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NEWSLETTER

A Core Project of the International Geosphere-Biosphere Programme

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Editorial

Manuel Barange, GLOBEC IPO, Plymouth, UK (m.barange@pml.ac.uk)

Many of you attended the highly successful 2nd GLOBEC Open Science Meeting in Qingdao, China, October 2002. The Proceedings of the meeting are ready for publication as a special issue of Fisheries Oceanography (FO 12 (4/5): 304 pp). They include 27 selected papers, peer-reviewed by scientists from our community. I use this opportunity to thank all the authors and reviewers for their hard work and for sticking to the deadlines! Attendants will receive their volumes shortly after publication, and extra copies can be purchased through the IPO at cost. The OSM marked a transition for GLOBEC, from a programme in implementation phase to a mature programme ready for integration and synthesis. Several GLOBEC activities at national and regional level are in synthesis, a process that will gather speed throughout the GLOBEC family as we approach our deadline of 2009. There is still a lot of science to implement in the process, and indeed new activities continue to be approved. For example read about the new Norwegian contribution to GLOBEC in this issue. Many of you would also be aware that new regional activities on Ecosystem Studies of Sub-Arctic Seas (ESSAS) and on Climate Impacts on Oceanic Top Predators (CLIOTOP) are in planning (see www.globec.org for more information). However, the emphasis on integration and synthesis of GLOBEC will increase in coming years. The Scientific Steering Committee is busy developing a strategy to facilitate this process. This integration will also occur in coordination with developments at the International Geosphere-Biosphere Programme (IGBP) and at the Scientific Committee for Oceanic Research (SCOR). In particular GLOBEC looks forward to co-operating with the new IGBP-SCOR initiative IMBER (Integrated Marine Biogeochemistry and Ecosystem Research, previously known as OCEANS), which is currently in planning. In future issues we hope to open our doors to IMBER and its research, to build and develop this broad and complex concept of 'Ecosystem Research'. IMBER will take over the space left by JGOFS, an incredibly successful programme that has just completed its work. JGOFS achievements are an inspiration and a lesson to GLOBEC. Goodbye JGOFS and welcome IMBER.

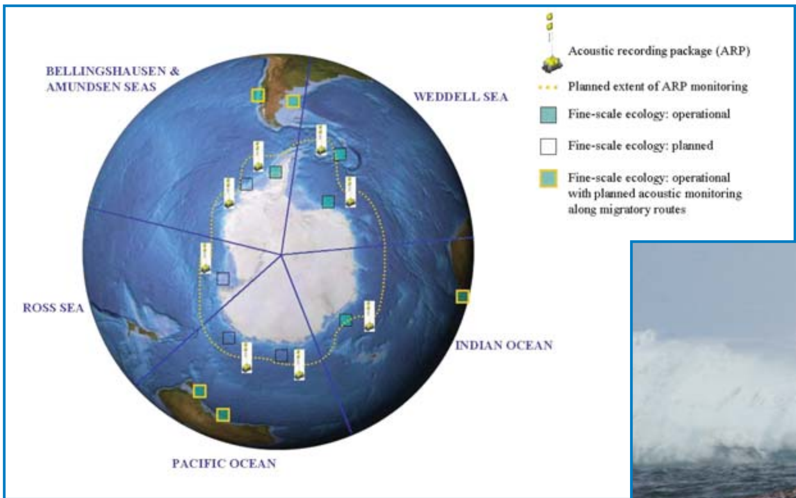


Figure 2. (Thiele, p. 9-11). Left- Map of existing and planned deployments of acoustic recording packages (ARP) for whale research around Antarctica. Right- Humpback whale lunge feeding.

A CORE PROJECT OF THE GLOBAL CHANGE IGBP

INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME
Co-Sponsored by: The Scientific Committee for Oceanic Research (SCOR)
and The Intergovernmental Oceanographic Commission of UNESCO (IOC)

Meeting announcement

The Small Pelagic Fish and Climate Change Programme (SPACC) is a regional programme of the Global Ocean Ecosystem Dynamics (GLOBEC) Project, and aims to understand and ultimately predict climate-induced changes in the productivity of small pelagic fish populations. SPACC announces two meetings in Chile, January 2004, on Spawning Habitat Dynamics of pelagic Fish.

1 – SPACC workshop on Characterizing and Comparing the Spawning Habitats of Small Pelagic Fish. Concepción, Chile, 12-13 January 2004.

The objectives of the workshop are:

1. To characterize in terms of environmental parameters the spawning habitats of small pelagic fish from a variety of ecosystems, including the Benguela, California, Canary, Humboldt and Kuroshio Current systems, the Bay of Biscay and the Iberian Peninsula, and southern Australia, using a variety of methods;
2. To use the results of the above analyses to conduct inter-ecosystem comparisons of anchovy and sardine spawning habitats;
3. To infer from the comparative analyses the likely responses of anchovy and sardine to changes in ocean climate and population size.

Convenors: C. van der Lingen (Marine and Coastal Management, S Africa), L. Castro (Universidad de Concepción, Chile), D. Checkley Jr. (Scripps Institution of Oceanography, USA), L. Drapeau (Institut de Recherche pour le Developpement, France).

Further information: Enquiries should be directed to Carl van der Lingen at vdlingen@mcm.wcape.gov.za. Visit the GLOBEC website for updated information.

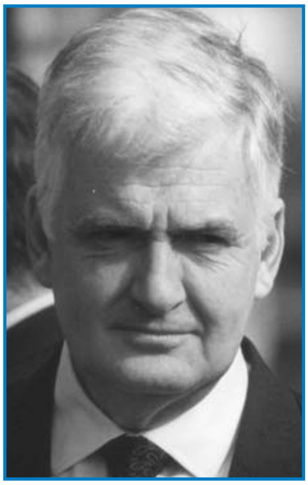
2- SPACC meeting on Small Pelagic Fish Spawning Habitat Dynamics and the Daily Egg Production Method, Concepción, Chile, 14-16 January 2004. The goal of this meeting is to analyze and compare the biological and oceanographic information obtained in DEPM studies around the world to assess the effect of environmental variability across spawning habitats on small pelagic fish populations. More specifically, the meeting will be organized around three major topics:

1. The relationship between the early life history of small pelagic fishes and their spawning habitat quality and dynamics;
2. The reproductive biology of small pelagic fishes and their spawning habitat;
3. New methodological approaches and spatial analyses in relation with the use of DEPM.

Convenors: L. Castro (Universidad de Concepcion, Chile), P. Freon (IRD, France), C. Van der Lingen (M&CM, South Africa).

Information: Questions regarding the Meeting should be directed to: Leonardo Castro: lecastro@udec.cl. Visit the GLOBEC website for updated information.

GLOBEC says goodbye to Jean-Paul Troadec



Jean-Paul Troadec, one of France's pioneers in multidisciplinary fisheries science, died of cancer on August 30th, 2003.

Dr Troadec was a retired senior scientist from IRD-France (formerly ORSTOM). He joined ORSTOM in the 1960's and soon became one of the leaders in the field of fisheries science in France. After spending several years in Ivory Coast at the Oceanographic Research Centre in Abidjan, he joined the Food and Agriculture Organisation (FAO, Rome) where he played a major role in its fisheries department. In the early 1980's, he became Director of the French Fisheries Research Institute known as ISTPM and initiated the merging with CNEXO that lead to the inception of IFREMER. Jean Paul Troadec was a brilliant scientist and a visionary. He had a major impact in fisheries science by initiating multidisciplinary GLOBEC-type research projects such as the French PNDR (Programme National sur le Déterminisme du Recrutement) in the mid-1980's. He was also one of the first fisheries scientists to highlight the importance of economic factors in controlling over-fishing and to emphasize the importance of access rights. Dr Troadec was a well respected fisheries expert at national and international level. The GLOBEC community wishes to express its condolences to his family and to the French scientific community.

CONTENTS

Third IGBP Congress: Connectivities in the Earth System
Banff Conference Centre, Banff, Canada. 19th -24th June, 2003

Manuel Barange, GLOBEC IPO, Plymouth, UK (m.barange@pml.ac.uk)

The third IGBP Congress took place in the beautiful surroundings of the Canadian Rockies, at the unique Conference Centre of Banff, Canada. For about a week the IGBP community got together in the land of elks and bears, surrounded by inspiring glaciers and mountains, to reflect and restructure the International Geosphere-Biosphere Programme, of which GLOBEC is a core project.

IGBP has just embarked on an ambitious restructuring, built solidly on the results of its first decade but focused on the emerging questions that are now challenging global change science.

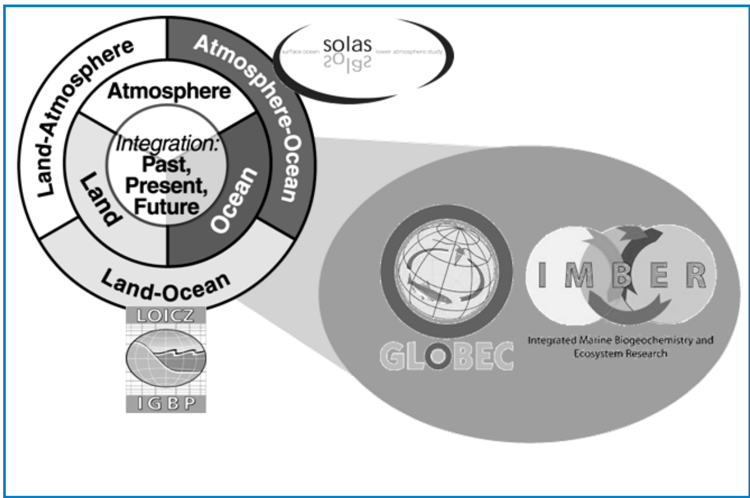


Figure 1. The structure of IGBP Phase II, with emphasis on the OCEAN box.

IGBP's new structure, launched in 2003, is based on work in the Earth's major compartments (atmosphere, ocean, land), the interfaces between them, and their integration in the past, present and future timeframes using a systems-oriented approach (Fig. 1). In addition, IGBP is joining with the other international global change research programmes (WCRP - World Climate Research Programme; IHDP - International Human Dimensions Programme on Global Environmental Change; and DIVERSITAS - an international programme of biodiversity science) to launch new joint projects centred on key issues of societal concern.

The third IGBP Congress was an exceptionally important opportunity to build further towards IGBP's second decade of research, as it brought together all Scientific Steering Committees and Transition Teams of IGBP projects and representatives of the joint projects and IGBP's partner programmes and agencies. In total, between 300 and 350 of the world's leading global change researchers, representing about 50 countries from every inhabited continent on Earth, were present in Banff. The Congress finalised the major scientific questions that will be tackled and, through a series of presentations and working group discussions, developed further the new implementation strategies that will be used to tackle these questions. The Congress was a highly stimulating gathering. Core projects discovered their commonalities, scientists from all fields of the natural and social sciences realised the potential of their common work, the IGBP as a whole understood its relevance and its capabilities.

The GLOBEC Scientific Steering Commitee had its annual meeting during the Congress (Fig. 2).

For more information on the Congress, including the scientific programme, powerpoint and PDF downloads of some of the presentations and working group reports, please visit http://www.igbp.kva.se/congress/ and read the forthcoming issue of the IGBP Global Change Newsletter 55, which will be devoted to the Congress.

Figure 2. The GLOBEC SSC in Banff. Left to right: Tang, Werner, Ottersen, Field, Harris, Parma, Ashby (IPO), Perry, Hofmann, Ommer, Barange (IPO), Lehodey, Runge, Baumgartner. Not pictured: Marrase.

Meeting announcement:

The first organizational meeting of the new planned GLOBEC regional activity on "Climate Impacts on Oceanic Top Predators" (CLIOTOP) will take place in Sete, France, 4-7 November 2003.

The main goal of the meeting is to write the science plan of the project (a draft document is available through www.globec.org) and to discuss implementation issues. Members of the steering committee, advisory committee, contact persons from relevant programs and organizations and representatives for each project (or team) involved are welcome to attend the meeting. For more information contact Olivier Maury, IRD, Victoria, Iles Seychelles (omaury@sfa.sc) or Patrick Lehodey, SPC, Noumea, New Caledonia (PatrickL@spc.int).

U.S. GLOBEC, NE Pacific (NEP) Cruises in the Gulf of Alaska and California Current

Ted Strub, Oregon State University, USA (tstrub@coas.oregonstate.edu)

During spring and summer of 2003, intensive multi-ship cruises were carried out in the northern Gulf of Alaska, on the broad shelf and shelf slope SW of Prince William Sound (and in the Sound). The objective was to quantify the variability in environmental forcing and ecosystem response during the period when juvenile salmon enter the region from fresh water sources. The goal was to increase our understanding of the factors affecting the survival of juvenile salmon during this critical period in their life-history. Over a four-year period, the GLOBEC NEP program has conducted intensive studies in the Gulf of Alaska during two years (2001 and 2003) and similar studies in the California Current off Oregon during two alternate years (2000 and 2002) (see the program descriptions in Oceanography Magazine, 15(2), 2002).

One of the unexpected findings in the California Current is the extent to which topography controls the mesoscale circulation off Oregon. As a result, "hot spots" in concentrations of biological production were found near these topographically controlled mesoscale circulation features, with increased concentrations of phytoplankton, zooplankton, fish, birds and mammals. A "virtual cruise" in the California Current during August 2002 can be found on the U.S. GLOBEC NEP web site: http://globec.oce.orst.edu/groups/nep/. Go to this site and scroll down on the left side to "Outreach". Click on Outreach and then

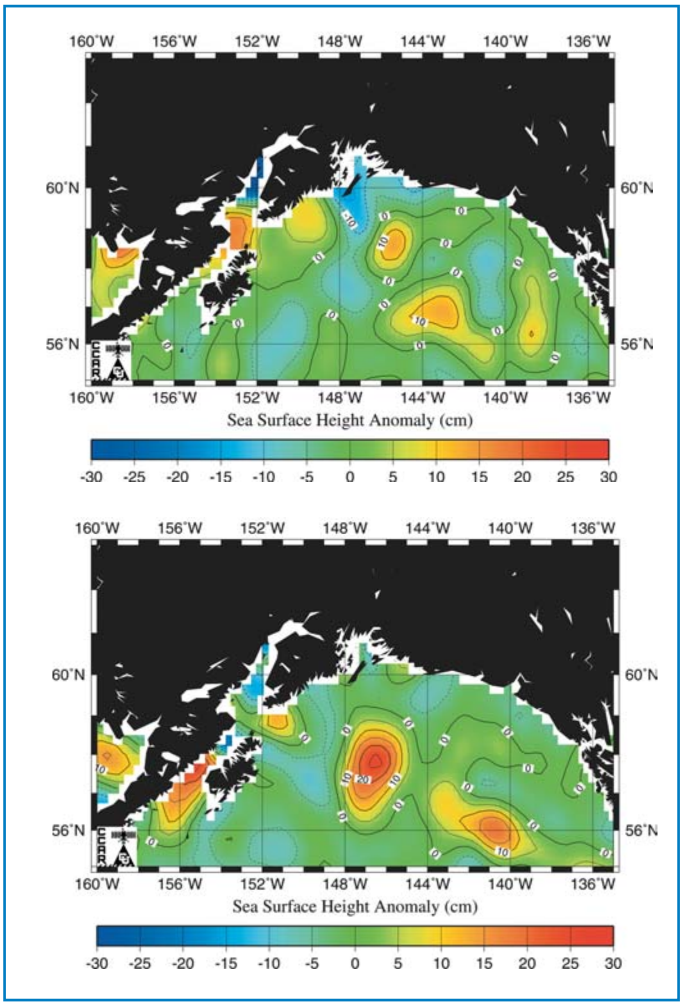


Figure 1. Sea surface height anomaly (cm) in (a) May 1, 2003 and (b) july 30, 2003

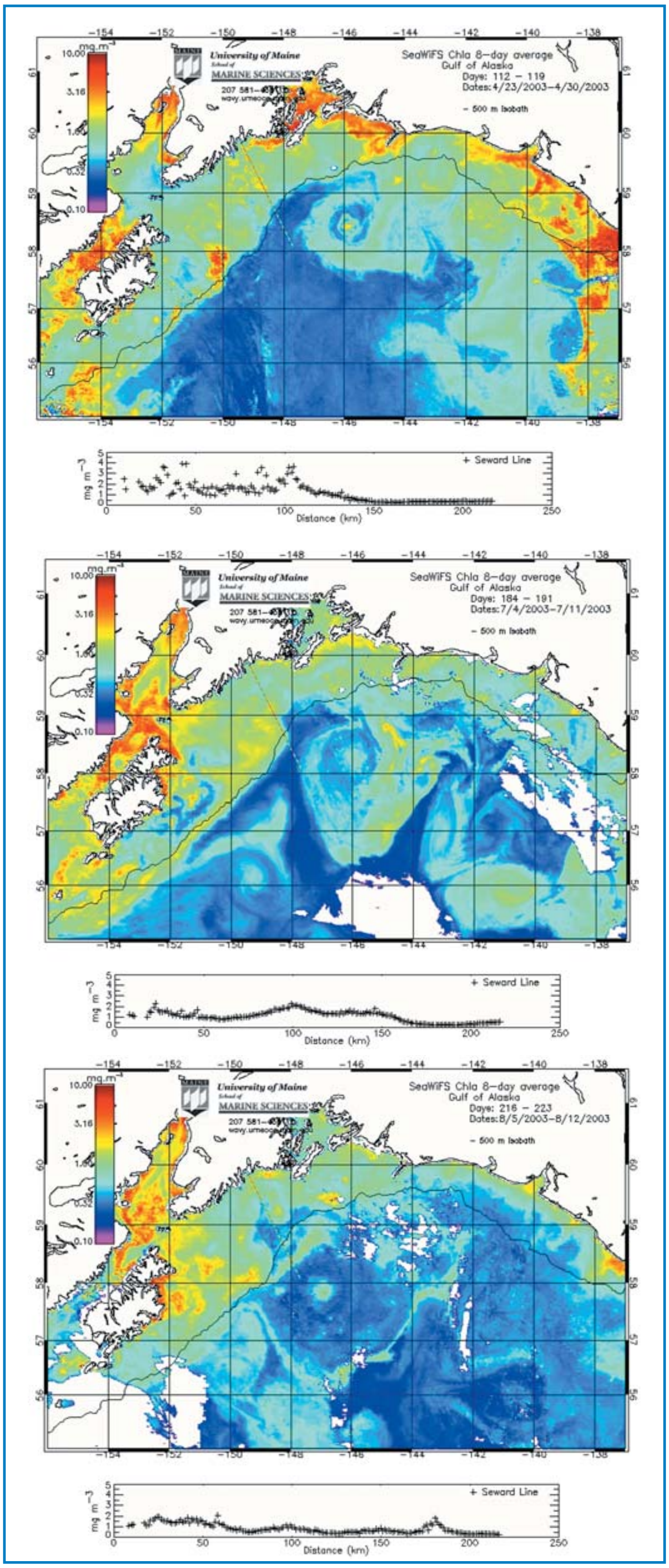


Figure 2. Composite 8-day averages of surface chlorophyll (mg.m $^{-3}$) in the Gulf of Alaska in (a) 23-30 April, (b) 4-11 July and (c) 5-12 August.

"Teacher at sea Real Time Activities Reports from the Roger Revelle August 2002..." Besides following daily activities, you can find out about the cruise participants, the NEP goals, etc.

