3. Development of ecological models. Simulate the 3-dimensional ocean circulation, temperature, salinity, and primary production of the Nordic Seas using an existing hydrodynamic model and analyse the numerical results. Develop a 3-dimensional population dynamics model of *Calanus*, driven by output from the circulation model, to simulate patterns of production and abundance under the contrasting climate phases, and develop an individual based model of herring feeding and migration for coupling to the *Calanus* population model, to simulate the fluctuations in condition and migration patterns of herring in the Nordic Seas under contrasting phases of climate.

ADAPT

At present, there exists a conceptual model of the effects of the physical and seasonal environment in the Norwegian Sea on the feeding behaviour, vertical and horizontal migrations, growth and life cycle of *Calanus finmarchicus* and herring, and also of the effects of these two populations upon each other. ADAPT aims at exploring this model in detail, and to move from a conceptual to a numerical model of the adaptation of these two populations to the environment and each other (Fig. 3). ADAPT will also challenge the conceptual model by analysis of field data for the hydrography-phytoplankton-*Calanus* and the *Calanus*-herring interactions. A numerical simulation model of hydrodynamics, phytoplankton, zooplankton and fish will be valuable for later studies of the impact on environmental variation and change.

Main goal

ADAPT aims at quantifying the effects of the physical environment and the other biological population for the evolutionary adaptation of the populations of *Calanus finmarchicus* and Norwegian spring spawning herring in the Norwegian Sea.

Specific objectives

Through both field work and modeling

1. Demonstrate the effects of the seasonality and physical environment on the life histories and spatial behaviour of *Calanus finmarchicus* and herring.
2. Quantify the effect of the other adaptive population on the behaviour and life history of the same two populations.

The SURVIVAL Project: Final results and new hypotheses

A. Miguel P. Santos (amsantos@ipimar.pt) & Álvaro Peliz (apeliz@ipimar.pt)
INIAP-IPIMAR, Lisboa, Portugal

It is known that the populations of small pelagic fishes (SPF) present important natural fluctuations in their abundance. These fluctuations seem to be related, among other factors, to environmental variability.

In the last decades, a decline has been observed in sardine (*Sardina pilchardus* Walbaum, 1792) recruitment, especially in the northwest coast of continental Portugal. A larger frequency of favorable upwelling winds (northerlies) during the months of winter has also been observed. Since the time of reproduction of SPF off Portugal happens in the winter, these events can influence recruitment. Results of the PO-SPACC project showed that a statistical relationship exists between these environmental factors and the variability of recruitment (Santos *et al.*, 2001; Borges *et al.*, 2003).

There is also evidence that these alterations could happen on a more global scale. The North Atlantic Oscillation (NAO) is a large-scale climatic phenomenon (e.g. Hurrel and van Loon, 1997). Positive values of the NAO index can lead to increased winter upwelling episodes in the Portuguese western coast (e.g. Borges *et al.*, 2003). Since the beginning of the 1970's, NAO has been in a positive dominant phase (e.g. Jones *et al*., 1997). This important alteration in the climatic regime between the period 1940-1960's and the 1970-1990's was coincident with the fluctuations observed in sardine catches - a cycle of high catches before the 1970's and a period of low catches in the years after (Borges *et al.*, 2003).

The basis of this hypothetical relationship is “simple”. In the presence of coastal upwelling, eggs and larvae can be dragged from the shelf to unfavorable areas, from hydrodynamic and trophic points of view. Thus, the increase of the frequency and intensity of northerly winds off the western Iberia during the reproduction time of SPF could lead to a decline of their recruitment.

To investigate these hypotheses, the SURVIVAL project (Santos and Borges, 2000), funded by the Portuguese Science Foundation (FCT) and coordinated by INIAP-IPIMAR, was developed as a national contribution to GLOBEC.

The results of SURVIVAL demonstrated that transport due to the wind *per se*, could not explain the complex circulation observed in the shelf/slope during the SURVIVAL'2000 survey (Santos *et al.*, in press), as well as the patterns of dispersion of eggs and larvae associated with it. It was clear that other factors contributed for the surface circulation and patterns of dispersion of ichthyoplankton, namely: (i) the structure and circulation of the Western Iberia Buoyant Plume-WIBP (Peliz *et al.*, 2002); and (ii) the circulation of the slope induced by a poleward current - the Iberian Poleward Current-IPC (Peliz *et al.*, 2003) and the mesoscale structures associated with it.

