems to be restricted in time, with the annual decrease in zooplankton biomass matching the onset of stratification (Fig.7).

Zooplankton species

Thermophilic and opportunistic species (as Temora stylifera, Oncaeamedia and Ditrichocorycaeus anglicus) have advantage if the environment changes towards warmer conditions whereas other species characteristic of cold waters and more dependent of phytoplankton blooms formed by large sized cells are in clear disadvantage if this type of change occurs (Fig.8).

CONCLUSIONS

Long-term research programmes based on systematic observations have render significant results to the Earth's Sciences in general and to the Oceanography in particular. The IEO Spanish project Radiales has allowed us to set with statistical significance the range of variability of several environmental variables and biological communities. We have determined significant warming trends as well as to describe some direct and indirect effects in the water column and in the pelagic ecology. The project has substantially contributed to get a deeper knowledge on planktonic communities and species and to produce baselines, climatologies and reference levels for the North Spanish's coast, which allow us to do accurate evaluations on the effects of environmental perturbations on the ecosystem, forecast the expected recovering time and monitor the ecosystem for reversion to the previous state.

References

Cabanas, J.M., Lavín, A., García, M.J., González-Pola, C., & Tel Pérez, E. (2003).Oceanographic variability in the northern shelf of the Iberian Peninsula. ICES marine Science Symposia, 219, 71-79.

González-Pola, C., Lavín, A., & Vargas-Yáñez, M. (2005). Intense warming and salinity modification of intermediate water masses in the southeastern corner of the Bay of Biscay.Journal of Geophysical Research, 110: C05020.

Lavín, A., Valdés, L., Gil, J., & Moral, M. (1998). Seasonal and interannual variability in properties of surface water off Santander (Bay of Biscay) (1991-1995). Oceanologica Acta., 21(2), 179-190.

Valdés, L., Lavín, A., Fernández de Puelles, M.L., Varela, M., Anadón, R., Miranda, A., Camiñas, J., & Mas, J. (2002). Spanish Ocean Observation System. IEO Core Project: Studies on time series of oceanographic data. In N.C. Fleming et al. (ed.), Operational Oceanography: Implementation at the European and Regional Scales, (pp 99-105). Elsevier Science, Amsterdam.

Valdés, L., O'Brien, T., & López-Urrutia, A. (2005). Zooplankton monitoring results in the ICES area, Summary Status Report 2003/2004. ICES Cooperative Research Report, 276, 34 pp.

Valdés, L., A. López-Urrutia, J. Cabal, M. Alvarez-Ossorio, A. Bode, A. Miranda, M. Cabanas, I. Huskin, R. Anadón and N. Rodríguez (en prensa).A decade of sampling in the Bay of Biscay: What are the zooplankton time seriestelling us?. Progress in Oceanography.