In the Gulf of Alaska, similar mesoscale surveys have been carried out during May-June and July-August 2003. To view a "virtual cruise" during the August cruise, go the above NEP site, scroll down and click on "Outreach" on the left side, then click on "Near real-time outreach (daily reports) of July-August 2003 Cruises..." Then click on "Check for daily logs from the Mesoscale Survey..." at the top of the page.

While the primary region of interest in the Gulf of Alaska is the shelf, where juvenile salmon spend their early days in the ocean, one of the more spectacular features at the shelf break of the Alaska Current is the presence of large anticyclonic eddies that travel from east to west just off the shelf. During spring and summer of 2003, a particularly strong eddy was found to the SE of the study area. Maps of the altimeter surface height fields (courtesy of Bob Leben, University of Colorado) in the region centered on May 01, 2003 and July 30, 2003 (Fig. 1) show that the eddy strengthened and enlarged during summer of 2003, but only moved slightly to the southwest (closer to the GLOBEC study region). Eight-day composite maps of SeaWiFS surface chlorophyll pigment concentrations (courtesy of Andy Thomas and Peter Brickley, University of Maine) in late April, early July and early August (Fig. 2) clearly show that the eddy draws higher chlorophyll concentrations off the coast and wraps the richer water around itself in a clockwise fashion, including an enriched central core. In Figure 2, the primary GLOBEC sampling line is seen extending to the southeast from the coast near Seward (~60ºN, 149.5ºW) to the shelf slope at 58ºN, 147.7ºW, ending to the west of the eddy on April 27 and just northwest of the eddy core on August 5 (the spot of high pigment at 57.8ºN, 146.8ºW). Satellite-derived surface pigment concentrations are presented at the bottom of the figure. The mesoscale survey vessel R.V. Wecoma (Chief Scientist, David Musgrave) sampled the eddy with CTD and optical sensors on an undulating SeaSOAR once in May and again in August, a fitting conclusion to an exciting and successful mesoscale survey program in the Gulf of Alaska.

News from GLOBEC-Norway: New Norwegian GLOBEC initiative with focus on cod, herring and Calanus in the Barents and Nordic Seas

Geir Ottersen, Institute of Marine Research, Bergen, Norway (geir.ottersen@imr.no)

The new contribution to GLOBEC-NORWAY encompasses three projects financed by the Norwegian Research Council for 2003-2006. The three projects are ECOBE (Effects of North Atlantic Climate Variability on the Barents Sea Ecosystem, project leader Svein Sundby, IMR) with a focus on climate-hydrography-zooplankton-early stages of cod, haddock and herring (http://www.ecobe.imr.no); CLIMAR (Climate and Production of Marine Resources, project leader Webjørn Melle, IMR) with a focus on climate-hydrography-zooplankton-herring in the Norwegian Sea, and ADAPT (Adaption to the Ecosystem: Co-evolution of Life History of Calanus and Herring in the Norwegian Sea, project leader Webjørn Melle, IMR). The proposed program involves a broad range of scientists from the Institute of Marine Research, the University of Bergen, the University of Oslo, the Bjerknes Centre for Climate Research, Nansen Environmental and Remote Sensing Centre, and Ålesund University College. Here we will briefly describe each of the components of the new GLOBEC-Norway program.

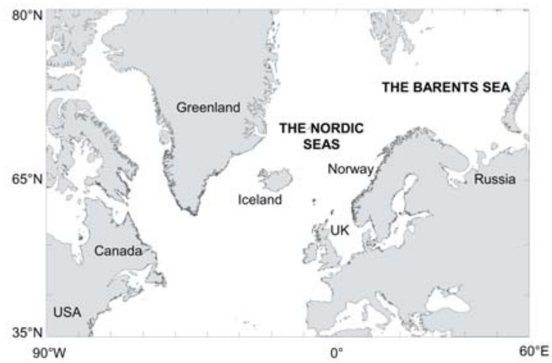


Figure 1. The North Atlantic Ocean with the Barents and Nordic Seas highlighted.

ECOBE

In arcto-boreal marine ecosystems the reproduction, recruitment and growth in fish stocks show large interannual variations. These variations are basically linked to ocean climate fluctuations that influence the fish stocks partly directly and partly indirectly through the lower trophic levels of the food web. In the Barents Sea ecosystem (Fig. 1) there are three key fish species in strong interaction: cod (*Gadus morhua*), capelin (*Mallotus villosus*) and herring (*Clupea harengus*). Ocean climate, not only sea temperature, but also light conditions, wind mixing, turbulence, vertical stability, and advection of water masses strongly influence the production of all these organisms. There are also interactions between the species where the climate effects are subordinated. The growth of the adult cod is strongly dependent of the abundance of capelin. In years of high abundance of young herring in the Barents Sea the predation pressure on larval and juvenile capelin from the young herring is strong resulting in poor recruitment to the capelin stock and bad feeding conditions for cod. Also, there are periods of strong interaction between young cod and older cod when cannibalism is important.

In order to understand the functional relationships between fish reproduction, recruitment and growth and climate, there is a need to investigate the linkages between the various climate parameters, how they influence production at trophic levels below fish production, at trophic levels above fish, and how they influence trophic transfer. Secondly, we will improve the basis for medium-term to long-term ocean climate forecasts by improving coupled ocean-atmosphere numerical models and statistical forecasting. These investigations will form the scientific basis for improved assessment of the fish stocks in the Barents Sea, with emphasis on predicting the development in the stocks on a medium-term to long-term time scale.

Main Goal

The overall goal is to understand and quantify the impacts of

Arctic climate variability on trophic transfer and ecosystem structure of the Barents Sea in order to improve the prediction of growth and recruitment on key fish species.

Specific objectives

1. Explore the linkages between large-scale weather patterns, such as the North Atlantic Oscillation (NAO), and the regional and local climate, and investigate how such patterns cascade into spatio-temporal changes in the ocean climate parameters that are of importance for biomass production.

2. Explore the effects of ocean climate and circulation on the production and advection of *Calanus finmarchicus* onto the northern Norwegian Shelf and the Barents Sea.

3. Develop an integrated model system based on first-principles physics and biology to simulate distribution, transport, growth and survival of fish larvae from the spawning areas in spring to 0-group distribution in autumn when year-class strengths are largely determined.

4. Develop egg production models for the key fish species, based on the combined effects of food abundance and temperature on gonad production and maturation.

5. Develop a trophodynamic model system that integrates the models described above to simulate growth and recruitment of Barents Sea fish stocks. The trophodynamic model system will form the basis for sensitivity analysis to explore quantitatively the effects of the range of physical and biological parameters and processes of importance to the general problem of fish recruitment.

CLIMAR

Fisheries managers are increasingly aware of the potential influence of climate fluctuations on the sustainable levels of exploitation for fish stocks. However, there are still few cases where climate conditions are formally taken into account in the setting of management targets. One of the most significant events in European fisheries of the 20th century, both ecologically and economically, was the collapse and subsequent recovery of the Norwegian spring spawning herring stock inhabiting the Nordic Seas (Fig. 1). The spawning biomass declined from >12MT prior to 1960 to <0.1MT in the late 1970's, returning to >5MT by the end of the century. There is no doubt that over-exploitation hastened the collapse of this stock in the 1960's and 1970's, but there is also evidence that climate during this period was adverse for the herring, and it is likely that a combination of the two factors sealed the fate of the stock.

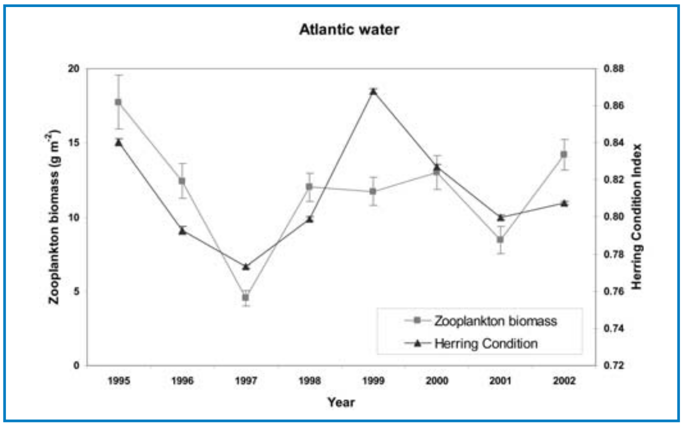


Figure 2. Apparent trophic link between zooplankton production and herring growth in the Nordic Seas. Zooplankton biomass in Atlantic water masses in the Norwegian Sea in May 1995-2002 vs. mean herring condition index in December the same year.

CLIMAR focuses on the vulnerability of the Nordic Seas pelagic food web to climate change, and especially on the effects of climate on the growth and migrations of the Norwegian spring spawning herring stock. The Nordic Seas ecosystem is particularly at risk with respect to climate change because its oceanographic characteristics are closely coupled to fundamental ocean-atmosphere interactions in the Polar regions where the meteorological and oceanographic manifestations of climate change are very pronounced. One way that climate influences herring is through primary and secondary production. Recent analyses show that the condition of herring is closely connected to zooplankton biomass (Fig. 2).

Main Goals

- Establish the processes which constitute the coupling between climate fluctuations and the growth and migration patterns of the Norwegian spring spawning herring in the Nordic Seas,
- Develop models of the oceanography, plankton food web, and fish growth and migration that will allow a quantitative analysis of the climatic factors involved, and prognoses of the consequences of future climate scenarios.

Specific objectives

1. Assemble historical data on hydrography, plankton and fish and perform statistical time series analyses of the time series.

2. Conduct process studies targeted at explaining the relationships between climate and herring. Through repeated, seasonal studies on an ocean basin scale explore the relationship between migration and feeding of herring and the temporal and spatial characteristics of *Calanus* production, and relate interannual variability in *Calanus* production and herring feeding to climate.

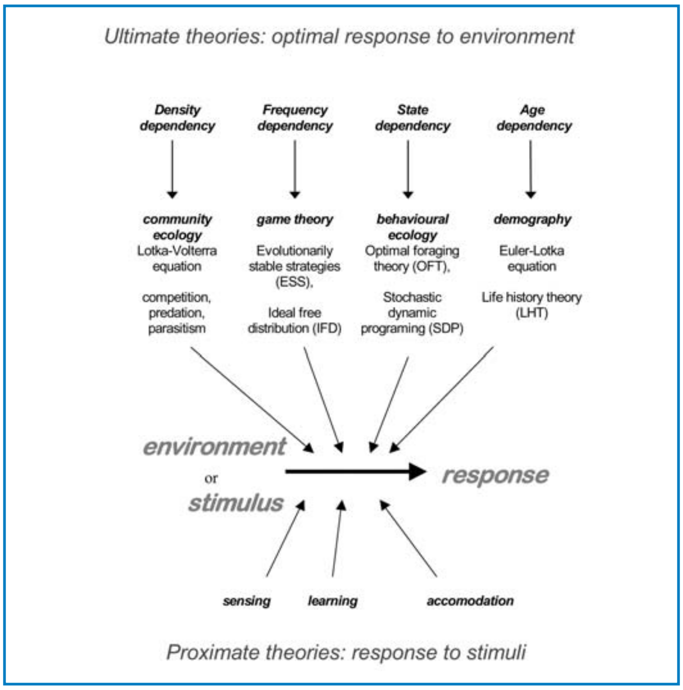


Figure 3. The classical optimisation-based modelling tools are only able to take a partial perspective of the organism and the environment. Through development of new adaptation-based tools, we will address the complexity of the ecosystem in spatially resolved individual-based models of several trophic levels.

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

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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

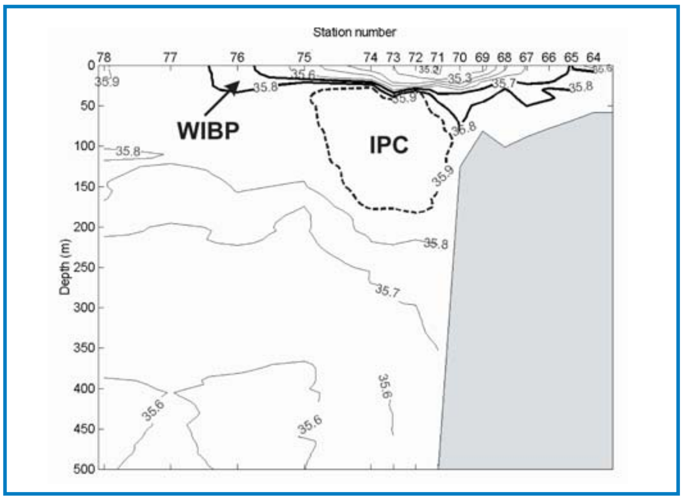

Figure 1. Vertical distribution of salinity at a transect during SURVIVAL'2000 survey The thick lines delimit the WIBP. The dashed line represents the IPC (Adapted from Chícharo et al., 2003).

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

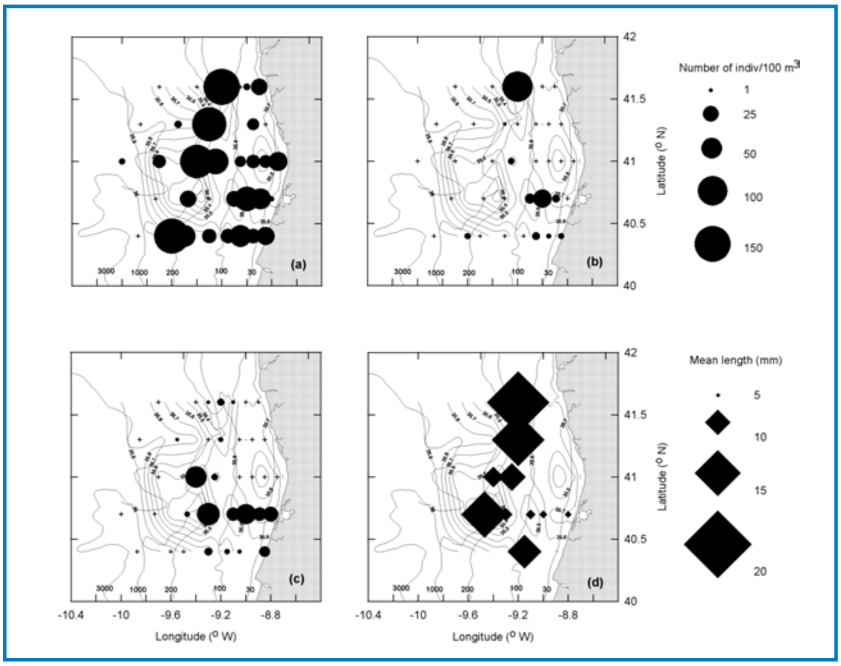

Figure 2. Distribution and abundance of ichthyoplankton during the SURVIVAL'2000 survey (February 2000): (a) number of fish eggs for 100 m^3; (b) number of sardine eggs for 100 m^3; (c) number of sardine larvae for 100 m^3; and (d) mean length (mm) of sardine larvae. The fine lines represent the bathymetric 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.

Acknowledgements: We would like to thank the institutional supports by Marcelo de Vasconcelos (former-president of IPIMAR), Joaquim Pissarra (Director of our Department-DAA), and Manuel Barange (Director of GLOBEC IPO) to the SURVIVAL project. To FCT for the financial support to the projects SURVIVAL (PRAXIS/P/CTE/11282/98), PO--SPACC (PRAXIS/P/CTE/11281/98), ProRecruit (POCTI/99/BSE/36663) and PELAGICOS (PLE/13/00). The projects SURVIVAL and PO-SPACC are affiliated to GLOBEC.

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

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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:

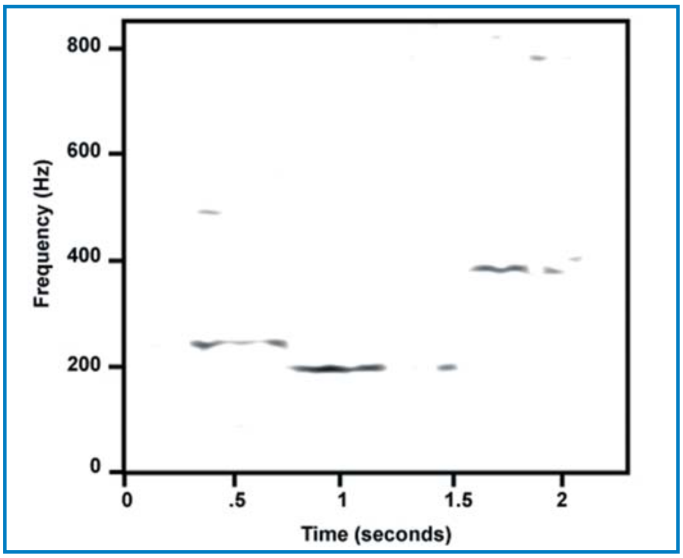

Figure 1. First recordings of feeding sei whale calls.

current velocity, complexity of bathymetry and proximity of the ice fringe and associated biological events. Preliminary results from the acoustic and sighting survey components of the IWC-SO GLOBEC collaboration will be presented separately in the first of a series of Deep Sea Research volumes on SO GLOBEC work. Analysis that integrates cetacean acoustic and visual survey data will be presented at the Ocean Science Meeting in Portland, Oregon (January 2004). Interdisciplinary analyses have already begun (e.g. predator biodiversity analyses by Erik Chapman, combining bird, seal and cetacean survey data) and further synthesis projects will be developed at the OSM.

Beyond SO GLOBEC

The SO GLOBEC program has an ecosystem approach to studying variability in populations, and the processes controlling that variability. Field research was conducted over one to two years and therefore has a limited ability to identify patterns and processes that operate at greater temporal scales, but which impact upon regional and finer scale ecosystems. The SO GLOBEC research community identified that a follow on long-term research effort would be needed to investigate circumpolar variability and connections to regional dynamics in Southern Ocean ecosystems. A new initiative (ICCED) has been developed as a joint venture in the Southern Ocean between GLOBEC and the global Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) long term research program, by members of the SO GLOBEC steering group and others (Murphy *et al*., 2003). The AAA/IWC program is a core component of the Southern Ocean ICCED initiative which will be a joint venture in the Southern Ocean between GLOBEC and the global Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) long term research program, due to commence in 2007 (Murphy *et al.*, 2003).

The IWC will continue to participate in national and international efforts in the Southern Ocean through the synthesis and analysis and field programs of SO GLOBEC. In the longer term, the IWC is well placed to build on recent and new collaborations to ensure that whale ecology becomes a core component of the next major phase of marine science focus in this region.

Circum-Antarctic monitoring – connecting ecology and ecosystem processes

The development of the AAA/IWC collaborative program is an important component in a circum-Antarctic approach to investigating the connections between whale ecology and the variability and dynamics of Antarctic ecosystems. The main objective of the IWC/AAA is implementing a circum-Antarctic continuous acoustic monitoring system for cetaceans (Fig. 2, see Newsletter cover), to investigate their connections with ecosystem processes at local, regional and circum-Antarctic scales.

The AAA program has been structured to include a variety of novel and historical cetacean research methods whilst simultaneously developing the potential of the new year-round acoustic recording packages (ARP's). While methodologically powerful, passive acoustic technology cannot provide a reliable measure of relative abundance on any temporal or spatial scale, and does not allow an assessment of the number of individual whales calling at any one time, both critical elements in determining seasonal abundance. Acoustic research needs to be partnered by studies to develop an ecological context for the analysis of acoustic data. For example, calling rates or spectra may vary with behaviour in response to changes in habitat characteristics. This can only be determined by ship-based research simultaneous with acoustic recordings.