The WIBP is a lens of water of ‘low' salinity (<35.8) fed by winter discharges of several rivers onto the NW coast of the Iberian Peninsula. During "typical" winter conditions (i.e. without coastal upwelling) the WIBP is bounded to the area of the shelf close to the coast and more pronounced to the north of the Mondego river's mouth (Peliz *et al.*, 2002). In situations of coastal upwelling, the WIBP can extend far beyond the shelf break, under the form of a thin surface layer of about 25m depth, over the warmer and more saline IPC (Fig. 1). As a consequence, the typical sea surface temperature signature of the IPC disappeared (Santos, 2000). It is also interesting to note that, close to the coast, there were salinity values particularly higher than the ones that characterized the discharge of the rivers.

This is an indication that the WIBP was advected offshore in consequence of coastal upwelling (Santos *et al*., in press).

The IPC is a current created by the interaction the Western

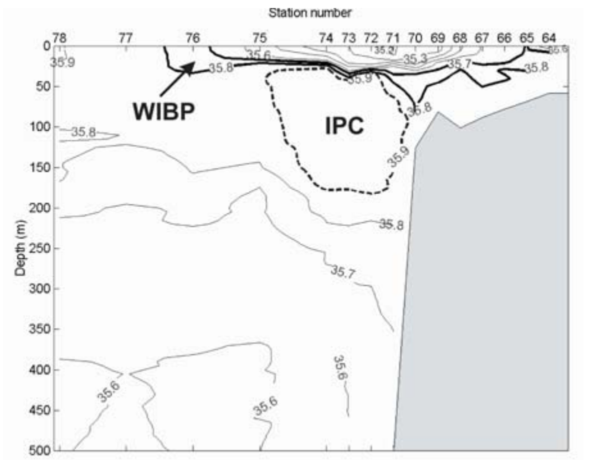

Figure 1. Vertical distribution of salinity at a transect during SURVIVAL'2000 survey The thick lines delimit the WIBP. The dashed line represents the IPC (Adapted from Chícharo et al., 2003).

Iberia Winter Front-WIWiF with the continental margin (Peliz *et al.*, in press). The WIWiF is located, in general, to the latitude of Lisbon. The IPC and all their associated structures are usually observed north of this area. In addition to the transport due to the wind, the slope current is very important in the definition of the advection patterns of larvae (e.g. Santos *et al.*, in press), because it can: (i) induce convergence areas in the continental shelf; (ii) work as a regulatory factor in the alongshore transport; and (iii) constitute a mode of change between the shelf and the open ocean, taking into account the mesoscale features (e.g. eddies) associated with it.

The biological consequences of these two important structures were evidenced in the results of the SURVIVAL project (e.g. Santos *et al.*, in press; Chícharo *et al.*, 2003; Ribeiro *et al.*, submitted). Mechanisms for retention and concentration of biological material were proposed for the ichthyoplankton (Santos *et al.*, in press) and for the phytoplankton (Ribeiro *et al.*, submitted).

Unlike what it would be expected in a situation of coastal upwelling during winter in the context of our hypothesis (great larval mortality in situations of winter upwelling), almost all of the sardine larvae captured in the survey were in good nutritional conditions and only 0.64% of them were classified as starving (Chícharo *et al.*, 2003). This result was explained in view of the good food conditions available at that time, which was estimated through the abundance of micro-zooplankton and by daily egg production of copepod (Chícharo *et al.*, 2003).

Ribeiro *et al.* (submitted) provide further support for this situation. Using SeaWiFS-derived phytoplankton biomass distributions and in situ measurements, these authors verified that the presence of the WIBP allowed a significant growth of phytoplankton biomass, contrary to expectations.

Santos *et al.* (in press) demonstrated that the transport of sardine larvae in the area was largely conditioned by local structures (e.g. WIBP and IPC), which cannot be simulated with simplified Ekman transport models. The retention of the ichthyoplankton in general, and of the sardine larvae in particular (Fig.2), along convergence areas formed by the interaction of these local structures, ensured their survival.