ARP's around Antarctic/IWC Southern Ocean collaboration work plan

Initially we plan to deploy single arrays (five ARP's) in each of the oceanic provinces of the Antarctic (Zwally *et al* 2002, Nicol *et al* 2002): the Indian Ocean, Pacific Ocean, Ross Sea, Amundsen-Bellingshausen Seas, Weddell Sea, and in the northern Antarctic Peninsula (Fig. 2). The design of the arrays will result in data that can be used to: accurately position animals at time of call; track individual callers over short periods within a 100km circle from the center of the array; locate areas of seasonal high concentrations of a range of species; and determine likely longitudinal movements. We currently have single ARP's deployed in the northern WAP and off Mawson, East Antarctica and will be deploying in the Ross and Weddell Seas in early 2004. We have collaborative agreements for long-term deployments with visual and acoustic survey on cruises in the Ross Sea, WAP, East Antarctica and South Orkneys; and plan to participate in the large scale CCAMLR (line transect) surveys in 2005/06 – from the Western Weddell Sea to 10˚E and 80˚E - 10˚E with Germany and Australia; and some southern hemisphere coastal deployments.

The next step is to conduct concurrent ecological studies around ARP arrays using visual survey, biopsy, video, acoustic tagging and expendable sonobouys. A major objective of this work is to develop a broad set of categories of association between behaviour, environmental conditions and calling rates for each species which will allow us to predict, link and extrapolate whale distribution, and causes at local, regional and circum-Antarctic scales.

Science components:

I. Acoustic Recording Packages (ARP's) - Broad scale deployment of ARP's around the Antarctic

Data from single instruments will provide information on baleen whale presence and call rates for 50 – 100km radius of instrument continuously for the year preceding an array deployment. The new HARP, which we will also use, records both baleen and odontocete calls. These data will be used shipboard on retrieval to assess final array positioning. The array design consists of five instruments (one central and four around in shape of cross). Data from the inner 100km diameter portion of this array design ensures multiple cross over between detection circles of each ARP and therefore can provide data that allows: positioning of individual whales when calling; short term tracking of many calling whales; determination of direction of migratory movements. Data from the outer detection area can be used to determine relative seasonal abundance at that wider scale and to locate areas of seasonally important concentrations.

II. ARP related ecological studies

Annual fine scale ecological studies in the region of ARP deployment will be directed at resolving specific issues with ARP data. Broad categories of association will be developed that reflect the ecological significance of calling rates. To do this we will locate concentrations of cetaceans, deploy acoustic tags, follow individuals, video group and individual behaviour while monitoring acoustically, biopsy calling animals and photo identify individuals to relate behaviour, genetic identity and ecological conditions to the ARP data. Participation in large scale multidisciplinary surveys is also an important component of the ecological work, for assessing potential array locations and providing the opportunity for integrated analysis of acoustic spectra and visual survey results with simultaneously collected data series for prey and ecosystem dynamics at regional scales.

Acknowledgements

The AAA program is a joint research effort between J. Hildebrand (Scripps), Sue Moore (NOAA), and Deborah Thiele (IWC/WEGSO) and others, and is a core part of the IWC collaborative work in the Southern Ocean. Debra Glasgow (IWC observer) took the photographs of the fin and humpback whales.

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3rd International Zooplankton Production Symposium

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The 3rd International Zooplankton Production Symposium was held in Gijón, Spain from 20-23 May. The conference was jointly organised by GLOBEC, ICES and PICES, and the local organiser was Luis Valdes from IEO, Spain. The Convenors of the Symposium were Dr Roger Harris (UK), Dr Tsutomu Ikeda (Japan) and Dr Luis Valdes (Spain). This Symposium follows on from the pioneering 1st Zooplankton Production Symposium in Charlottenlund, Denmark in 1961, and the successful 2nd Symposium in Plymouth, UK, in 1994. The 3rd International Zooplankton Production Symposium was probably the largest ever gathering of zooplankton ecologists, and also the most successful

Figure 1. Roger Harris at the closing ceremony.

in the series to date, with 333 delegates from nearly 50 countries attending 153 oral presentations and viewing 238 posters.

The conference consisted of eight theme sessions. Five themes dealt with zooplankton from the micro- to macro-scale (the role of microzooplankton in the marine pelagial; the role of zooplankton in biogeochemical cycles; the impact of physical variability on zooplankton; the effect of climate on long-term zooplankton time series; and basin-scale comparisons of life history strategies between the North Atlantic and North Pacific). Three themes focused on the application of state-of-the-art methodologies (zooplankton modelling; molecular biology; and new technologies). Detailed information about the oral and poster presentations from the Symposium can be found in the comprehensive Book of Abstracts. In addition, many of the oral papers will be published in a special issue of the ICES Journal of Marine Science due out in early 2004.

"Apart from getting an insight in the work on zooplankton in almost all parts of the world, I got a lot of new input on my working area and some ideas how to proceed with my project. I also enjoyed the session on new technologies a lot, as I am still working with the old-fashioned plankton nets. However, there should have been a little bit more time available for the poster presentations since there were quite a lot of them. The social events in the evenings were another great surprise, as they offered a good opportunity to talk to people." *Malin Daase, University Center on Svalbard, Norway (Malin.Daase@unis.no)*

"As it was my first time presenting outside my country I was very excited about attending the 3rd International Zooplankton Production Symposium in Gijon. My expectations were surpassed with the excellent presentations, interesting discussions and great organization. I particularly enjoyed the session on "Application of new technologies" which was a very stimulating, fascinating and well-attended session." *Viviana Farstey, The Hebrew University of Jerusalem, Israel (viviana@vms.huji.ac.il)*

Figure 2. Luis Valdes, local organiser.

I will not try and provide a comprehensive summary of the major findings from the Symposium presentations, but would like to highlight briefly three areas of significant progress. First, gelatinous zooplankton such as ctenophores, larvaceans, salps and their kin, although difficult to study, are important grazers and maybe even more important to vertical fluxes in many oceans of the world. The bias toward crustaceans in zooplankton ecology is slowly being addressed, and the Symposium workshop on gelatinous zooplankton served to increase awareness of this issue. Second, with the IPCC (International Panel of Climate Change) confirming the reality of climate change at the beginning of the 21st century, and the realisation that global climate teleconnections link distant areas, regional and even basin-scale comparisons of zooplankton time series are now being conducted to distil coherent signals of climate change. This will be an increasingly important topic over the coming decades. Last, several of the new technologies are moving from the developmental to the application stage. This includes molecular techniques that are now providing rapid

"Being in Gijón for the 3rd International Zooplankton Production Symposium (May 20-23, 2003) was a charming experience. It was the first time I presented results obtained during my PhD in an International conference, and of course I was thrilled about it. The poster session, in particular, was very well organized, and the presence of typical "tapas" and wine made the atmosphere more informal. I thank GLOBEC for having funded my participation at the Symposium and the Secretariat for the support in Gijón." *Marco Uttieri, Stazione Zoologica "Anton Dohrn", Napoli, Italy (uttieri@szn.it)*

estimates of zooplankton growth rate and digital imaging systems that now have sufficient resolution for plankton identification. Dr Charlie Miller in his remarks summarising the Symposium highlighted that novel methods provide new insights into zooplankton ecology, and will compliment traditional techniques.

There was also an excellent exhibition of plankton art at the symposium. Dr Per Flood from Norway displayed the most impressive collection of photographs of live plankton that I (and many other delegates) have ever seen. His photographs really capture the beauty of plankton. There was also a collection of early taxonomic illustrations from some of the pioneers in our field. The Sir Alister Hardy Foundation for Ocean Science also exhibited some of the watercolour paintings of plankton by Sir Alister Hardy, a very influential figure in the history of zooplankton ecology.

At this point I would like to provide some more personal perspectives of the Symposium. A striking feature of the Symposium was the number of dynamic young scientists

Figure 3. Luis Bode and Miguel Alcaraz share views.

present, particularly women. Young scientists are often poorly represented at such prestigious international conferences, but the Session Chairs selected speakers of all experience levels from around the world. There were many presentations from scientists from developing countries, although few from Africa. The identification of and financial support for good African researchers is a difficult issue.

The quality of the presentations and the science was also extremely high and bodes well for the future of our discipline. Within the GLOBEC community, US-GLOBEC were particularly well represented at the symposium and stressed their affiliation and contribution as a coherent GLOBEC programme. From an organisational perspective, posters were given good exposure, being available for viewing throughout the entire Symposium (as well as at the dedicated wine and cheese poster session). Because of the size of the Symposium and breadth of topics, all talks were held in parallel. This resulted in some difficult choices for delegates, and it was unfortunate that it was not possible to hear all invited speakers.

The social side of the Symposium was organised by Luis Valdes. He was an impeccable host, very proud of Spanish culture, cuisine and wine, and we were (thankfully) on the receiving end of several organised functions. The social scene contributed to the conference being a real exercise in stamina. We would begin each day at about 8:30 am and finish about 6 pm. Many would

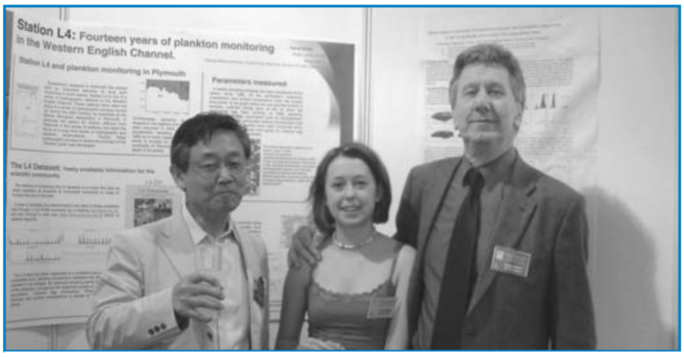

Figure 4. Takashige Sugimoto, Tania Smith and Roger Harris at the poster session.

then relax at a local cider bar (Sideria) that are a speciality of the Asturias region reminiscent of its Celtic roots. Afterwards we would find a rustic local restaurant that would inevitably have fantastic cuisine. Restaurants would only open about 10 pm, so by this time we were feeling the effects of the cider! Only after dinner at around midnight would the nightlife really start to warm up in Gijón …

A great time was had by all delegates. I would like to take this opportunity to thank Luis Valdes and our Spanish hosts for an excellent and very successful Symposium. The 3rd International Zooplankton Production Symposium was a landmark in zooplankton research, defining the current state-of-the-art and new research directions in our discipline at the beginning of the 21st century. Following the enormous success of this Symposium, it was decided that nine years is far too long to wait for the next Zooplankton Production Symposium. Negotiations are already underway to have the next Zooplankton Symposium in just three years time, just enough time to recover after this one!

"Attending the 3rd International Zooplankton Production Symposium in Gijon has been a most valuable experience and I thank the organizers for financial support through GLOBEC. Discussion and comparison of scientific techniques was a strong point, which was not only part of the scheduled talks and discussions, but was also further continued in small workgroups. For myself, participating in a multinational workgroup discussing image analysis techniques for zooplankton recognition (initiated by Phil Culverhouse and Bob Williams) has been very fruitful " *Anne Sell, University of Hamburg, Germany (anne.sell@uni-hamburg.de)*

SAHFOS PAGE

Ecological status of the North Atlantic: results from the Continuous Plankton Recorder survey 2001/2002

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The CPR survey is currently the only programme capable of assessing plankton changes at an ocean-basin scale and is highly relevant to addressing issues of the marine response to climate change and ecosystem health. Using data from the Continuous Plankton Recorder (CPR) survey collected in 2001/2002, we provide a synopsis of the 'ecological status' of the North Atlantic. This article summarises unusual species found, large phytoplankton blooms, changes in community structure and trends in hydrobiological indicators from regions in the North Atlantic (with an emphasis on the North Sea). The term 'unusual' or 'large' in referring to phytoplankton blooms and zooplankton swarms refers to population increases greater than four standard deviations above the species recorded baseline mean (baseline mean: 1980-2000). Notable blooms that are geographically large refer to patch sizes greater than 100 km in diameter. The primary region used to monitor changes in community structure, biomass and phenological changes is the central North Sea, an area that has been consistently sampled by the CPR on a monthly basis over the last six decades. Most data analysis has been performed to highlight the year 2001 in relation to the long-term dataset. Preliminary data for 2002 is presented here although it has not yet undergone quality checks. Refer to the SAHFOS website (www.sahfos.org) for information on the methodology and sampling procedures of the CPR survey.

The spring bloom and phytoplankton biomass

In early February 2001 in the North Sea, two early diatom blooms occurred, one dominated by *Odontella regia* and the other by *Thalassionema nitzschioides*. A very early bloom of *Thalassionema nitzschioides* was observed in the second week of February on Georges Bank (north-west Atlantic), which was also present the following month. *Rhizosolenia imbrica shrubsolei*, *Thalassiosira* spp. and *Thalassionema nitzschioides* dominated early March and April blooms in the North Sea. Peak spring biomass reached a maximum in the third week of March in the North Sea, one week earlier than the baseline mean (1948-2000). Early April saw the development of a large bloom of *Thalassiosira* spp. off the Celtic Sea shelf edge and in the Bay of Biscay. The dominant species in the shelf areas of the north-west Atlantic (Georges Bank, Scotian Shelf and the Grand Banks) around this time were *Rhizosolenia hebetata semispina* and *Chaetoceros* spp. The northern shelf edge of the Grand Banks continued to experience large blooms of *Chaetoceros* spp. well into June.

Phytoplankton colour is an index of total photosynthetic biomass. Figure 1 shows the long-term monthly values of phytoplankton colour in the central North Sea from 1948 to 2001. It is clear from this figure that there has been a large increase in phytoplankton biomass since the late 1980's. From the late 1940's to the late 1980's, the majority of biomass was restricted to the spring and autumn bloom periods, i.e. diatoms dominated the phytoplankton assemblage. Since the late 1980's, biomass has increased throughout the seasonal cycle. While spring and autumnal bloom values have remained relatively similar compared to the baseline mean (1948-2000), phytoplankton colour has significantly increased during the winter and, in particular, the summer months. Considering normal phytoplankton succession, it is likely that the phytoplankton community has shifted from a traditional dominance of diatoms to flagellates and dinoflagellates. The year 2001 continued with this trend, with particularly high values recorded in July. In other parts of the North Atlantic, high increases in phytoplankton biomass are also seen off the Newfoundland Shelf (with an increase in winter blooms), the Scotian Shelf and the Labrador Sea. In the northern North Atlantic and in the sub-polar gyre, phytoplankton biomass has been declining over the last decade. Taking the North Atlantic as a whole, the large-scale spatial patterns over time show similarities to satellite-derived estimates of chlorophyll over the same period.

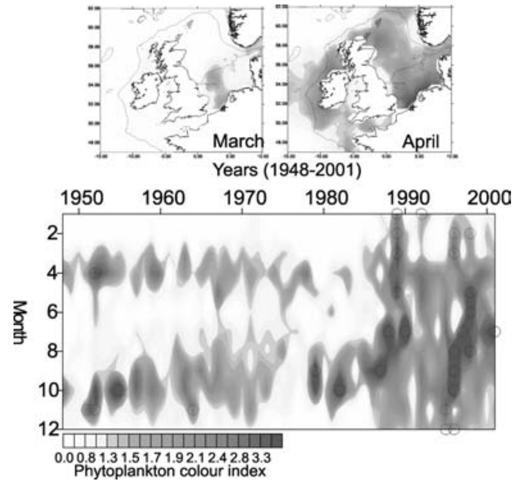

Figure 1. (top) Typical early development of the spring bloom in the north-east Atlantic, beginning on the Dogger Bank, in the Southern Bight and at the entrance to the Skagerrak in March and spreading to other shelf areas in April; (bottom) long-term monthly values of phytoplankton colour in the central North Sea from 1948 to 2001. Circles denotes colour values >2 SD above the long-term monthly mean.

Phenological changes

Phenology is the study of the timing of recurring natural phenomena (e.g. seasonal events). Interannual changes in

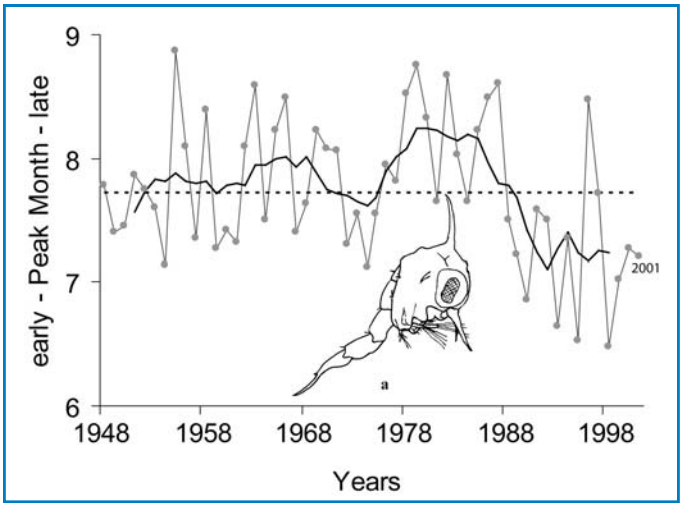

Figure 2. Interannual variability (light line) in the peak development of decapod larvae (centre of gravity index) in the central North Sea between 1948-2001 (dark line: 3 year running mean; dashed line: baseline mean 1948-2001).

seasonal/successional timing is considered to be a good indicator of climate change. For example, interannual changes in the timing of species associated with the spring bloom, or the earlier appearance of dinoflagellates, may indicate hydroclimatic changes. Due to the sensitivity of the physiological development of meroplankton to temperature, we have chosen decapod larvae as a representative of phenological changes in shelf sea environments.

Figure 2 shows the annual peak seasonal abundance 'centre of gravity index' of decapod larvae from 1948–2001 in the central North Sea. There is a strong relationship between winter sea surface temperature and the early/late development of the decapod seasonal cycle (r = 0.67; p<0.01). Although there is considerable inter-annual variability in the period 1948–2001, a major pattern has emerged over the last decade. Since 1988, with the exception of 1996 (a negative NAO year), the seasonal development of decapod larvae has occurred much earlier than the long-term average (baseline mean: 1948–2001). For example, the seasonal cycle has been up to 4-5 weeks earlier in the 1990's than the long-term mean. The peak seasonal appearance of echinoderm larvae also shows the same pattern and is correlated with the trend in decapod larvae. This dramatic trend towards an earlier seasonal appearance of meroplanktonic larvae during the 1990's is reflected in the equally dramatic changes in the climate of the North Atlantic. The 1990's in the Northern Hemisphere, for example, were the warmest decade since records began in 1860, having nine out of the ten warmest years on record (Hadley Centre, U.K. climate database). The year 2001 continued this trend in both the early seasonal appearances of meroplankton mlarvae and dinoflagellates.

Community structure and biogeographical shifts

Figure 3 shows a multi-dimensional scaling plot of the annual zooplankton community in the central North Sea. Decadal changes in the community are generally characterised by a colder-water community in the 1960's and a warmer-water community in the 1990's. The two most distinguishable shifts are those that occurred in the late 1970's and late 1980's. Both these community shifts are associated with ocean climate anomalies (Edwards *et al.*, 2002). Since the late 1980's the planktonic community has remained in a warm-water state. The most outstanding years, in terms of community structure, since this period are the years 1989 and 1990 when the North Sea plankton community was characterised not only by warm-water species but also by oceanic fauna.

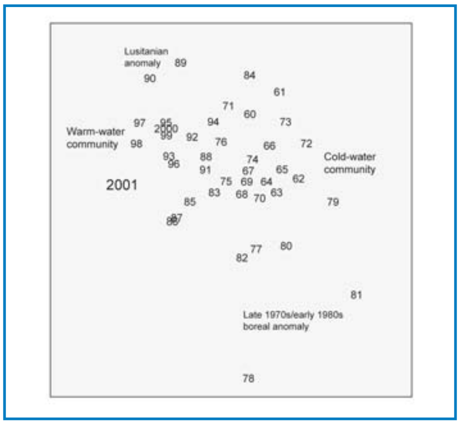

Figure 3. Multi-dimensional scaling plot of the annual zooplankton community structure in the central North Sea from 1960-2001. Stress = 0.19.

Even though the NAO index was negative in 2001, the general warming pattern observed over the last decade in the north-east Atlantic continued, with sea temperatures above the long-term average. The planktonic community in 2001 has shown a slight shift in structure compared with 2000, but still remains in a warm-water state.

Over the last decade there has been a progressive increase in the presence of warm-water/sub-tropical species in the more temperate areas of the north-east Atlantic, with 2001 continuing this trend. A useful indicator of this trend is the ratio of the cold-temperate *Calanus finmarchicus* and the warm-temperate *Calanus helgolandicus* copepod species. Figure 4 shows that the percentage of *C. helgolandicus* (as a proportion of total *Calanus* abundance) was much higher in 2001 than its long-term average, a trend that has been evidently accelerating over the last decade. Earlier work showed that these patterns were related to trends in the NAO index. In the north-west Atlantic an unusual range extension that has occurred recently is the presence of *Zoothamnium pelagicum* in the Labrador Sea. This species is normally associated with warm-temperate environments and may have been introduced into this area by the Gulf Stream loop, which penetrates the Labrador Sea. Preliminary evidence has shown that the north wall of the Gulf Stream showed a northern extension around the time of the presence of *Z. pelagicum*. More detailed information on biogeographical shifts (describing a 600km shift in zooplankton assemblages over the last 30 years) were given by Gregory Beaugrand in the October 2002 edition of the GLOBEC International Newsletter (Vol. 8, No. 2).

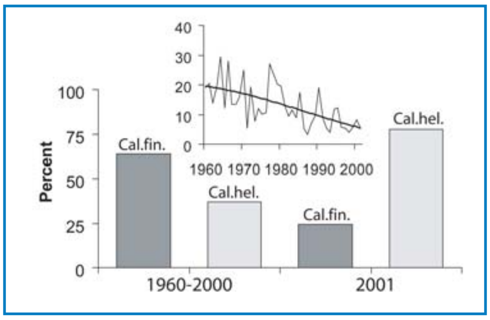

Figure 4. The mean abundance of adult Calanus per sample in the central North Sea 1960-2001 (line graph) and the mean percent of C. finmarchicus and C. helgolandicus (bar chart) comparing the long-term mean with 2001.

Zooplankton abundance and species trends

Figure 5 shows changes in the zooplankton community of the North Sea from 1958-2001. PC1 is a good representation of the long-term changes in zooplankton abundance, explaining 53% of the inter-annual variation. PC1 shows many relatively small peaks from 1958-1996, followed by a massive increase since 1997. PC1 is dominated by echinoderm larvae, reflecting the recent striking change in the zooplankton community of the North Sea. Other taxa that contributed to a lesser extent to this PC were decapod larvae and larvaceans. By contrast, euphausiids showed the opposite relationship to PC1, suggesting a recent rapid decline. The change in the relative dominance of the two *Calanus* species was also captured in this PC, with *C. helgolandicus* positively related and *C. finmarchicus* negatively related to this PC. PC2 explained 20% of the inter-annual variation in zooplankton abundance. By contrast with PC1, PC2 showed a strong decline in abundance; it was also influenced by more species than PC1. All taxa that contributed most to PC2 declined in abundance. The taxa that most strongly showed the decline of PC2 were the small copepods *Para-Pseudocalanus* spp., *Oithona* spp., and *Pseudocalanus* adults. Other taxa that also declined were the predators *Limacina retroversa*, *Clione limacina*, Gammarids, and chaetognaths, the copepods *C. finmarchicus* and *Calanus* juveniles, and cyphonautes larvae. From the PCs, it can be seen that there are long-term changes in the zooplankton community in the North Sea, with the overall structure of the zooplankton community in 2001 conforming to these trends: the position on PC1 of the year 2001 is similar to that of the last three years, and the position on PC2 is similar to the previous seven years. Also shown on PC2 for zooplankton is PC2 for phytoplankton, which mirrors the same decline. This PC is mainly influenced by the strong decline in the 13 most abundant diatoms. There is strong concordance between these PCs for zooplankton and phytoplankton for the North Sea, suggesting bottom up control.

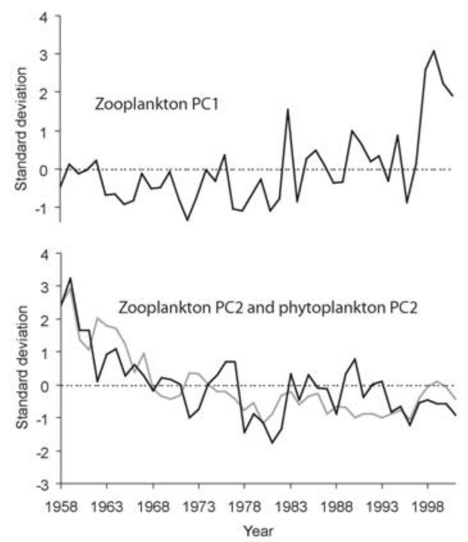

Figure 5. Principal component analysis (PCA) of the zooplankton community structure in the North Sea 1958-2001. PC1 = 53% (top figure), PC2 = 20% and the phytoplankton community (grey line) PC2 = 34% (bottom figure). The PCA was performed on the covariance matrix to give more weighting to more abundant species. Only species that occurred in more than 1% of the samples in the North Sea were included (33 species).

Status summary

The spring bloom in 2001 was slightly earlier than the long-term mean, but in terms of total spring biomass it was fairly typical. However, annual means of phytoplankton biomass in 2001 remained above the long-term mean. Particularly high phytoplankton biomass values were recorded in July in the North Sea and in winter months in the north-west Atlantic (Newfoundland shelf and Labrador Sea). There were a number of Harmful Algal Blooms in the North Atlantic in 2001, in particular blooms of *Dinophysis* spp. were well above average for the North Sea. Using decapod larvae to summarise phenological changes in the plankton, seasonal timing of life-cycle events are occurring much earlier over the last decade. The seasonal cycle of decapods was 2-3 weeks earlier in 2001 than the long-term mean. These trends are strongly correlated with the NAO index and winter sea temperatures.

Probably the most important changes evident in the zooplankton assemblage over the last few years is the increasing dominance of meroplankton, in particular echinoderm larvae (PC1). Conversely to this, total calanoid copepod abundance, which dominated the zooplankton community from the 1950's to the late 1970's, has declined (PC2). For example, the large calanoid copepod *C. finmarchicus* (contributing to a large amount of zooplankton biomass), and small copepods have declined drastically since the 1960s. The decline in copepod biomass is mirrored in the decline of total diatoms, suggesting bottom-up control. The dominant spectral cycles (7-8 years) apparent in the plankton community trends also are typical of the NAO index and temperature.

Holozooplankton biodiversity in the North Sea has been steadily increasing over the last few years mainly due to the greater presence of warmer more southerly distributed calanoid copepods. While the zooplankton community in 2001 has shown a slight shift in structure compared with 2000, it is dominated by a warm-temperate assemblage. Preliminary results from 2002 hint at an exceptional year in the North Sea both in terms of sub-tropical species present and the number of oceanic species. Annual sea temperature for the North Sea in 2002 was one of the highest recorded.

The fingerprint of climate warming is strongly evident in the plankton recorded by the CPR survey from both the biogeographical shifts in many populations and the changing seasonal cycles associated with the timing of life-cycle events. For example, recent work using CPR data shows a 600 km biogeographical shift in some planktonic assemblages over the last 30 years (Beaugrand *et al.*, 2002). The year 2001 continued with this trend that first became apparent in the late 1980's. While it is not yet possible to distinguish natural changes in populations from those caused by anthropogenic influences, the evidence presented in this summary suggests that climate variability plays an important role in modifying planktonic patterns at the sampling scale of the CPR survey. More sophisticated ecological indices are currently in development at SAHFOS so we can better summarise the biological changes we are witnessing in the North Atlantic.

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Socio-ecological health: identifying resilience and vulnerability in coastal communities of fish and fishers

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The GLOBEC Focus 4 Working Group on the human dimensions of marine ecosystem changes held its second meeting in Banff, Canada, on 25-26 June 2003. This meeting reported on accomplishments since the previous meeting in June 2002 and discussed on-going projects and possible new directions. One of the topics discussed related to resilience and vulnerability of communities of fish and fishing communities, which stimulated the following discussion among the participants.

Resilience, according to the classic article by Holling (1973), is the ability to "absorb and accommodate future events in whatever unexpected form they may take". Its opposite is vulnerability. The more resilient a socio-ecological system, the less vulnerable it is to major changes under conditions of strong disturbance. By the same token, lessened resilience increases vulnerability and the likelihood that, when faced with crisis, a critical threshold will be reached beyond which the system can no longer maintain itself, and will shift into a new, qualitatively different state. When dealing with coupled social – ecological systems, this new state may be perceived by humans as less desirable.

In both Focus 4 of GLOBEC and its partner, *Coasts Under Stress* (www.coastsunderstress.ca), we have begun to identify the main characteristics of the socio-ecological systems that comprise "communities of fish and fishing communities" that lead them to have high (low) or low (high) vulnerability (resilience) to disturbances. We look at fish and fishery related socio-ecological webs in order to see what we might learn from them to contribute to the general understanding of the relationship between societies and nature, and to understand better the origins and nature of change in marine ecosystems. This, in turn, will allow us to identify potentially wiser ways to interact with our marine resources and human coastal communities.

By "communities of fish and fishing communities" we mean the nested, socio-ecological webs that are made up of humans, human institutions, and natural marine environments. Natural communities include interacting biological elements such as species assemblages and their predators and prey which humans identify as a food web. These are typically related to a particular niche, place, or environment. The species in such communities usually comprise different year classes, sex composition, and life history strategies for juveniles and adults, all of which are believed to help provide ecological resilience. The ecological system is the interaction of these biological communities with the wider physical – chemical environment.

Human fishing communities are built from individuals within families which, in turn, are embedded in communities that are themselves part of larger socio-economic systems. We prefer to think of communities as the fundamental unit for the purposes of resilience, as we believe it is the diversity or lack thereof of opportunities and responses within communities that influences resilience. Communities are analogous to fish assemblages, in that variety in assemblages and their responses to change can influence resilience. However, human communities also include language, knowledge, memory, motivation, built and social institutions, power, culture, and so on.

In marine ecosystems, change can be triggered by climate variability and trends, internal ecosystem processes, fishing, pollution, and habitat degradation. An important consideration is the match of the life cycles of fish, plankton, etc. to the time and space scales of the environmental variability. Fast growing fish with short life cycles (e.g. in tropical areas) can take advantage of pulses and so their abundance might be more directly affected by climate variability. High latitude fish have evolved to grow more slowly which may put them at greater risk of impacts from direct human activities, but there is also variability among high latitude fish, e.g. the differences in size and growth rates among Atlantic cod.

For any fish assemblage, human activities can reduce the adaptive capacity of that assemblage, thereby increasing its vulnerability to change, such as by altering the evolutionary characteristics of individual species – for example, shortening the life span by removing all large, old, fish. In human communities, change can result from demographic processes, technological innovations, law and property relations, relationships between generations, knowledge, relations of production/reproduction, gender relations, relationships to wider society, shifting flows of wealth, alterations in values, and many other things as well, both endogenous and exogenous.

Since we are thinking in terms of *linked socio-ecological systems*, we must think in terms of the bi-directional nature of change causation – some changes in human communities will affect the marine ecosystem, and some changes in marine ecosystems will affect human communities. Nor will these impacts necessarily be linear. There are also some caveats here which must be recognized: the risk of becoming deterministic, and the probability that not all feedback processes will be of equal importance.

Can we identify parallel processes of resilience and responses to change in communities of fish and fishing communities? First, we must bear in mind that change is multi-dimensional: there are temporal, spatial, and organizational dimensions of change. Change may also be caused by dynamics *within* communities of fish or fishing communities. There are also some parallel principle drivers of change. Evolution and related strategic adaptations, such as broad versus narrow niche adaptations, for example, are found in both human communities and the natural world. Human societies' commodity chains might be thought of as somewhat analogous to food chains in the natural world but they also differ in fundamental ways. It might be fruitful to explore the parallel concepts of ecological efficiency and efficiency in human societies. Parallel notions of justice as applied to nature and societies have proved useful in exploring alternative socio-ecological systems.

In both kinds of communities, minimum population size for survival is one issue, as is diversity (species, behavioural, genetic, occupational, cultural, etc.). These can be essential components of resilience. In this respect it is interesting to note that with respect to human communities, fisheries and fishing strategies have, historically, often been quite diverse both within and across communities. Occupational pluralism was a significant adaptive strategy associated with seasonal variations in the availability of fish and variations in access to processing facilities and markets. Communities of fishers also do not necessarily live in the same town. In the larger fleets, whether present-day or in history, fishers may come from a number of different towns. For some, their fishing has been an adaptive strategy designed to maintain the household (family) or the occupational community rather than the geographical settlement. This is, of course, a variation of the use of multiple ecological niches (a broad niche strategy, in effect) in order to survive. Highly migratory fish and fish tolerant of a broad range of temperatures, depths, and fishers have therefore to be considered, as has the impact of in- and out-migrants on local areas – out-migration into other sectors, places, may be a way of bringing capital (either income in human terms, or new genes in natural terms) back to invest in fisheries or fish stocks. This is an adaptive strategy which, in human terms has been referred to as "leaving in order to stay" (Sinclair, 2002).

Other system qualities associated with particular marine ecosystems include differences in species composition, productivity, efficiency, biodiversity, predator-prey relationships, and reproduction. The parallel qualities seen in human fishing communities are some specialization within and between them (which allow them to inhabit particular economic/social/political/natural niches), sex and gender, class, culture, age, and other sources of diversity, such as built environments, and multiple uses of natural environments. Factors responsible for continuity/resistance to change or for channeling change in particular directions in communities of fish include reproduction, metabolic rates, evolution. In fishing communities the equivalents are demographic patterns, ecological exploitation, institutional structures including regulatory frameworks (which can lead to inertia), training, technologies, knowledge frameworks (dominant paradigms), knowledge flows, and built environments.

Adaptive capacity, according to Folke *et al* (2003), requires the presence of four factors: learning to live with change and uncertainty; nurturing diversity for resilience; combining different types of knowledge for learning; and creating opportunity for self-organisation towards social-ecological sustainability. To date we have not met such requirements well at all. The spatial scale of management (science), and the spatial dynamics of fish communities, has been mismatched. Likewise, single species management and management systems that treat fish as a commodity only, and fishers as atomized individuals who are not embedded in society, in households and communities, have not promoted a management environment in which such factors would flourish. It is important, therefore, to begin to think what might be a wiser way to proceed – perhaps by treating communities of fish and fishing communities as linked units, thinking of humans as part of the marine ecosystem and acknowledging that these socio-ecological systems are a product of history. What is clear is that we can no longer treat either species (or communities) of fish, or human social units as monolithic. We must learn to focus on each as multi-dimensional, dynamic and interdependent. In the case of rapid and major change (regime shifts or threshold levels) in the natural system, considerable re-organisation of the ecosystem may occur, with markedly different relationships among species including colonisations of new species from elsewhere. In human societies, we get changed communities – as when the big company comes in, buys up the local processing plant and closes it down and the actors change – the parallel may be to exotics in terms of ecosystem effects! We need to think resilience when we think regulatory frameworks, build history and dynamism, as well as different spatial, temporal and organizational scales into our thinking, and use the wider forms of knowledge that exist in human communities, not just management science based on normal natural science. The challenge is not simple and straightforward, but it must be faced.

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Climatic warming impacting pelagic fish stocks in the Black Sea due to an ecological regime shift during mid-1990s

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The Black Sea may be considered one of the best marine examples for the present Anthropocene era because of the complex human-induced effects on its ecosystem superimposed on climate-driven changes. Since the 1970's, it has been drawn into a highly unstable mode through a series of perturbations, mainly imposed by manipulation of river discharges, high input of nutrients and organic loads, invasion of the gelatinous carnivore species *Mnemiopsis leidyi*, and excessive fishing. The most serious deterioration of the Black Sea ecosystem was recorded towards the end of the 1980's when it was dominated entirely by the top predator jellyfish *Mnemiopsis* (Fig. 1).

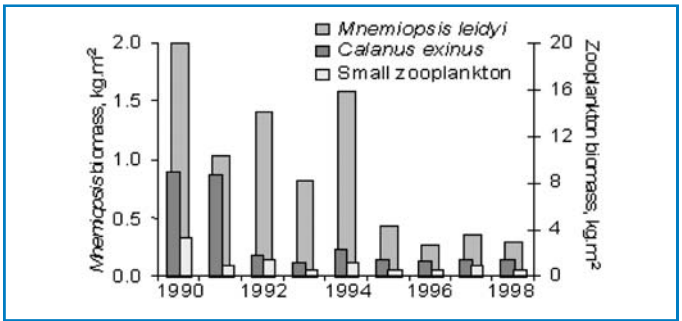

Figure 1. Autumn biomass distributions (kg m^{-2}) of Mnemiopsis, Calanus exinus and small mesozooplankton in offshore waters of the Black Sea (after Anninsky et al. 1998).

Adverse effects of human-induced perturbations have continued controlling the ecosystem during the last decade as well, even though some signs of recovery were noted (Kideys, 2002). The recovery of the ecosystem, suggested by the gradual decrease of the *Mnemiopsis* biomass (Fig. 1) and increase in the anchovy catch during the first half of the 1990's, was attributed to some measures for controlling eutrophication as well as a weaker top-down grazing control of *Mnemiopsis* on mesozooplankton community. On the other hand, abrupt decreases of both *Mnemiopsis* biomass and anchovy catch during the second half of 1990's together with low microzooplankton and mesozooplankton biomass levels comparable to those before 1995 indicate a different structure of the Black Sea ecosystem.This was caused by variations in its physical climate introduced by intensive warming of its surface waters (Oguz *et al*., 2003). The climatic signal coincided with 4 cm yr^{-1} net sea level rise in the basin, and a substantial change in the net annual mean fresh water flux from 150 km^3 yr^{-1} in 1993 to 420 km^3 yr^{-1} in 1997. These occurred as a consequence of the decadal scale climatic oscillations over the North Atlantic (Stanev and Peneva, 2002).