In view of those results, further modelling efforts were conducted using the Regional Oceanic Modeling System (ROMS) to simulate more realist oceanographic conditions in the region and to study other mechanisms of larvae transport other than driven by the wind (Peliz *et al.*, 2003; Peliz *et al.*, in press). A first step was the modelling of the IPC. The most striking characteristic of this modeling is the warm anomaly to the north of the Estremadura Promontory associated to the poleward advection of lighter southern waters. The time-scale for the development of the IPC as a tongue-like slope-trapped flow is about one month. After that period, a slope-following 20-30km wide current with intensities between 0.15-0.30ms^{-1} is observed. The poleward flow is usually confined to the upper 300-400m. Below this layer, weaker equator-ward currents (0.05 ms^{-1}) are found with cores at about 500 to 600 meters. In a time-scale of about 2 months, the turbulent nature of the IPC starts developing. The most evident features are anticyclones generating in the lee of topography (mainly the Estremadura Promontory, Aveiro Canyon, and Porto Canyon). These eddies are 60 to 80km wide and may remain trapped to the slope for several months or be expelled offshore. The interaction of these different structures of the flow contributes to the generation of the Coastal Transition Zone and to the ejection off the slope of some of these eddies (Swoddy generation). The modeled Swoddies are deep (1000m) dipolar structures with the anticyclonic eddy intensified at the surface and the cyclone intensified at about 500 meters.

These results indicate that major features of the interaction of the WIWiF with the shelf and the generation of the IPC can be simulated with an encouraging degree of realism. We foresee

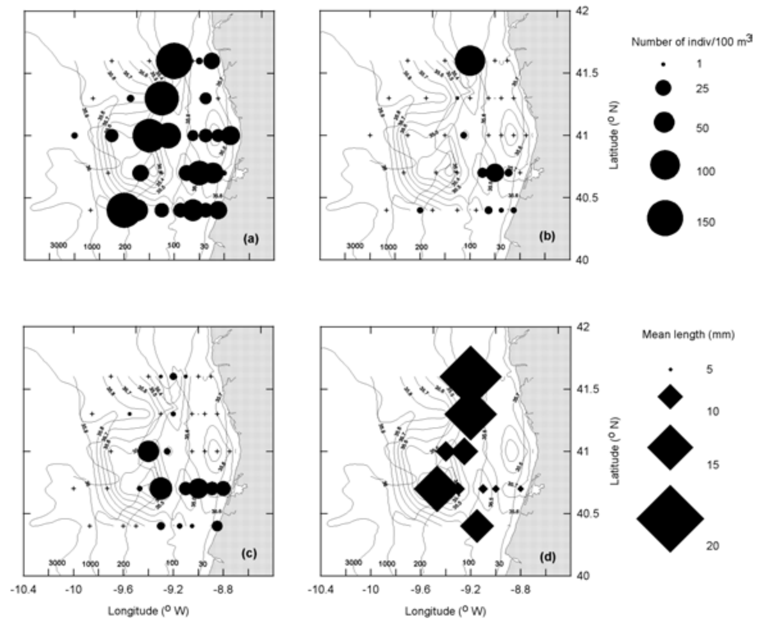

Figure 2. Distribution and abundance of ichthyoplankton during the SURVIVAL'2000 survey (February 2000): (a) number of fish eggs for 100 m^3; (b) number of sardine eggs for 100 m^3; (c) number of sardine larvae for 100 m^3; and (d) mean length (mm) of sardine larvae. The fine lines represent the bathymetric of the 30, 100, 200, 1000 and 3000 m. (Adapted from Santos et al., in press)

the development of different circulation scenario by varying the governing factors: intensity and meridional position of the WIWiF, volume and structure of the WIBP, and the variable atmospheric forcing. It is expected that simple particle tracking exercises within this circulation scenarios may provide us with a better understanding of the variability in sardine larvae distribution.

In conclusion, the studies in the frame of the SURVIVAL project demonstrated that atmospheric parameters (e.g. wind), in spite of their importance, are not by themselves enough to understand such complex systems. Only with a better appreciation of the oceanographic processes can we move forward in our understanding of the dynamics of these ecosystems.

The INIAP-IPIMAR team keep these research activities related with GLOBEC in the frame of national and international projects, funded by FCT and the UE. As examples, we can refer the PELAGICOS Programme (www.ipimar.pt/pelagicos) ProRecruit (www.ipimar.pt/pelagicos/portugues/novidades/prorecruit.html) and SARDYN. The team has been working with several national and international institutions, and is interested in enlarging the collaboration and in enhancing our capacity to study oceanographic processes, their climatic fluctuations, and their impact in the marine ecosystems. One of the objectives is to enlarge the Portuguese participation in GLOBEC.

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References:

Borges M.F., A.M.P. Santos, N. Crato, H. Mendes and B. Mota. 2003. Sardine regime shifts off Portugal: a time series analysis of catches and wind conditions. *Scientia Marina* 67(Suppl.1): 235-244.

Chícharo M.A., E. Esteves, A.M.P. Santos, A. dos Santos, A. Peliz and P. Ré. 2003. Are sardine larvae caught off northern Portugal in winter starving? An approach examining nutritional conditions. *Marine Ecology Progress Series* 257: 303-309.