Sea surface temperature (SST) data provide a clear indication of warming of surface waters in the Black Sea during the 1990's. The basin-averaged winter (December-March)-mean and annual-mean SST variations during 1985-2001 period (Fig. 2) reveal an intense cooling period in the early 1990's followed by an equally strong winter warming phase during 1994-1996. The winter warming phase is maintained for the rest of the 1990's by a more gradual temperature variation. The basin-averaged winter SSTs retained at least their 1997 level of warming, and

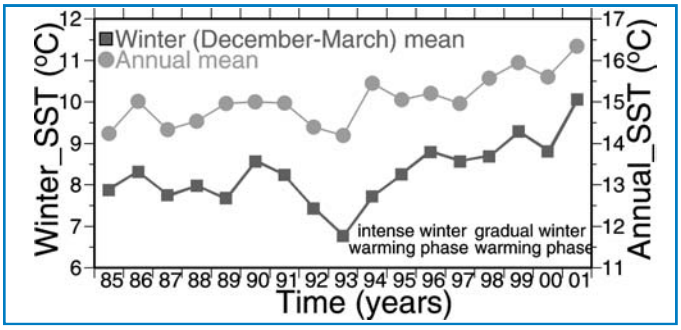

Figure 2. Basin-averaged, winter (December-March)–mean (squares) and annual-mean (dots) AVHRR sea surface temperature distributions in the Black Sea from 1985 to 2001. They are obtained from 9 km monthly-mean, gridded NOASS/NASA AVHRR Oceans Pathfinder data set. The averaging excludes the shelf areas shallower than 200 m. The temperature scale for the winter-mean data is given on the left, and for the annual-mean data on the right (after Oguz et al., 2003).

may be as high as ~10°C in 2001. These warmer winter SSTs were found to be correlated with milder winters characterized by relatively higher air temperatures (Krivosheya *et al.*, 2002), weaker heat loss to the atmosphere and weaker wind stress forcing exerted on the sea surface (Nezlin, 2001). The warming trend is also well-pronounced in the annual-mean data in the form of linear SST rise by about 2°C from 1993 to 2001 (Fig. 2).

The subsurface signature of the warming can be traced from the structure of the Cold Intermediate Layer (CIL), characterized traditionally by temperatures colder than 8°C. This cold water mass, convectively generated every winter within the upper 50-75m of the water column, preserves its identity between the seasonal and permanent thermoclines during rest of the year. As shown in Fig. 3 the average winter CIL temperature shows a linear trend of increase from its minimum value of 6.2°C in 1993 to around 7.7°C during the winters of 2000 and 2001. This trend follows quite closely the air temperature variations at the same site. Moreover, approximately 5-10 m rise of the anoxic interface level during the second half of 1990's (Yakushev *et al.*, 2001) might reflect destabilization of the permanent pycnocline as a consequence of warming of the surface waters.

The warming period may well be teleconnected to changes in

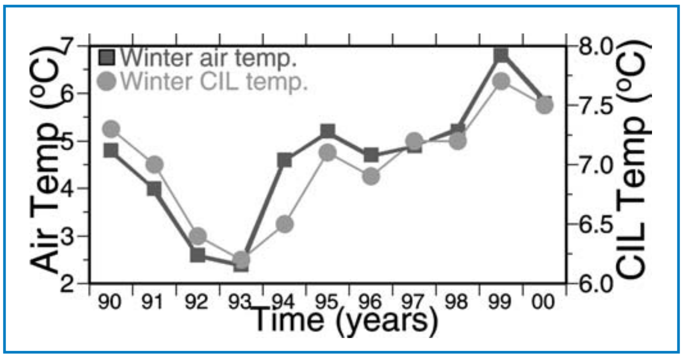

Figure 3. Winter (December-March)–mean air temperature (dots) and average CIL temperature (squares) distributions at a specific site along the northeastern coast of the Black Sea, off Gelendzhik from 1990 to 2000. The data are taken from Krivosheya et al. (2002).

the North Atlantic Oscillation (NAO) cycle, and the climatic warming trend of the Northern Hemisphere. Stanev and Peneva (2002) pointed out that the constant sea level rise of ~12cm in the Black Sea from 1993 to 1996 was correlated with the increased net fresh water flux into the basin which in turn is correlated with the dramatic decrease of the NAO index (from +2 to -2) during the same period. These changes in the physical climate of the sea imply a disintegration of the prevailing basinwide cyclonic circulation cell (Korotaev *et al.*, 2003), and weakening of the associated upward motion within the interior part of the basin after 1995.

In the Black Sea, different sets of biological time series data collected systematically at several coastal locations are available and show consistently similar features which might be correlated with local changes in the physical characteristics of the water column.

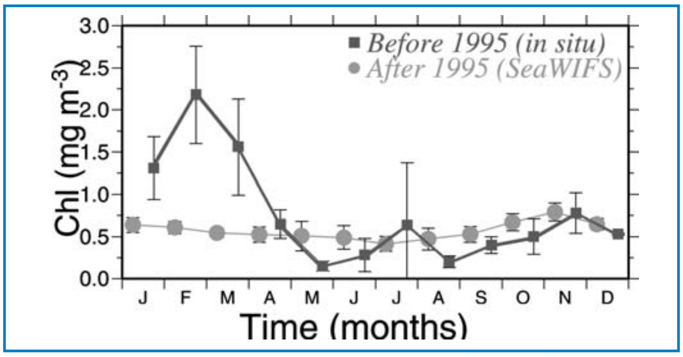

Figure 4. Monthly mean surface chlorophyll (mg m-3) distributions obtained by averaging all the monthly mean surface chlorophyll concentrations composed from different measurements carried out in deep parts of the sea prior to mid-1990's (squares) and from 9 km gridded SeaWIFS data for 1997-2002 and Ocean Color and Temperature Scanner (OCTS) data during November 1996-June 1997 (dots). The basin-averaging excludes the coastal regions shallower than 200 m (after Oguz et al., 2003).

The intimate relationship between climatic warming and the annual phytoplankton production can be inferred by comparing the multi-year average and basin-average monthly chlorophyll distributions for the periods before and after 1995 (Fig. 4). The Black Sea ecosystem up to mid-90's has been characterized by two distinct chlorophyll peaks (Yunev *et al.*, 2001). The major peak occurred either during February or March with a secondary peak in October or November. The surface mixed layer is characterized by much lower chlorophyll concentrations during the warm part of the year, from May to September, due to limited nutrient supply into the mixed layer. On the contrary, the composite ocean color data set representing the monthly mean chlorophyll concentrations since 1996 onwards (shown by dots in Fig. 4) indicates steady winter values of about 0.5 mg m^{-3} in contrast to a well-pronounced peak of ~2.0 mg m^{-3} in the data set prior to the mid-90's. Weaker turbulent mixing and stronger stratification during mild winters of all these years should be responsible for more limited nutrient supply from the nutricline, and consequently erosion of the late winter-early spring peak of the annual surface chlorophyll distribution by more than half after the mid-90's. Such a poor new production-based biological activity in February-March is followed by equally poor regenerated production during rest of the spring season. The annual structure acquires only a weak autumn peak of about 0.75 mg m^{-3} comparable to its counterpart in the former data set.

The measurements near Gelendzhik along the northeastern coast of the Black Sea also reveal two different forms of the annual mesozooplankton biomass distributions before and after

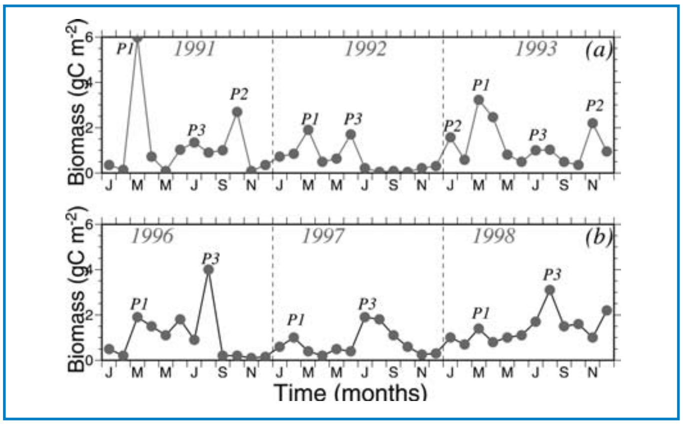

Figure 5. Distributions of mesozooplankton biomass (gC m^{-2}) near Gelendzhik along the northeastern Black Sea. Measurements are carried out during (a) 1991-1993 period, (b) 1996-1998 period (after Oguz et al., 2003).

1995 (Fig. 5). Their distributions for the 1991-1993 period possess two distinct maxima with the primary one in March, and the secondary one in October-November. They, denoted in Fig. 5a by P1 and P2, respectively, thus follow the spring and autumn phytoplankton blooms. These two peaks are connected with the relatively weaker summer mesozooplankton activity (given by the peak P3). The intensity of the latter peak is controlled by two contrasting processes; the subsurface phytoplankton production, and the feeding pressure of anchovy larvae which imposes its strongest control during the summer. This structure slightly differs during 1992 by weaker spring peak P1, and shift of the autumn peak P2 towards the following early winter season.

Similar measurements carried out at the same site during the 1996-1998 period, i.e. in warming phase of the Black Sea, show a systematically different annual pattern. The early-spring mesozooplankton bloom (i.e. the peak P1 in Fig. 5b) is no longer a dominant feature of their annual structure due to the bottom-up resource limitations in the spring primary production. The autumn mesozooplankton biomass distributions after the mid-1990's (i.e. the peaks P2 in Fig. 5b) are also somewhat lower than those of the early 1990's displayed in Fig. 5a. On the contrary, the summer peak P3 emerges as the most dominant feature of the annual mesozooplankton structure after mid-90's. It possibly arises due to a relatively weaker top-down grazing pressure introduced by reduced anchovy population. Somewhat similar annual structure is also observed within the Sevastopol Bay from September 1999 to November 2001 (Finenko *et al.*, 2003; see Fig. 12 in Oguz *et al.*, 2003). Once again, the mesozooplankton biomass is highest during summer months, even though the summer peak is shifted towards the autumn during the year 2000.

The effect of bottom-up limited unfavorable phytoplankton growth and subsequently reduced mesozooplankton stocks associated with climatic warming emerge at higher trophic levels in the form of decreasing trends in both the gelatinous carnivore biomass and the anchovy catch data during the second half of the 1990's (Fig. 1). Evidently, mesozooplankton stocks can no more meet the annual food demand of the pelagic fish community at a steady level. As warming prevails longer, both mesozooplankton and pelagic fish stocks are expected to decline further due to stronger bottom-up limitation associated with continual loss of nutrients from the euphotic zone against their more limited supply from subsurface levels. From the fishery perspective, a closer look at future evolution of the plankton community structure is therefore of critical economical importance.

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ICES/GLOBEC Cod and Climate Change Programme – results and achievements

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Cod stocks have generally declined over the past twenty years and landings fell from about 1.6 million tons in 1980 to just over half that in 2000. Climate change probably played a part in this decline for some stocks, but the overwhelming cause was excessive levels of fishing. Productivity and distribution of cod has been affected by environmental variability, with major consequences for recovery rates of depleted stocks.

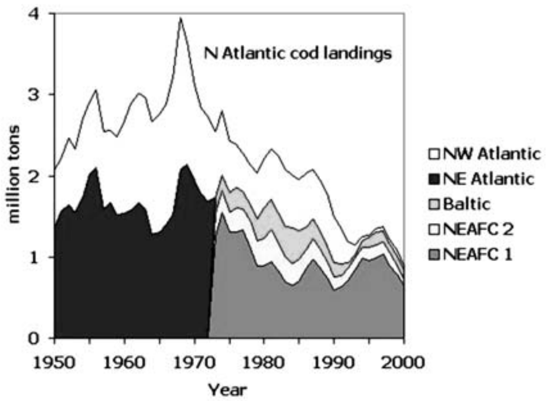

Figure 1. Catches of cod in the North Atlantic, by region (1950-2000)

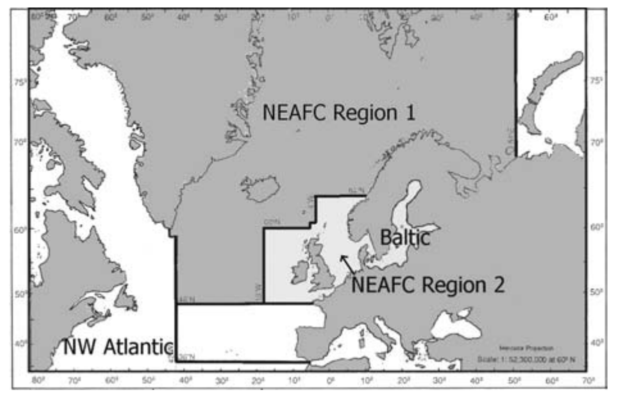

Figure 2. Main North Atlantic fishing regions, as reported in Fig. 1

The decline in cod stocks was steepest in the NW Atlantic, where landings in 2000 were 10% of their 1980 level and most fisheries remain closed. In many of these stocks individual growth rates declined from the early 1980's onward and condition of individual fish was also poor, so that mean weights at age fell by 50% or more. Poor condition contributed to lowering of recruitment rates, while natural mortality increased. The consequence of these changes, which are due in part to environmental variability and climate change, is that the productivity of some stocks has declined to the point where they are unlikely to recover even if the ban on fishing continues.

In the NE Atlantic the changes are less adverse. From 1980 to 2000 landings dropped by 50%, but in NEAFC Region 1 the decline was only 28%. Recruitment rates have fallen at the warm end of the species range, around the British Isles, but growth rates remain high and there is no evidence to date of increased natural mortality, such as has been observed in the NW Atlantic.

Information about the effects of climate on the processes which govern production (growth, maturation, egg production, transport during early life, survival and natural mortality) can be used in appraising the management options for sustainable fisheries. The development of methods for doing so has been

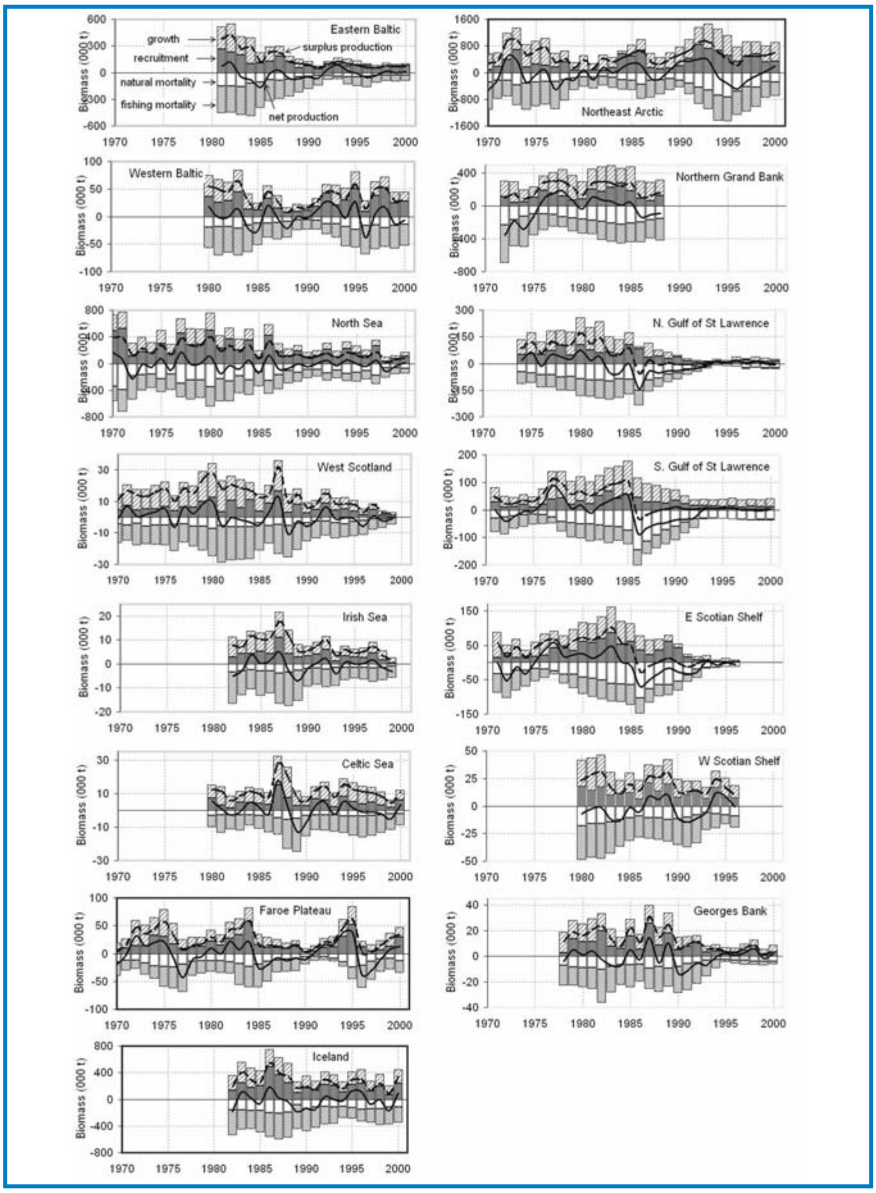

Figure 3. Biological production of Atlantic cod stocks. Increases in biomass (positive values) are due to growth and recruitment and losses of biomass are due to natural and fishing mortality. Surplus production (-----) equals net production (——) plus catch. From Dutil and Brander (Fisheries Oceanography 12 (4-5))

an ongoing theme of the programme. Most of the processes have been the subject of workshops and theme sessions over the past few years, for example a workshop on Transport Processes in 2002 evaluated the effects of variations in transport during early life on subsequent recruitment and examined the coupling of circulation models with early life history models to determine the physical and biological processes responsible for the transport or retention of cod larvae. Cod eggs and larvae travel up to 1600 km during the pelagic stage, but greater distance does not lead to greater variability in survival and recruitment. The workshop is being followed up with a Theme Session in 2003 which will hear about further coupled modelling to explore survival and the transport between stocks. The results will be published as an ICES Cooperative Research Report.

Talks at the Session on Comparative studies of North Atlantic ecosystems at the 2nd Open Science meeting in Qingdao dealt with the response of plankton and fish to climate forcing and the effects of food and environmental limitations on growth production of cod. An ICES Workshop and Theme Session on cod growth provided much new information about the role of size selective fishing, food availability, environment and genetics in determining the changing growth patterns (ICES Cooperative Research Report 252).

Future Plans

The Cod and Climate Change programme is currently in a synthesis phase, with three major activities dominating the timetable until the end of 2004:

1. Publication of a book in the IGBP series on the current state of knowledge about cod and its response to climate change

The biological and life history processes underlying climate driven changes in cod include recruitment (i.e. the number of young fish produced), growth, maturation, natural mortality and migration. Thanks to its commercial importance, a long history of research and a dedicated programme within ICES on Cod and Climate Change over the past decade, much has been learned about these processes and about their interaction with each other and with the food chain, predators and other components of the marine ecosystem. Cod is probably the most comprehensively studied marine fish species, occupying a key role in several North Atlantic ecosystems. An understanding of its dynamics is of direct and indirect relevance to other species and to gaining insight into the response of the marine ecosystem to climate change and variability. Chapters of the book will review many aspects of our knowledge of cod, but will also report new results and analyses. They will use a comparative approach to draw conclusions from differences and similarities between the many stocks, which occupy a range of different physical and biological situations.

2. A Symposium on the Influence of Climate Change on North Atlantic Fish Stocks in Bergen in May 2004

This will be an opportunity to measure progress against the 1993 Cod and Climate Change Symposium, held in Reykjavik. Invited talks will include Climate variability in the North Atlantic: past, present and future (J. Hurrell), The impact of climate on the distribution and migration of fish populations (G. Rose), The effect of climate variability on growth, maturity and recruitment (G. Marteinsdottir), Zooplankton and the link between climate variability and fish (M. Heath), Taking account of climate in the evaluation of the state of fish stocks (C. O'Brien) and Managing fish stocks under future climate scenarios and in the face of climatic uncertainty (L. Richards).

3. An update of Cooperative Research Report 205 on Life History Information for Cod Stocks.

This is a detailed compilation of information for all major cod stocks, based on checklists which has been circulated to experts on each stock. It is intended as a comprehensive data source for those studying cod and will update the material and references contained in the previous report. The scope will be somewhat wider than the earlier report and will include information on migration and adult growth.

The above synthesis activities will be completed in 2004, but a plan for continuing work within the Cod and Climate Change programme has been put forward for the period to 2009, when the GLOBEC programme as a whole is due to end. The work will be drawn together in a series of workshops:

1. Workshop on the Impact of Zooplankton on Cod Abundance and Production (in 2005)

Early stages of zooplankton are important prey for larval and early juvenile stages of cod. For most cod stocks *Calanus* species are the main prey, while in some areas, e.g. the Baltic, other species dominate. Survival and growth through these early stages have been shown to be critical for establishing a strong cod year class in some cod stocks. A better understanding of zooplankton-cod linkages should therefore be an important step towards better early estimates of year-class strength and thus recruitment to the cod stocks. The workshop would therefore examine relations between temporal and spatial dynamics of zooplankton and early stages of cod. Issues to be addressed would include how timing of zooplankton production and spatial dynamics of nauplii relates to the spawning and distribution patterns of early stages of cod and ultimately cod recruitment. Links between later stages of cod and zooplankton will also be addressed. A combination of statistical data analyses, process studies and a variety of modelling approaches will be applied. The workshop will build on the results of the 2002 workshop and the 2003 theme session on transport of cod eggs and larvae as well as output from the ICES 2003 Zooplankton Symposium. The WG felt that this should be undertaken together with the ICES Working Group on Zooplankton Ecology (WGZE). The co-chairs were requested to contact the chair of the WGZE to ask their interest in co-sponsoring and participating in such a workshop.

2. Workshop on The Decline (and Recovery) of Cod Stocks Throughout the North Atlantic (in 2006)

During the presentations on the update of the cod stocks around the North Atlantic, the WG was struck by the similarity in the abundance trends of many of the stocks, from high values in the 1960's that in some cases persisted through into the 1970's and 1980's, followed by a decline to relatively low levels. In addition, there were often declines in size-at-age and age of maturity. The cause of these declines and the potential for recovery are among the most important issues for cod fisheries today. The Workshop will compare the changes that have occurred in all of the cod stocks around the Atlantic and address the relative importance of fishing and climate induced ecosystem changes.

3. Workshop on the Influence of Climate on Tropho-Dynamics of Cod Ecosystems (in 2006)

This Workshop also addresses the observed changes in size–at-age and maturity, but from a tropho-dynamic and bioenergetic perspective. It can therefore be regarded as complementary to the previous Workshop and could be linked to it. The Workshop will consider both observations and theory, including mass balance and scaling from individual based modelling. The role of forage species will be reviewed, particularly capelin in the Barents Sea and at Iceland and sprat in the Baltic. To what extent are observed changes cod stocks due to climate induced variability in their principal prey species? What is the role of climate change on predators of cod (e.g. harp seals)?

4. Workshop on The Future of Cod in a Changing Climate (in 2007)

Over the last decade, concern over the impacts of global change in climate have increased. New evidence documents the ecological impacts of rising temperature in northern high latitudes. Scenario studies from GCMs indicate substantial climate change over the next 50 years therefore further investigation into the impacts on cod are warranted. The Workshop will assess how abundance, distribution, and production of cod may respond to future climate scenarios. Results from statistical and dynamic downscaling will be applied together with relations established through retrospective analyses. The WG felt that this topic, which gave the programme its name, should be addressed directly before GLOBEC ends. Scientists working on statistical or dynamical downscaling from GCMs, especially in marine settings (e.g. in Norway the RegClim project), should be invited. K. Drinkwater was willing to be one of the co-chairs.

5. Workshop on Implications of Results from CCC for Fisheries Management (in 2008)

As recognized at the CCC meeting in 2002, more work is need on the application of the results from the CCC to fisheries management. The WG reconfirmed this by agreeing upon a workshop on the subject. Its aims were not well developed, but should be discussed at all Workshops during the intervening period, in order to ensure that they are addressed. The aim will be to develop techniques and methods for incorporating environment into fisheries and ecosystem management and to provide examples.

6. Synthesis II Workshop (in 2009)

The WG felt that if the CCC program ends in 2009 when GLOBEC is scheduled to finish, a second Synthesis Workshop should be held to highlight the results of the CCC program. The subjects to be addressed by the Workshop will depend on results and issues that arise during the next 5 years.

ICES/GLOBEC CCC reports (2000 to date)

ICES. 2000. Report of the Working Group on Cod and Climate Change. *ICES Council Meeting Papers* CM 2000/C:11, 16pp.

ICES. 2000. ICES/GLOBEC Workshop on the Dynamics of Growth in Cod. *ICES Council Meeting Papers* CM 2000/C:12, 114pp.

ICES. 2001. Workshop on Gadoid Stocks in the North Sea during the 1960's and 1970's. *ICES Cooperative Research Report* 244, 55pp.

ICES 2001. Report of the Working Group on Cod and Climate Change. *ICES Council Meeting Papers* CM 2001/C:12, 10pp.

ICES. 2001. Report of the Steering Group for the ICES/GLOBEC North Atlantic Regional Office. *ICES Council Meeting Papers* CM 2001/C:13, 13pp

ICES. 2002. Report of the Workshop on the Transport of Cod Larvae. *ICES Council Meeting Papers* CM 2002/C:13, 44pp.

ICES. 2002. Report of the Working Group on Cod and Climate Change. *ICES Council Meeting Papers* CM 2000/C:12, 10pp.

ICES. 2002. Report of the Steering Group for the ICES/GLOBEC North Atlantic Regional Office. *ICES Council Meeting Papers* CM 2002/C:17, 18pp

ICES. 2002. ICES/GLOBEC Sea-going Workshop for Intercalibration of Plankton. *ICES Cooperative Research Report* 250, 25pp plus 4 CDs.

ICES. 2002. Report of the ICES/GLOBEC Workshop on the Dynamics of Growth in Cod. *ICES Cooperative Research Report* 252, 97pp plus 1 CD.

ICES. 2003. Report of the Working Group on Cod and Climate Change. *ICES Council Meeting Papers* CM 2003/C:11, 16pp.

ICES. 2003. Report of the Workshop on a Synthesis of the Cod and Climate Programme. *ICES Council Meeting Papers* CM 2003/C:10, 28pp.

GLOBEC SCIENCE

A column for scientific notes of relevance to the GLOBEC community

Modeling the Peru Upwelling System seasonal dynamics

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The Peru Upwelling System is located along the west coast of South America, approximately between 20°S to 5°S and between 90°W to 70°W, where an equatorward wind forces a strong coastal upwelling. With the Benguela Current System, the Canary Current System and the California Current System, the Peru Upwelling System is one of the four major coastal upwelling regions of the world. These four upwelling systems are highly productive. The Humboldt Current Large Marine Ecosystem (i.e. from the South of Chile to the North of Peru is the most productive marine ecosystem in the world, as well as the largest upwelling system. It produces approximately 18-20% of the world's fish catch (http://na.nefsc.noaa.gov/lme/text/lme13.htm). This production is highly variable and strongly dependent on environmental factors such as sea temperature and currents. In this area, El Niño is a major contributor to environmental variability. In an attempt to investigate the dynamics of the Peru Upwelling System and the coupling between the environment and the ecosystem dynamics, a set of physical and biological models will be implemented. This is part of a joint initiative between IMARPE and IRD. The implementation of the hydrodynamic model and the analysis of its seasonal behaviour presented here are the first steps in the design of a coherent set of numerical tools.

The circulation in the Peru Upwelling System is very complex. Unlike other upwelling systems, the Peru Current System is closely connected to the eastern limit of the equatorial currents (Lukas, 1986). Hence, a model of the Peruvian upwelling should explicitly resolve as well the eastern equatorial dynamics. In this work, the focus is on the average circulation, the seasonal cycle and the mesoscale dynamics of the Peru Current System; the inter-annual variability will be addressed in the near future.

After a presentation of the characteristics of the model, the modeled annual mean circulation is described. Model/data comparisons are then performed as a first test of the ability of our regional configuration to simulate the seasonal cycle in the Peru Upwelling System.

Model characteristics

The ocean model is the Regional Oceanic Modeling System (ROMS). The reader is referred to Shchepetkin and McWilliams (2003) and to Shchepetkin and McWilliams (in press) for a more complete description of the model. ROMS solves the Primitive Equations in an Earth-centered rotating environment, based on the Boussinesq approximation and hydrostatic vertical momentum balance. ROMS is discretized in coastline- and terrain-following curvilinear coordinates. The model grid, forcing, initial and boundary conditions are built using the ROMSTOOLS package (Penven, 2003). To encompass the whole Peru Upwelling System, we have designed a grid extending from 20°S to 3°N and from 90°W to 70°W (Fig. 1) at a resolution of 1/9° (i.e. 10km). The grid contains 192 by 256 points and 32 vertical levels.

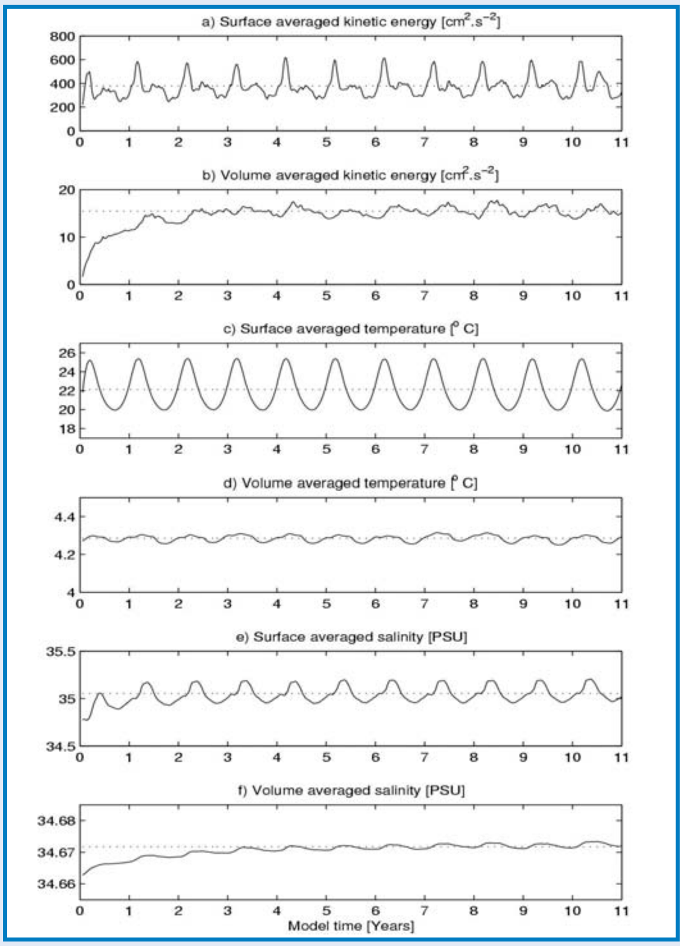

Figure 2. Time evolution of different model variables: a) Surface averaged kinetic energy (cm2.s^{-2}), b) Volume averaged kinetic energy (cm2.s^{-2}), c) Surface averaged temperature (°C), d) Volume averaged temperature (°C), e) Surface averaged salinity (PSU), and f) Volume averaged salinity (PSU)

Our modeling procedure is based on a step by step approach. It starts by addressing the mean circulation and seasonal cycle in the Peru Current System, leaving aside the inter-annual variability. The model is forced by COADS ocean surface monthly climatology for the heat and fresh water fluxes, and by a climatology derived from QuickSCAT satellite scatterometer data for the wind stress. The three lateral open boundaries (Marchesiello *et al.*, 2001) are forced using a climatology derived from the OCCAM global ocean model (Saunders *et al.*, 1999).

The model solution reaches a statistical equilibrium after a spin-up of about 2 years. Figure 1 (see page 2) presents a snapshot of the modeled surface currents and sea surface temperature for 8 January of model year 11. One can notice the cold upwelled water along the shore, the upwelling filaments extending from the upwelling front, the equatorward flow along the shore, the offshore Ekman transport, and the strong equator eastward current. The major ingredients of the known physical dynamics in the region appear to be represented. The cold tongue extending Northwestward from Punta Falsa to the equator is also a typical pattern observed at this time of year. Figure 2 depicts the time variations of surface-averaged kinetic energy (a) volume-averaged kinetic energy (b) surface-averaged temperature (c), volume-averaged temperature (d), surface-averaged salinity (e), and volume-averaged salinity (f). For each of these variables, after a spin-up of 2 years, the model exhibits no significant temporal drift.

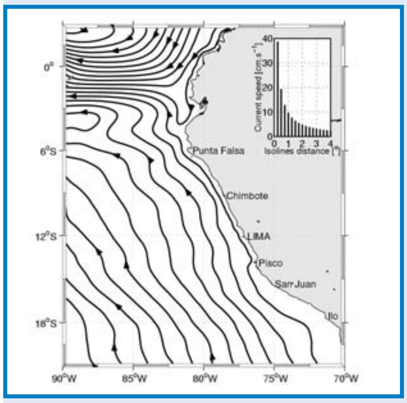

Figure 3. Streamfunction calculated from the annual mean surface velocities. The interval between the isocontours is 10^{-4} $m^2.s^{-1}$. A diagram presenting the distances between the isolines and the corresponding currents speeds is inserted in the upper-right corner

Annual mean circulation

A streamfunction, representative of the nondivergent component of the surface annual mean currents, is derived from the model outputs and portrayed on Figure 3. In this depiction, the principals surface currents described by Lukas (1986) and Strub *et al.* (1998), are represented with a very high degree of realism. In this simulation, the South Equatorial Current is extending from about 2°N to 2°S. It flows westward with velocities in the 25cm.s^{-1} - 40cm.s^{-1} range. An important part is fed by a southwest current that is coming from the Northern model boundary. At the western border, around 4°S, a branch of the South Equatorial Counter Current enters the model domain, with velocities of about 10cm.s^{-1} to 15cm.s^{-1}. At the shore, the Peru Coastal Current is flowing northward following closely the Peruvian coastline, with velocities ranging from 10cm.s^{-1} to 25cm.s^{-1}. Offshore, in the South-West corner of the model domain, we can detect the presence of the Peru Oceanic Current. From this figure, we can conclude that this simulation gives a most realistic representation of the known ocean surface circulation for this region.

Figure 4 presents a streamfunction calculated from the modeled annual mean velocities at 50m depth. This image shows that already at 50m depth, a poleward undercurrent (the Peru-Chile Under Current) is noticeable at the shore with a speed of about 5cm.s^{-1} to 15cm.s^{-1}. Part of this flow is fed by the Equatorial Undercurrent (current speed: 20cm.s^{-1} to 30cm.s^{-1}) and the South Equatorial Undercurrent that enters the model domain at about 4°S with speeds of about 10cm.s^{-1} to 20cm.s^{-1}. The South Equatorial Undercurrent is also clearly feeding a Peru Subsurface Countercurrent that travels southward at about 5cm.s^{-1} from a latitude of 6°S. The Peru Subsurface Countercurrent is veering to the left to leave the model domain between 15°S and 18°S. This offshore veering could be a plausible explanation for the termination of the Peru Subsurface Countercurrent.

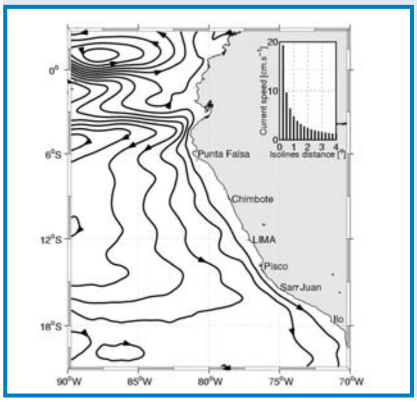

Figure 4. Streamfunction calculated from the annual mean velocities at 50 m depth. The interval between the isocontours is 0.5 x 10^{-4} $m^2.s^{-1}$. A diagram presenting the distances between the isolines and the corresponding currents speeds is inserted in the upper-right corner.

Seasonal cycle

Being locally forced as well as remotely forced by equatorial variations, the Peru Upwelling system exhibits an important seasonal cycle in sea surface temperature. Figure 5 presents the seasonal variations of sea surface temperature from three different sources: the COADS climatology, our regional model and a climatology derived from Pathfinder AVHRR satellite data. Because COADS sea surface temperature is used as a correction in the model heat fluxes, comparisons between a model forcing (COADS), the model solution, and a more precise dataset (Pathfinder) can help to obtain an evaluation of the model skills.

In summer (Fig. 5a, b and c), the three products show the occurrence of a strong upwelling over the shelf. They all present comparable broadscale patterns: warm water at the equator and colder water in the South. A warm pocket of water is also found around 6°S. Our regional model and Pathfinder are much

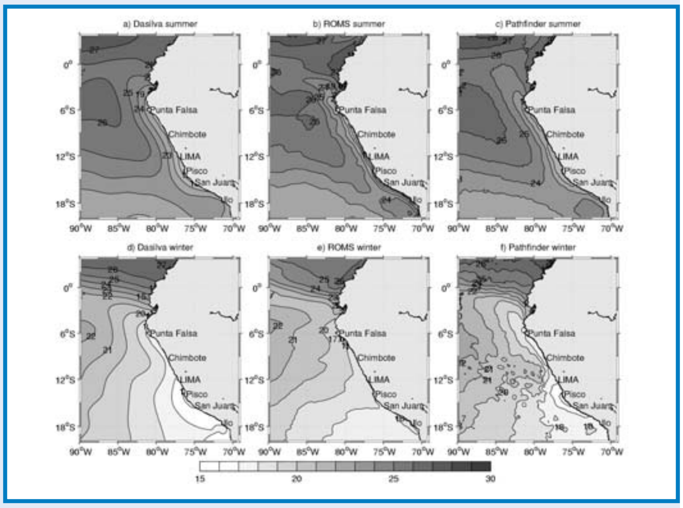

Figure 5. Seasonal variations of sea surface temperature (°C) for the COADS climatology, our regional configuration and a climatology derived from Pathfinder AVHRR satellite data.

similar in their representation of the upwelling front, the cold water tongue extending toward the equator, and the presence of warm water in the southeastern part of the domain. This comparison between model and data suggests that the surface currents simulated by our model adequately compare with reality. The simulation also improves the sea surface temperature patterns, even in comparison to what is used in the model forcing. A few biases are noticeable in our model: the sea surface is slightly too cold close to the shore and a pocket of warm water is present along the Ecuadorian coastline.