Hurrell J.W. and H. van Loon. 1997. Decadal variations in climate associated with the North Atlantic oscillation. *Climatic Change* 36: 301-326.

Jones P.D., T. Jonsson, and D. Wheeler. 1997. Extension to the North Atlantic Oscillation using early instrumental pressure observations from Gibraltar and South-West Iceland. *International Journal of Climatology* 17: 1433-1450.

Peliz A., J. Dubert and D.B. Haidvogel. 2003. Subinertial response of a density driven eastern boundary poleward current to wind forcing. *Journal of Physical Oceanography* 33(8): 1633-1650.

Peliz A., J. Dubert, D.B. Haidvogel and B. Le Cann. In press. Generation and unstable evolution of a Density-Driven Eastern Poleward Current. *Journal of Geophysical Research*.

Peliz A., T. Rosa, A.M.P. Santos and J.L. Pissarra. 2002. Jets, eddies and counterflows in the Western Iberian upwelling system. *Journal of Marine Systems* 35(1-2): 61-77.

Ribeiro A, A. Peliz, A.M.P. Santos. submitted. A study of the response of *chl-a* biomass to a winter upwelling event off western Iberia using SeaWiFS and *in situ* data. *Journal of Marine Systems* (April 2003).

Santos A.M.P. 2000. The SURVIVAL 2000 cruise: first results. *GLOBEC International Newsletter* 6(2): 5-6.

Santos A.M.P. and M.F. Borges. 2000. The activities of IPIMAR in the frame of GLOBEC. *GLOBEC International Newsletter* 6(1): 15-17.

Santos A.M.P., M.F. Borges and S. Groom. 2001. Sardine and horse mackerel recruitment and upwelling off Portugal. *ICES Journal of Marine Science* 58(3): 589-596.

Santos, A.M.P., A. Peliz, J. Dubert, P.B. Oliveira, M.M. Angélico and P. Ré. In press. Impact of a winter upwelling event on the distribution and transport of sardine (*Sardina pilchardus*) eggs and larvae off western Iberia: a retention mechanism. *Continental Shelf Research*.

Progress on a circum-Antarctic cetacean acoustic monitoring and ecology program (AAA/IWC)

Deborah Thiele, Deakin University, Australia (dthiele@deakin.edu.au)

The AAA/IWC program was introduced in the October 2002 issue of this newsletter. The program was developed during the IWC collaboration with US Southern Ocean GLOBEC in the Western Antarctic Peninsula (WAP) (2001 – 2003). It is an extension of IWC collaborative work in the Southern Ocean that has been successfully conducting research with national programs since 2001.

Update on IWC-SO GLOBEC Western Antarctic Peninsula

The first year-round cetacean acoustic monitoring studies in the Antarctic were conducted in the WAP in 2001 to 2003, using a recently developed tool, acoustic recording packages (ARP's). Initial analysis of the two years' continuous acoustic data have provided exciting results which challenge long held views on whale migration: i.e. near year round blue whale presence and marked seasonal changes in fin whale presence (Širovic *et al.,* 2003); and the first recordings of feeding sei whales (Fig. 1), until now believed to be almost silent. The sighting survey data showed that the seasonal distribution of humpback and minke whales was influenced by a combination of factors including:

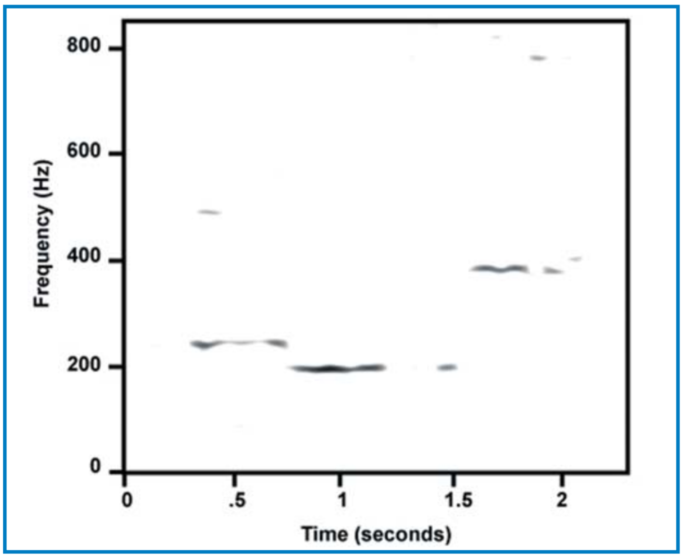

Figure 1. First recordings of feeding sei whale calls.