In winter, COADS, our model and Pathfinder show the same large scale sea surface temperature pattern (Fig. 5 d, e and f). The position and the width of the equatorial front in the model

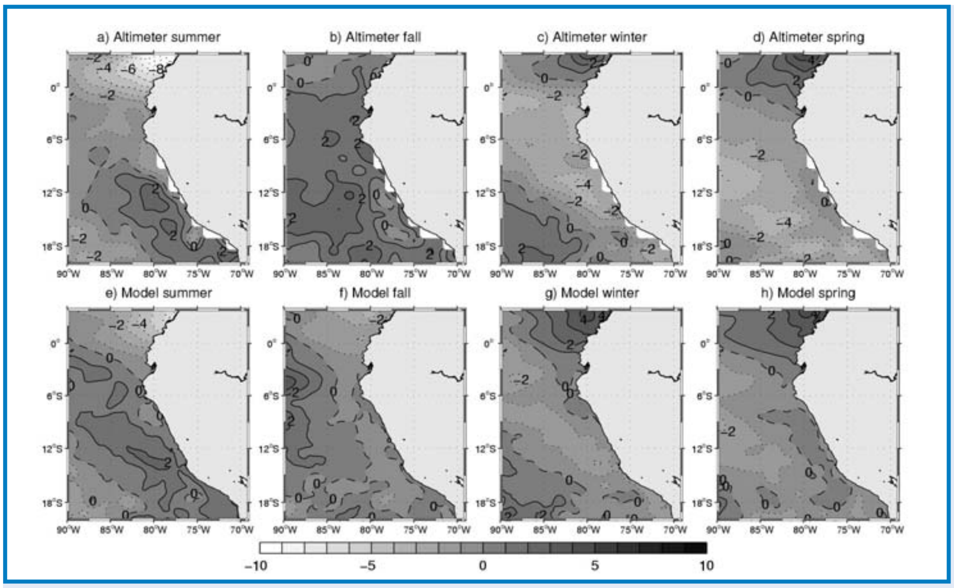

Figure 6. Seasonal mean sea surface height anomalies (cm) for the model simulation and satellite altimeter.

match Pathfinder observations. But, close to the Peruvian coastline, there is still an upwelling for COADS and Pathfinder, a feature that is almost absent in the model simulation. This might be the signature of an important so called El-Niño poleward current that could reduce the upwelling, and/or this also might be associated to weaknesses in local surface forcing.

Seasonal-mean sea surface height anomalies are presented on Figure 6 for both the model simulation and satellite altimeter. Altimeter measurements come from high-resolution merged TOPEX/Poseidon and ERS-1 and -2 data (Ducet *et al*., 2000). The simulated and observed sea surface height anomalies are relatively similar in their patterns. In the northern part of the domain, a strong seasonal oscillation is noticeable in both model and observations. It gets a minimum value of -10cm for the satellite (Fig. 6a) and -6 cm for the model (Fig. 6e) in summer, and a maximum value of 4 cm for both model and altimeters in winter and spring. For the Central Peru Upwelling System, in summer, a large (about 1000km) anticyclone, centered at about 12°S and 80°W, showing a 2cm maximum of anomaly in sea surface height, is present in both altimeter and model solutions (Fig. 6a and e). The seasonal geostrophic current anomaly is thus south-westward, with strong similarities for each product, in summer in the south-east corner of the domain. A first signature of this anticyclonic structure is noticeable along the Peruvian shore in spring (Fig. 6d and h). This pattern is reversed in winter, and the seasonal geostrophic current anomaly in the south-east corner of the domain is now directed toward the north-east for the model and altimeter (Fig. 6c and g).

This comparison between data and simulated fields gives us confidence in the model ability to adequately reproduce surface oceanic patterns as well as the large scale surface circulation in the Peru Current System. A few biases such as the weakness of upwelling in winter, are still present and will be addressed in the near future.

Conclusion

In this short note, the implementation and first tests of a high resolution model of the Peru Upwelling System are presented. The model domain encompasses both the Upwelling System and the equatorial current area; thus the equatorial influence on the Peru Upwelling System is explicitly resolved. The simulated surface and subsurface annual mean circulation patterns seem to be in agreement with the known dynamics of the region. For the seasonal cycle, our regional configuration compares well with Pathfinder AVHRR sea surface temperature data and with altimeter data. Further analysis of this simulation will be conducted to gain more insights on the Peru Upwelling System dynamics. This model could then be used to conduct inter-annual simulations, such as El-Niños or inter-decadal variations.

At IMARPE, this model is currently coupled to an ecosystem model to simulate the primary and secondary production patterns. We also expect to use the model outputs to conduct an analysis of the Lagrangian transport patterns in this area. These studies will be used at a later stage to gain insight on fisheries and marine resources related questions, such as fish eggs and larvae transport.

Acknowledgments

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New structure and developments in China GLOBEC

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China GLOBEC Programme on ecosystem dynamics and the sustainable utilization of marine living resources has been supported by the National Scientific Foundation of China since 1997, after 3 years of planning and development. The first phase of the project was entitled "Ecosystem Dynamics and Sustainable Utilization of Marine Living Resources in the Bohai Sea" (BoSEC or China GLOBEC I). Prof. Jilan Su and Qisheng Tang were chief scientists of the project, which concluded in December 2000. A 5-year long China GLOBEC II was then activated by the Ministry of Science & Technology of China in 1999. Professors Qisheng Tang and Jilan Su are again the chief scientists. It is called "Ecosystem Dynamics and Sustainable Utilization of Marine Living Resources in the East China Sea and the Yellow Sea" (EYSEC or China GLOBEC II). Six main research topics were established by Chinese GLOBEC scientists:

. Energy flow and conversion in key resource species,
. Dynamics of key zooplankton populations,
. Cycling and regeneration of biogenic elements,
. Ecological effect of key physical processes,
. Pelagic and benthic coupling,
. Microbial loop contribution to main food web.

The questions are suitable not only for GLOBEC studies in coastal ocean and marginal seas in China but also globally. China GLOBEC is guided by a GLOBEC Committee that is attached to the Chinese National Committee for IGBP. The national GLOBEC committee plays an integral and important role in coordinating Chinese scientists from different institutions conducting GLOBEC research.

After 15 years of significant scientific achievements, IGBP is evolving into an exciting second phase in 2003. Chinese GLOBEC scientists are paying considerable attention to developments in the ocean domain in IGBP II, in particular synthesis research. Seven Chinese GLOBEC scientists participated in the OCEANS Open Science Conference, demonstrating how positive the Chinese are to the new project. GLOBEC scientists have subsequently hosted two planning workshops to develop new scientific questions for Chinese ocean research. In response to developments in IGBP II, Prof. Qisheng Tang suggested to combine Chinese GLOBEC and IMBER (Integrated Marine Biogeochemistry and Ecosystem Research, the new name for the OCEANS initiative) studies. It is recognized that a new committee of GLOBEC-IMBER would replace the CNC-IGBP/GLOBEC Committee, as a better structure to guide Chinese ocean research in the coming years. The establishment of a Chinese GLOBEC-IMBER committee is aimed at supporting IMBER development. Chinese National Committee for IGBP has approved the suggestion. The new CNC-IGBP/GLOBEC-IMBER Committee is chaired by Prof. Qisheng Tang. Prof. Jing Zhang is the vice-chairman of the committee. The committee takes responsibility for building the research framework for Chinese GLOBEC and IMBER research, in particular on integrating biogeochemical cycles and marine food webs. The continental sea and marginal sea will be the main geographical area of interest.

One of the activities by the CNC-IGBP/GLOBEC-IMBER Committee is to apply for a Xiangshan Science Conference on "Sustainable Ecosystem and Biogeochemistry in the Coastal Ocean" to strengthen understanding and development of GLOBEC and IMBER in China. Xiangshan Science Conference is the most influencing scientific regular forum joined by distinguished scientists at national level. The conference covers all scientific fields and its meetings focus on frontier research of science and technology in the present world. 200 Xiangshan meetings had been conducted since 1993. Four scientific topics for discussion are proposed for this meeting:

1. Impact of physical processes on biogeochemistry in the coastal ocean,
2. Carbon cycle in the coastal ocean and influence of recent anthropogenic activities,
3. Biogeochemical processes of marine nutrient elements and trace elements and its control on the microbial loop,
4. Marine food webs, ecosystem diversity, stability and productivity and feedback on the system.

The Xiangshan Science Conference will be held in the spring of 2004. The CNC-IGBP/GLOBEC-IMBER Committee is making efforts to promote this development.

Challenges of Integrated Modelling of Ocean Basin Ecosystems

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The Focus 3 Working Group (F3WG- Prediction and Modelling) has begun an initiative to study the potential for developing ecosystem models at the basin scale. A writing group has been formed to prepare a review paper that will be submitted for publication later this fall. Members of the working group, scientists working in the Pacific, Atlantic and Southern Oceans, have been involved with an array of major ocean programs (GLOBEC, JGOFS, WOCE *et al.*) – F. Chai, B. deYoung, M. Heath, M. Kishi, B. Megrey, P. Monfray, E. Murphy and F. Werner. The writing team met for three days in Harlow, England, in late May, has been busy writing since then, and will meet again in late October to finalise the review in preparation for submission for publication.

The goal of the review is to establish the conceptual and practical steps needed to formulate a quantitative approach to forecasting the consequences of climate variability and anthropogenically induced climate change for living resources in the oceans. This challenge will require modelling of ocean basin, multi-decadal ecosystem dynamics, and ultimately the development of a basin scale prognostic capability based on the "green" ocean concept - a continuum from nutrients to upper trophic levels. First and foremost, we need sound conceptual models of the coupling between life history characteristics and the physical and biogeochemical environment at the basin-scale, or at least at the population scale of the key organisms. This coupling dictates the climatological, spatial patterns of abundance and genetic structures of populations in the ocean.

Its understanding will provide the basis for predicting the consequences of climate change for these populations.

Integrated atmosphere-ocean models are now in widespread use in earth system science and form the mainstay of efforts to forecast climate under different CO_2 emission scenarios. Some of these models explicitly include elements of nutrient cycling and the ocean plankton ecosystem in order to reflect the coupling of the ocean and atmosphere with respect to CO_2 sink/source terms and the role of biogenic gases such as DMS. There is, however, a growing need to move beyond forecasts of the physical climate, and provide assessments of the likely consequences of climate variability and anthropogenically induced climate change for terrestrial and aquatic living resources. So far, such assessments for the marine systems have been largely qualitative and empirical, based on historical correlations or partial understanding of processes. Marine ecologists have developed some understanding of the processes that determine the biological variability, and numerical modeling of this variability at seasonal time-scales and regional spatial-scales is relatively well advanced. Modelling the multi-decadal time-scale variability at the basin scale, essential for predicting the consequences of climate variability and change, is, however, far more complex than simply running a seasonal-cycle model over many years. Processes that are of lesser importance for seasonal dynamics can assume major significance over multi-decadal time scales. Formulating and parameterising these processes will be a major challenge in linking ocean physics, biogeochemistry and marine ecosystems.

Much of the economic and societal justification for marine ecological forecasting rests in the shelf seas where the major exploitation of living resources takes place. Shelf-sea fisheries science, for example, which operates on the basis of annual reviews of the state of fish stocks and future projections of probable catches under different exploitation strategies, has begun to accommodate inter-annual variability. There is, however, an implicit assumption that the multi-decadal variability that dominates the fisheries time-series is driven mainly by exploitation, so called “top-down” control. The role of climate is generally discounted and yet there are examples of coherence between multi-decadal time series from reproductively isolated fish stocks around the margins of ocean basins, implying that large scale physical climate forcing is important. There are also other examples of coherence between trophic levels within particular regions suggesting that energy, or carbon, propagation through the entire food web, including phytoplankton or nutrients, is important, so called “trophic cascading” or “bottom-up” control.

We will review progress made in developing integrated models of ocean basin ecosystems, with a focus on the conceptual issues and some consideration of the practical model development concerns. Our goal is to stimulate researchers working on these problems and provide some guidance for future work. We gratefully acknowledge the support of the Intergovernmental Oceanographic Commission (IOC), the Scientific Committee on Oceanic Research (SCOR), the Global Ocean Ecosystem Dynamics (GLOBEC) project, the Joint Global Ocean Flux Study (JGOFS) and the North Pacific Marine Science Organization (PICES) in providing financial and logistical support for our meetings.

Unusual water mass advection affected Central Baltic key species 1: Sprat and the summer inflow

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As a consequence of the stable high state of the North Atlantic Oscillation (NAO) a period of mild winters have occurred since the late 1980’s in northern Europe. The winter of 2001/2002 was the fifth mild winter in succession resulting in positive water temperature anomalies in the southern Baltic Sea of up to 4.8 ºC in February (ICES, 2003). Positive deviations from the long-term mean air temperature continued, with very warm air masses from southern Europe causing unusually stable “subtropical” conditions in August and September. Meteorological conditions in late summer caused an inflow of extremely warm waters from the western Baltic into the eastern basins. The advection of water masses resulted in exceptionally high water temperatures in October 2002 of up to 14°C in the surface layer, and 10°C in the near bottom layer of the Bornholm Basin, which is 3°C higher than the long-term mean (Fig. 1, see page 29).

Sprat (*Sprattus sprattus*) is presently the most abundant commercial fish stock in the Baltic, being the result of released predation pressure by cod (*Gadus morhua*) and climate-related high reproductive success (Köster *et al.*, 2003). Spawning in clupeids is induced by sufficient temperature and energy levels (e.g. Johnson 1970, Hunter and Leong 1981). Sprat in the Central Baltic deep basins normally spawn between March and July with a peak in early June.

Within the GLOBEC-GERMANY programme (www.globec-germany.de), sprat were sampled for maturation and fecundity studies from April 2002 to April 2003. This extensive sampling programme, covering already a full annual cycle (and still continuing), allowed to detect the effect of the warm water intrusion on the sprat maturation cycle. The proportion of mature individuals in spawning condition firstly peaked as expected between April and June 2002 (Fig. 2). But, during winter 2002/2003 the unusual high temperatures induced a secondary maturation cycle and spawning individuals were observed from November onwards with a second spawning peak in January 2003. However, the unusual winter spawning was characterised by extremely high spawning frequencies indicating that no regular spawning patterns could be established.

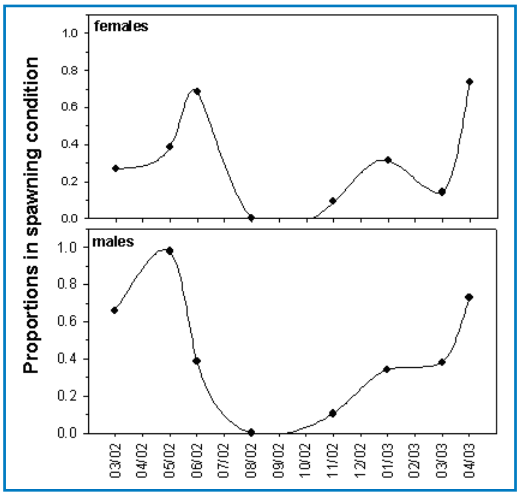

Figure 2. Males and females in spawning condition calculated as proportion from mature individuals.

The further effect of this event on the "normal" spring spawning in 2003, as well as on overall recruitment of the stock is unclear yet and presently under investigation. The Baltic sprat example clearly shows how a changing (warming) climate may impact on the life-cycle of temperate fish species, and that investigations are needed evaluating the consequences of climate change scenarios for fisheries and management issues.

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Unusual water mass advection affected Central Baltic key species 2: Pseudocalanus and the winter inflow

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Since the late 1980's a period of stable positive North Atlantic Oscillation (NAO) has resulted in an increase in average water temperatures (Fonselius and Valderrama 2003), and a dominance of "westerly weather", i.e. a wetter climate, increased further the amount of runoff entering the Baltic Sea (Hänninen *et al*, 2000). Increased river runoff due to these conditions affected salinity in the Baltic directly by freshening surface waters, and indirectly by preventing inflows of saline and oxygenated water from the North Sea (Matthäus and Schinke 1999). These inflows are needed for renewing the bottom water of the deep Baltic basins below the permanent halocline, and their frequency has drastically decreased since the early 1980's with the last major event observed in 1993. Consequently salinity and oxygen levels have decreased in the deep Basins with profound effects on "marine" species in the brackish Baltic Sea such as cod (*Gadus morhua*) and the calanoid *Pseudocalanus* (Köster *et al.*, 2003; Möllmann *et al.*, 2003).

A new major inflow was observed in January 2003 driven by a rather low water level due to a stable high pressure cell over Scandinavia and associated north-easterly winds. After this period the wind in the Western Baltic changed to gale strength from westerly directions in early January. This resulted in a lowering of the sea level in the Western Baltic Sea and a strong inflow commenced (for more information see www.io-warnemuende.de). The inflow greatly enhanced the salinity and oxygen hydrographic conditions in the Bornholm Basin. The subsequent change in habitat quality potentially impacting upon a number of key trophic players in the Baltic Sea. For example, previous long-term investigations documented large interannual fluctuations in the standing stock of *Pseudocalanus* with a pronounced decrease especially in the 1990's (Möllmann *et al.*, 2003). This development has been related to the decreasing salinity and first studies within the GLOBEC-GERMANY programme (www.globec-germany.de) have indicated that the decrease of salinity and oxygen concentrations in the deep basins may have resulted in a degradation of suitable habitat for reproduction of *Pseudocalanus* (Möllmann *et al.*, 2002).

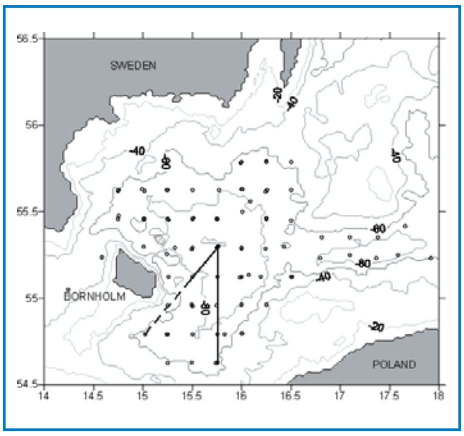

Figure 1. The Bornholm Basin and VPR-tracks in May 2002 (solid line) and April 2003 (solid plus dotted line); dots indicate standard CTD and net sampling stations of GLOBEC-GERMANY.

In May 2002 and April 2003, a Seascan Video Plankton Recorder (VPR) was deployed in the Bornholm Basin (Fig. 1) during GLOBEC-GERMANY cruises to obtain in situ observations of reproducing *Pseudocalanus* females. These observations allow the testing of the hypothesis of reproductive habitat degradation during stagnation periods. Preliminary results indicate that in May 2002, during stagnation, *Pseudocalanus* females were found in a deep and narrow band below the permanent halocline with maximum ambient salinities of about 16psu and low oxygen concentrations to in minimum 1ml.l^{-1} (Fig. 2, left panels). Due to the enhanced hydrographic conditions in April 2003, after the major inflow, *Pseudocalanus* females were able to utilize deeper portions of the basin with ambient salinities of up to 19psu and minimum oxygen concentrations of 5ml.l^{-1} (Fig. 2 see page 36, right panels). Additionally the favourable ambient conditions allowed the *Pseudocalanus* to populate a wider depth range and hence larger realised habit in the water column.

The effect of the potentially favourable reproductive habitat on the population dynamics of *Pseudocalanus* after the advection of North Sea waters will be further examined using conventional net-samples and egg production experiments. Further analyses of the effects of changes in the hydrographic conditions on key trophic players are presently underway within GLOBEC-GERMANY.

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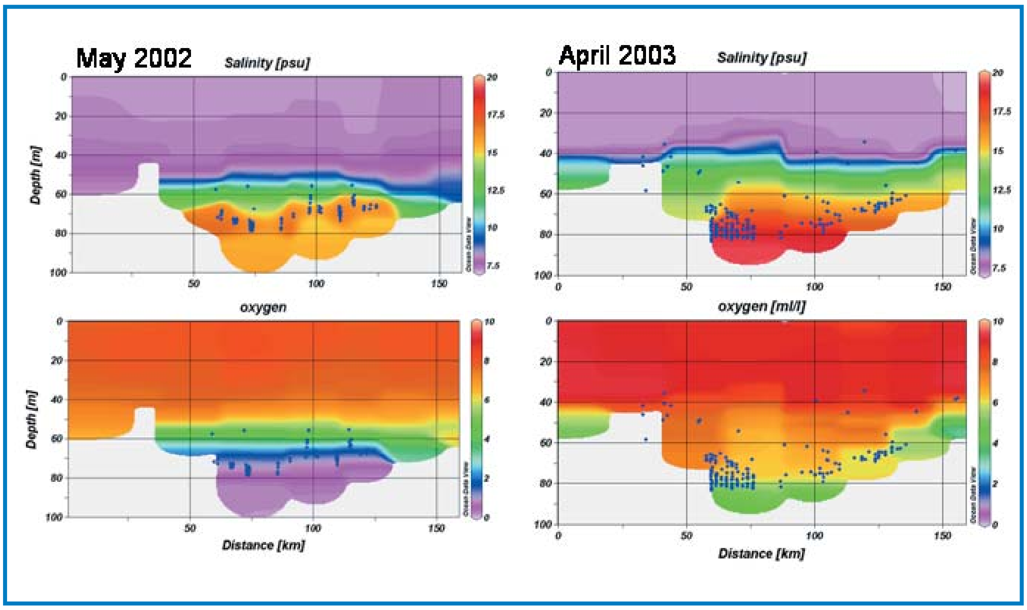

Figure 2. Salinity annd oxygen profiles during the VPR-tracks in May 2002 and April 2003; blue dots indicate individual egg carrying Pseudocalanus females observed with the VPR. From article pages 34 & 35.

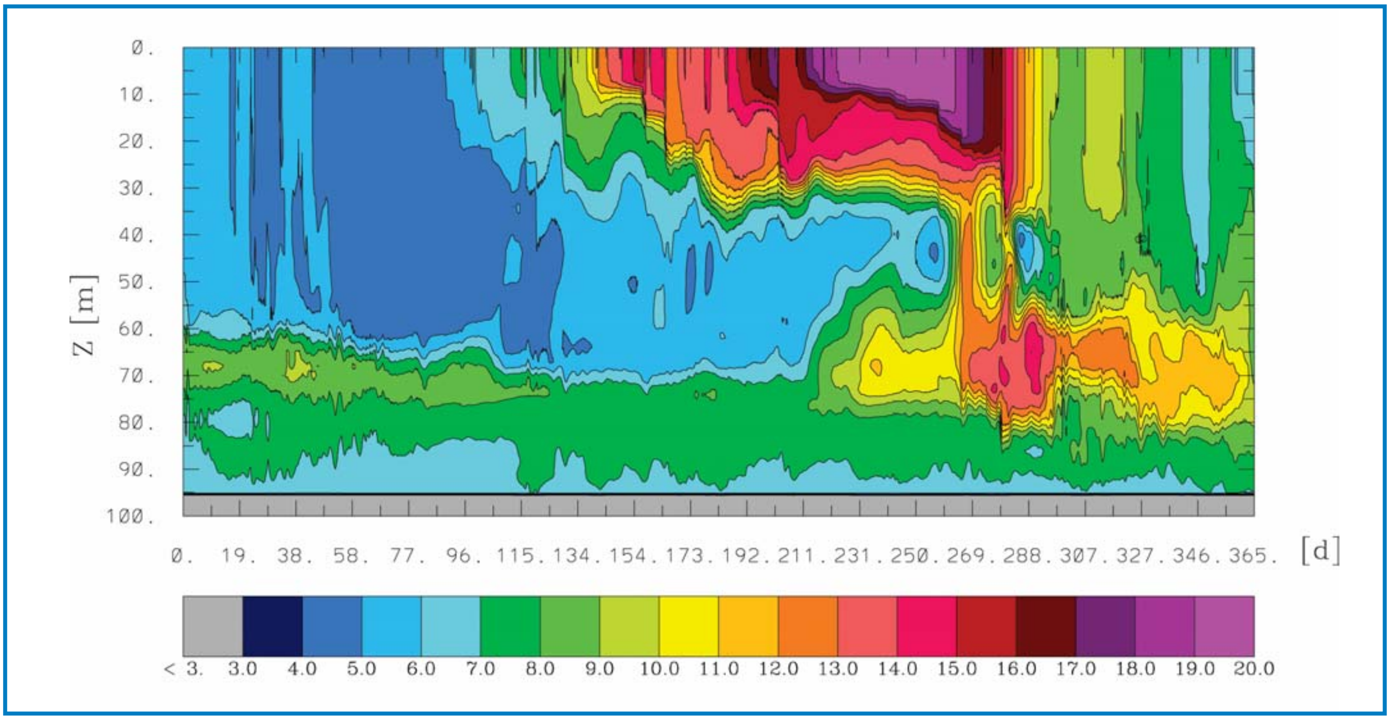

Figure 1. (Kraus et al., p. 27 - 28) Water temperature at depth over Julian days in 2002 at a central station in the Bornholm Basin. Data derived from a coupled three dimensional Baltic Sea Ice - Ocean model.

Ecosystem Studies of Sub-arctic Seas (ESSAS)

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Under the auspices of SCOR and GLOBEC, a new program, Ecosystem Studies of Sub-arctic Seas (ESSAS) is being developed for adoption as a GLOBEC Regional Program. The goal of the ESSAS Program is to compare, quantify and predict the impact of climate variability on the productivity and sustainability of sub-arctic marine ecosystems. The ESSAS program will provide the basis for understanding how global change may impact ecosystem structure and productivity, and thus the ability of these critical regions to support the Northern Hemisphere's most productive and valuable fisheries, subsistence activities of the many communities along the sub-arctic coasts and immense populations of marine birds and mammals. The sub-arctic seas including the Bering Sea, the Barents Sea, the waters of Iceland and Greenland, the Newfoundland/Labrador Shelf, the Oyashio Shelf, and the Sea of Okhotsk support some of the world's most productive fisheries, most of which are based on cod or pollock. All but the Sea of Okhotsk also exchange water with the Arctic, modifying it on its passage to and/or from lower latitudes.

The sub-arctic seas are subject to decadal-scale and secular changes in climate. The extent and nature of the seasonal ice zone impacts all levels of the physical and biological systems of these seas. They also have strong seasonal cycles of insolation, temperature and production. The last few decades of modern ocean observation have recorded significant year-to-year variations in both the seasonal ice and the ecological dynamics of these regions. However, the critical processes linking these important aspects are not well known. Our ability to predict and prepare for fluctuations in critical biological resources caused by regional, short-term climate variability is limited. This lack of process-level predictive capability for a system that is important to commercial and subsistence harvests, as well as to non-harvested marine life, is a powerful motivation to learn more about how climate change will affect sub-arctic marine ecosystems and their connections.

Recent, unprecedented changes in some sub-arctic marine ecosystems (e.g. Newfoundland/Labrador Shelf, the eastern Bering Sea) and a lack of information about the possible linkages between these changes and climate forcing resulted in the convening of an international workshop in Laguna Beach, California, in September 2002, to assess the requirement for a large-scale, integrated study of the sub-arctic seas. The workshop participants agreed unanimously that there is an urgent need to improve our understanding of the linkages between climate variability and the responses of sub-arctic marine ecosystems and their productivity in the light of global change, as detailed in the Workshop Report: Ecosystem Studies of Sub-arctic Seas: Results of a Workshop held in Laguna Beach, California, 4-6 September 2002 (http://www.arcus.org/bering).

Two additional planning workshops have been convened. The first was in May 2003, in Bergen, Norway, and the second will be in late October 2003, in Seattle, USA, the result of which will be a Science Plan for the ESSAS Program. This document will outline a multi-year research effort that will provide improved understanding of the effects of climate variability at various temporal and spatial scales on the ecosystems of the sub-arctic seas. A goal of ESSAS is to provide a framework for coordinated, interdisciplinary studies of the effects of climate change on the sub-arctic seas. A draft Science Plan will be available in winter 2004 for comment from the marine science community.

The ESSAS Science Plan will provide background information and will frame science questions to serve as guidelines for integrated, interdisciplinary studies of the marine ecosystems of the sub-arctic seas. The proposed studies will focus on the mechanisms and processes that determine the biological production of the sub-arctic seas and the fate of production as it is transferred through the ecosystems to upper trophic level consumers, including humans.

An important component of the ESSAS Program will be investigation of the connections between external forcing mechanisms and the hydrographic structure and physical processes in the sub-arctic seas. Two major external physical forcing mechanisms dominate the sub-arctic seas, atmospheric forcing (solar insulation and winds) and transport of water from the temperate North Pacific and North Atlantic to the Arctic. Variability in these forcing mechanisms occurs on all spatial and temporal scales, including local episodic events (storms), interannual variability at the scale of basins, and decadal- and climatic-scale events at North Pacific/Atlantic- and global-scales. Issues of particular importance include re-supply of nutrients to the continental shelves, fluxes through the sub-arctic seas to the Arctic Ocean, and how the location, timing, frequency, and intensity of storms affect shelf ecosystems. Flow through the sub-arctic seas to the arctic appears to be changing, but the effect of this change on the heat balance, nutrient flux, and ecosystem structure of the sub-arctic seas remains unknown. There is a new appreciation of the potential role of storms, but how changes in the characteristics of storms will influence the sub-arctic marine ecosystems is not well understood. Changes in these parameters could have a major impact on upper trophic level organisms, including people, in this region.

Another area of investigation will be the connection between physical aspects of the marine environment such as wind mixing, sea ice cover, and water temperature and the responses of the biota. For example, although seasonal sea ice cover is a dominant feature of the sub-arctic seas, the ecosystem-level impact of changes in sea ice cover is not well understood. For instance, at least in the southeastern Bering and Barents Seas, the timing of sea ice retreat affects the timing and possibly the fate of the spring bloom (Fig. 1, see page 2), but the ecosystem consequences of these different modes of bloom need to be determined. There is evidence supporting the hypothesis that water temperatures during the spring phytoplankton bloom affect the productivity of copepods, and possibly whether the recruitment of important commercial fish species, such as walleye pollock (*Theragra chalcogramma*), northern cod (*Gadus mohrua*), herring (*Clupea* spp.), and capelin (*Mallotus villosus*), will be determined by bottom-up or top-down mechanisms. Climate-driven differences in the mechanisms controlling fish populations would have important implications for fisheries management.

A third area of effort in ESSAS will be the development of tools for integrating the effects of climate change across spatial and temporal scales with the goal of providing forecasts of how the sub-arctic marine ecosystems might be expected to behave under different climate scenarios. Accomplishment of both the full range of down-scaling and the related up-scaling back to ecosystem function would be a major accomplishment. Such a series of linked models would have the prospect of providing not only intellectually exciting opportunities to investigate the ways in which the ecosystems might respond to climate change, it would also be a valuable tool for management of the sub-arctic seas' fisheries.

The ESSAS Program will benefit from information developed in the ASOF and CLIVAR programs, particularly as ESSAS synthesizes its results and attempts to develop models of what global change may bring to the sub-arctic seas. For these goals, information on how climate forcing and fluxes into and out of the Arctic Ocean are expected to change will be vital. In return, the ESSAS Program will be able to provide ASOF with information on how the qualities of the water flowing from the sub-arctic into the Arctic Ocean will change given different climate scenarios. There should also be opportunities to share logistics with ASOF in the North Atlantic and Barents Sea, as the areas of operation may overlap considerably. ESSAS will complement ASOF which focuses on physical and chemical aspects of flux between the Arctic and sub-Arctic. The Bering Ecosystem Study (BEST) Program, being developed for support by the United States National Science Foundation, is planned as a multi-year, multi-ship program, and is expected to be an integral part of ESSAS. The ESSAS Program would also be expected to interact closely with PICES and ICES and the newly forming IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) Program.

GLOBEC CALENDAR

2003

10-18 October: PICES XII, Seoul, Korea (CCCC and GLOBEC Focus 4 sessions)

16-18 October: IHDP Open Science Meeting, Montreal, Canada. (GLOBEC Focus 4 session)

31 October - 1 November: 2nd Planning meeting of GLOBEC ESSAS, Seattle, USA

4-7 November: 1st planning meeting of GLOBEC-CLIOTOP, Sete, France

17-19 November: Global Change Young Scientists Conference, Trieste, Italy.

17-20 November: GEOHAB Open Science Meeting, Lisbon, Portugal.

9 -11December: SPACC workshop on Long-term Dynamics of Small Pelagics and Zooplankton in Japanese waters, Tokyo, Japan

December (tbc) : GECAFS/ GLOBEC/ IAI-EPCOR workshop on Environmental Uncertainty and information Flow in Fisheries Management in the Humboldt Current system. Guayaquil, Ecuador.

2004

12-13 January: SPACC workshop: Characterizing and comparing the spawning habitats of small pelagic fish. Concepción, Chile.

14-16 January: SPACC meeting: Spawning habitat quality and dynamics and the daily egg production method. Concepción, Chile

17-18 January: SPACC Executive meeting, Concepción, Chile

26-30 January: Ocean sciences meeting, Portland, Oregon, USA (GLOBEC session)

15-20 February: Ocean Research Conference (ASLO), Honolulu, Hawaii (GLOBEC session)

26 February: UK-GLOBEC Open Meeting, Royal Society, London, UK

1-5 March: SC IGBP Committee Meeting, St Petersburg, Russia

10-11 March: Meeting of ICES Working group on Modelling Physical-Biological Interactions (WGMPBI). Barcelona, Spain.

31 March - 3 April: IOC-SCOR Symposium on 'Quantitative Ecosystem Indicators for Fisheries Management'. Paris, France

March (tbc): GLOBEC SSC Meeting, Swakopmund, Namibia.

March (tbc): BENEFIT-GLOBEC Annual Forum, Swakopmund, Namibia.

2-6 May: 4th World Fisheries Congress, Vancouver, Canada

7-10 May: ICES-GLOBEC CCC working group meeting. Bergen, Norway

11-14 May: ICES-GLOBEC Symposium on 'The Influence of Climate Change on North Atlantic Fish Stocks', Bergen, Norway

21-25 June: CLIVAR Science Conference. Baltimore, USA.

September (tbc): SPACC Workshop on the economic consequences of small pelagic fish fluctuations. Portsmouth, UK.

1-3 September: Bjerknes Centenary: "Climate change in high latitudes". Bergen, Norway.

11-14 October: SOLAS Open Science Conference. Halifax, Canada.

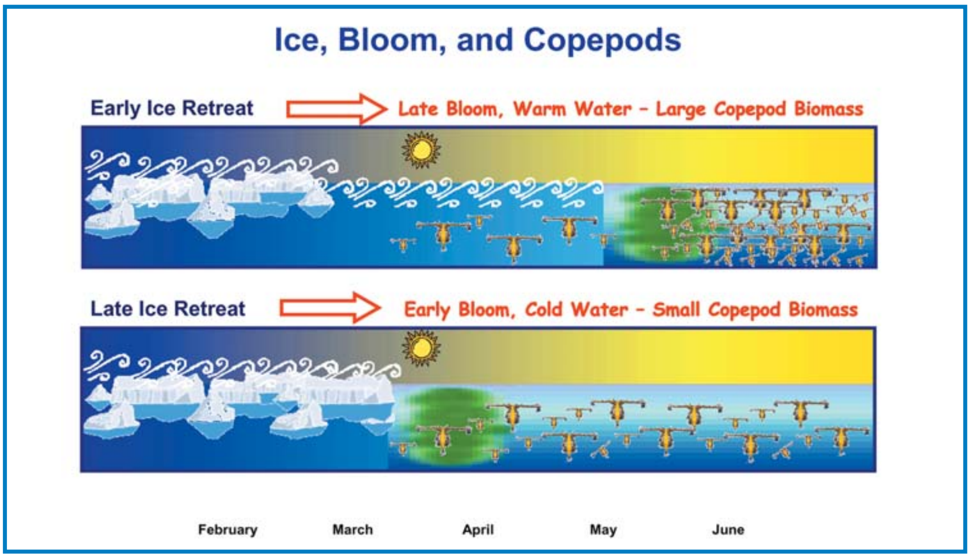
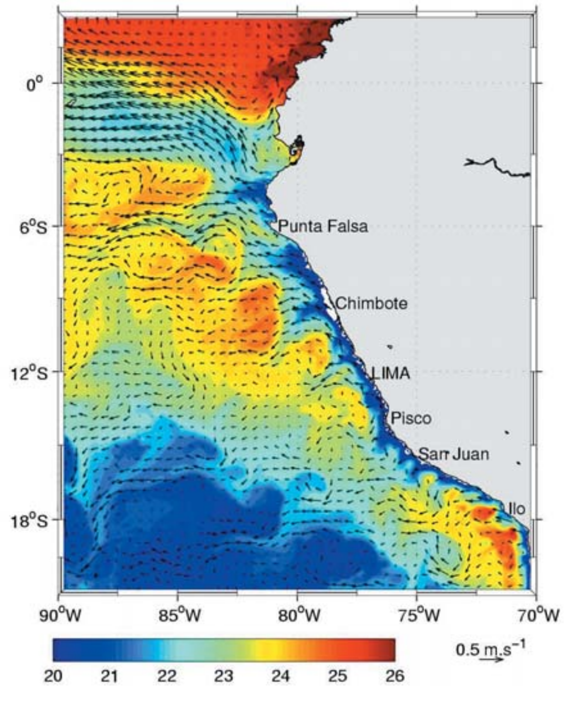


Figure 1. (Hunt, p. 30 -31) The relationship between the timing of sea ice retreat and the timing and fate of the bloom. Top: If the ice retreats in mid-March or earlier, the bloom is delayed until insolation warms and stratifies the water column. The bloom then occurs in warm water and is more strongly coupled to zooplankton grazing. Bottom: If ice retreat is delayed into late-March or April, there will be an ice-associated bloom in cold water that is decoupled from copepod grazing. Full article on pages 30 - 31.

Figure 1. (Penven, p. 23 - 25) An example of modeled surface currents (1 vector every 4 grid points) and sea surface temperature (°C) for the 8 January of model year 11. Full article on p. 23 -25.



SPACC Workshop on the economics of small pelagics and climate change. University of Portsmouth, Portsmouth, UK. September 2004.

The focus of the workshop is on the economic implications of small pelagic fish fluctualtions. We are looking both for papers that are backward looking and theoretical or forward looking. Abstracts should be sent to the GLOBEC IPO through its webpage (www.globec.org, follow signs to "SPACC Economics Workshop") by February 29, 2004. Authors of accepted papers will be invited and sponsored. It is expected to publish the papers presented at the conference as a special volume of a relevnat journal or as a book of case studies.

GLOBEC INTERNATIONAL

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